# Relinquishment Report PL 681

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# Relinquishment Report PL 681

# 1 Key license history

Production License 681 was awarded to Tullow Oil Norge AS (64% and operator), Petoro (20%), Det Norske AS (16%) on 14. January 2013. The license covered part of blocks 31/3, and 35/12, see Fig. 1.1.

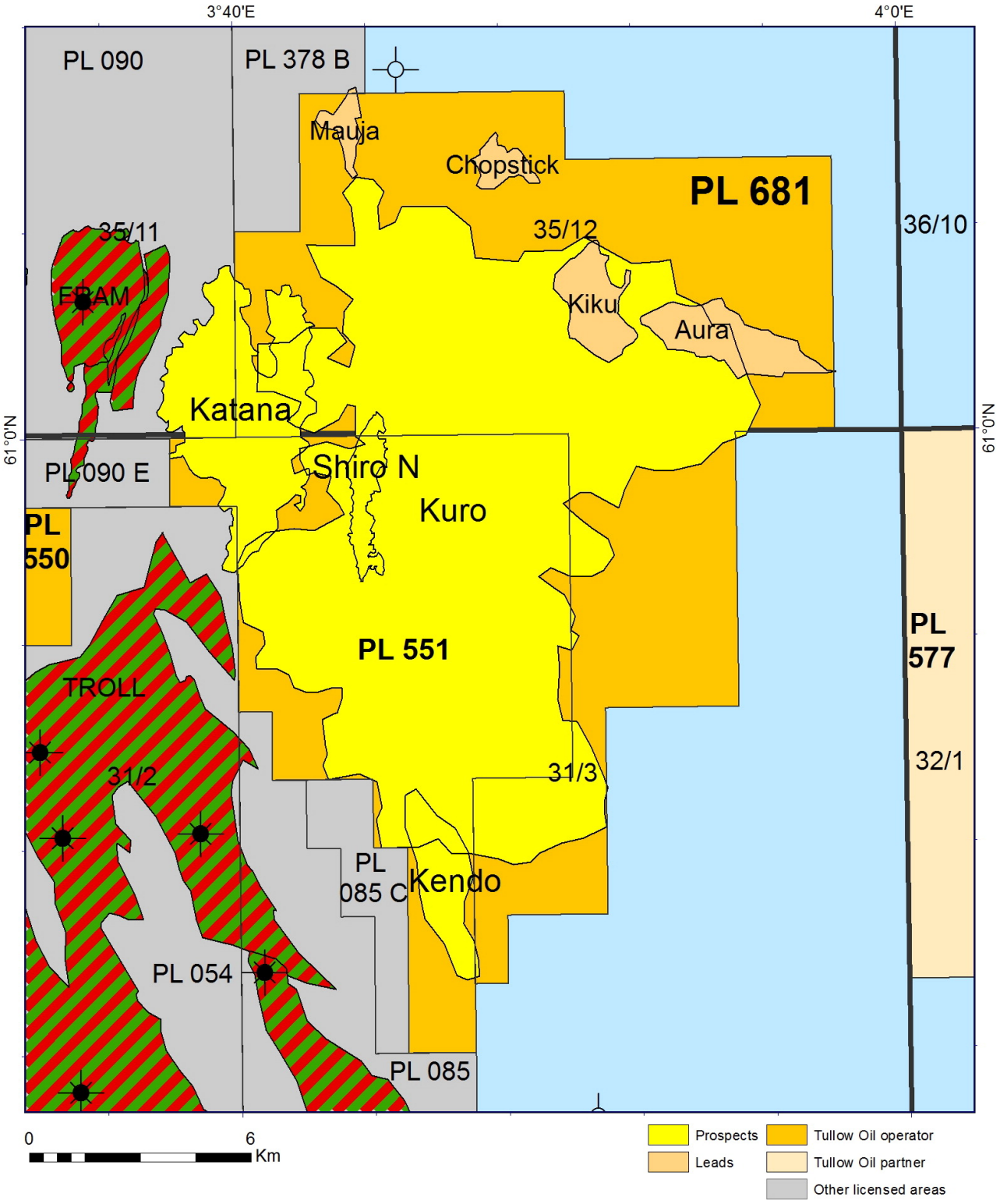


**Fig. 1.1 Initial License prospect and lead map**. *Common PL551 and PL681 licence map with initial prospect and lead outlines.*

The license shared the prospective resources with production license 551 and the APA 2012 application submitted was an extension application to PL551. The main prospects were the Upper Jurassic Katana prospect and the Paleocene Kuro prospect.
The work programme was closely linked to the PL551 activity and the results of exploration well 31/3-4 which tested the Paleocene Kuro prospect in a down dip position. (The main target of well 31/3-4 was the Sognefjord FM).

The decision of continuation, initially after the first year of the award, was granted extension to 08.02.2016 (letter from MPE dated 26.03.2014). Reasons for the deadline extension were to take into account the results of exploration wells 31/3-4 and 31/2-21S.

Four formal ECMC meetings have been held in the license, and two work-meeting (EC members). Minutes and/or presentations from the meetings are found on L2S.
Due to the shared prospective resources and the license group setting, the exploration committee (EC) meetings has been held together with the PL551 EC meetings. The management committee (MC) meeting were held separately.

In summer of 2014 the license acquired 1270km$^2$ of 3D CSEM data together with production licenses 550 and 551 to fully cover the license area and the identified prospectivity. Based on the new data, the license group(s) has performed extensive geological and geophysical analysis to evaluate the prospectivity and commercial potential of the license acreage.

Based on the CSEM data and 3D seismic data, studies based on well 31/3-4, and observations from well 31/2-21S, the licence has concluded that the probability of proving commercial quantities of hydrocarbons is too low to justify a decision to drill an exploration well.

A unanimous decision to relinquish the license was taken by the Management Committee, and the Ministry of petroleum and Energy was notified by letter dated 05.01.2016

# 2 Database

Well database

The work commitment for PL681 initial phase was to perform G&G work. The result of the well 31/3-4 was important for the definition and risking of the Paleocene Kuro prospect and the well is included in the well database as seen in Fig. 2.1.

| WELL NAME | COMPLETION DATE | TD | LITHOSTRATIGRAPHY | HC DISCOVERY | OPERATOR |
|---|---|---|---|---|---|
| 31/2-6 | 17/10/1981 | 1760.0 | FENSFJORD FM | OIL/GAS | SHELL |
| 31/2-8 | 18/08/1982 | 3375.0 | HEGRE FM | OIL SHOWS | SHELL |
| 31/2-N-11 H | 24/08/2005 | 4275.0 | BRENT GP | OIL/GAS | HYDRO |
| 31/3-2 | 30/04/1984 | 2090.0 | DRAKE FM | OIL/GAS | HYDRO |
| 31/3-3 | 18/11/1984 | 2573.0 | STATFJORD GP | DRY | SAGA |
| 35/11-4 | 27/01/1992 | 3127.0 | STATFJORD GP | OIL/GAS | MOBIL |
| 35/11-7 | 29/09/1992 | 2895.0 | STATFJORD GP | OIL/GAS | MOBIL |
| 35/11-10 | 23/06/1997 | 2950.0 | COOK FM | OIL/GAS | HYDRO |
| 35/11-B-23 H | 13/01/2008 | 3653.0 | EARLY JURRASIC | OIL | STATOIL |
| 31/3-4 | 05/01/2014 | 2122.0 | MIDDLE JURASSIC | DRY | TULLOW |
| 35/12-3 S | 16/02/2011 | 2807.0 | ETIVE FM | DRY | WINTERSHALL |

**Fig. 2.1 Well database for the PL681**

Seismic and CSEM database

After the results of the well 31/3-4 a 3D CSEM survey was acquired over Kuro and Katana. The 3D CSEM survey covering a total of 1270 km2 is included in the database, see Fig. 2.2. A new pre-stack inversion using the NH9401WIM11 survey as input was carried out and used in the G&G work.

| SEISMIC SURVEY | PROCESSING YEAR | SURVEY TYPE |
|---|---|---|
| NH9401WIM11 | | |
| NH9401WIM11-AVO-FMD-TIME | 2011 | 3D |
| NH9401WIM11-AVO-GRADIENT-TIME | 2011 | 3D |
| NH9401WIM11-AVO-INTERCEPT-TIME | 2011 | 3D |
| NH9401WIM11-BKG-MOD-VP | 2011 | 3D |
| NH9401WIM11-BKG-MOD-ZP | 2011 | 3D |
| NH9401WIM11-COLOUR-INV-ZP | 2011 | 3D |
| NH9401WIM11-FAR-TRIM-PSDM-TIME | 2011 | 3D |
| NH9401WIM11-INV-ABS-VP | 2011 | 3D |
| NH9401WIM11-INV-ABS-VPVS | 2011 | 3D |
| NH9401WIM11-INV-ABS-VS | 2011 | 3D |
| NH9401WIM11-INV-ABS-ZP | 2011 | 3D |
| NH9401WIM11-INV-ABS-ZS | 2011 | 3D |
| NH9401WIM11-INV-REL-VP | 2011 | 3D |
| NH9401WIM11-INV-REL-VPVS | 2011 | 3D |
| NH9401WIM11-INV-REL-ZP | 2011 | 3D |
| NH9401WIM11-MID-TRIM-PSDM-TIME | 2011 | 3D |
| NH9401WIM11-NEAR-TRIM-PSDM-TIME | 2011 | 3D |
| NH9401WIM11-PSDM-FAR-ANGLE-TIME | 2011 | 3D |
| NH9401WIM11-PSDM-FULL-OFFSET-DEPTH | 2011 | 3D |
| NH9401WIM11-PSDM-FULL-OFFSET-TIME | 2011 | 3D |
| NH9401WIM11-PSDM-MID-ANGLE-TIME | 2011 | 3D |
| NH9401WIM11-PSDM-NEAR-ANGLE-TIME | 2011 | 3D |
| NH9401WIM11-STK-RMO-ANELLIPTICITY-TIME | 2011 | 3D |
| NH9401WIM11-STK-RMO-VEL-RMS-TIME | 2011 | 3D |
| TUN13302 | 2014 | 2D |
| TrollMC14 | 2014 | 3D CSEM |

**Fig. 2.2 Seismic and CSEM database for PL681**

# 3 Review of geological framework

The following studies has been done after the APA 2012 application and has been important in the resource evaluation within the license area.

- The report: "Mantra Prospect well 31/3-4: Geological interpretation from FMI borehole images" by Eriksfiord March 2014 were of particular importance to derisk the Kuro reservoir model. The injectite model was rejected based on this study and concluded that the sand discovered in Kuro is deposited by gravitative processes.
- A 2D structural reconstruction study shared between licences PL550, PL551, PL681, and PL744 performed by Badleys in July 2015 gave sufficient insight to conclude on the Katana reservoir model(s).
- An in-house study on bio-strat and well-log correlation helped to constrain the age of Katana reservoir model(s).
- A PaleoScan study, a semi-automatic seismic interpretation product, was carried out to get higher level of detail in the seismic surfaces and isochrones.
- FIS-study on well 31/3-4 shows that Upper to middle Jurassic reservoirs Sognefjord to Brent Fms have not experienced any significant hydrocarbon charge, only minor anomalies were seen. No evidence of hydrocarbon (fluorescent) inclusions were reported. This increased the migration risk on the leads and prospects in the licence.
- CSEM inversion for resistivity using both 3D and 2D algorithms. [redacted]
- Heather Maturation sensitivity carried out by Exploro and external source rock study prior to drilling 31/3-4. Showed that the Heather shales could be mature but most likely gas prone in the UER-basin North East of the Troll area sourcing the Mantra prospect.
- Pore pressure data from 31/3-4 imply no pressure communication between Troll and the Palaeocene Kuro sandstone. The same study also show pressure communication with most other Palaeocene sands in the area, and sub-cropping of the Palaeocene sand towards Quaternary eastwards is likely, thus putting a significant risk on a structural pinch-out trap on the Kuro prospect.
- Geochemical analysis of the core extracts from reported oil shows in the Palaeocene of 31/3-4, are different from the oil sampled in the Troll field, and shows more genetic relationship with oils from 35/11-7 and 35/11-8 S, implying a migration route from the northwest thru Fram fields and not being part of the migration route to (and from) Troll. However, it should be noted that due to samples showing evidence of biodegradation and that no mud samples were analysed some ambiguity are associated with interpretation of these samples
- Headspace gas analysis from 31/3-4 confirms thermogenic and biogenic gas mixtures, these gases are oil/condensate associated, with a uniform maturity of 1.3-1.5 VRo%. However, the gas concentrations drops entering the Palaeocene sandstone, as does the mud weights, implying a deficient migration system in the Palaeocene unit. Based on geochemical data it is assumed that the same gas is leaking thru whole vertical section of the well

# 4 Prospect update

The main prospects in the licence were the Upper Jurassic Katana and the Paleocene Kuro prospects. Both prospects stretches into PL551, see Fig. 1.1.

**Kuro prospect**

The Paleocene Kuro prospect is summarized in Fig. 4.1. The reservoir units were thought to be remobilized sands of Early Paleocene age. Sand injection geometries were interpreted on 3D seismic data. The prospect outline was defined on a seismic amplitude pattern interpreted to be the extent of remobilization, i.e. a stratigraphic trap. The main risks were migration and trap.
Exploration well 31/3-4 tested the Kuro prospect in a down-dip position. The well proved presence of 57.8m of net sand with 25.5% porosity in the predicted injectite interval. Weak shows and oil stainings were encountered in the sandstone interval. No sandy parent bed was found in the Early Paleocene which was expected in the injectite model.
Analysis of FMI data over the interval concludes that the sandstones are a result of a primary depositional process, most likely turbiditic flow in offshore conditions. The pressure obtained in the sandstone unit was near hydrostatic and it could not be in communication with the Troll gas accumulation.

Observations and interpretation of data obtained in 31/3-4 called for a new trap definition. The source area for the sandstones were probably mainland Norway. It has not been possible to definea a structural trap in the up-dip direction (Eastwards) using seismic data. A last attempt to derisk Kuro was to aquire 3D CSEM data across the prospect.

[redacted]

The geological risk of success is very low and the resource range is highly uncertain.

**Katana prospect**

The Upper Jurassic Katana prospect is a stratigraphic trap defined on seismic amplitudes as shown in Fig. 4.2 which is taken from the APA 2012application. The reservoir was interpreted to consist of Draupne sandstones similar to those in the Fram Field realizing that most of the Fram area turbidites are of Heather sandstones.
Well 31/2-21S provided important information on the interpretation of the seismic amplitude response at top of the reservoir. The well failed to find the Draupne sandstone at the predicted level. Internal seismic analysis using the NH9401WIM11 demonstrates that both the 31/2-21S and parts of the Katana prospect have a common amplitude with offset behaviour. Careful selection and edits of the seismic offset data suggests that the seismic anomalies resembles a AVO class IV anomaly rather than AVO class III as initial observations suggested. Internal seismic modelling and processing suggest that the farthest offset traces could be affected by refracted energy and processing effects which in sum increases the magnitude of the amplitude.
According to our database both the Fram and Troll exhibit a AVO class III at the top of the reservoir.

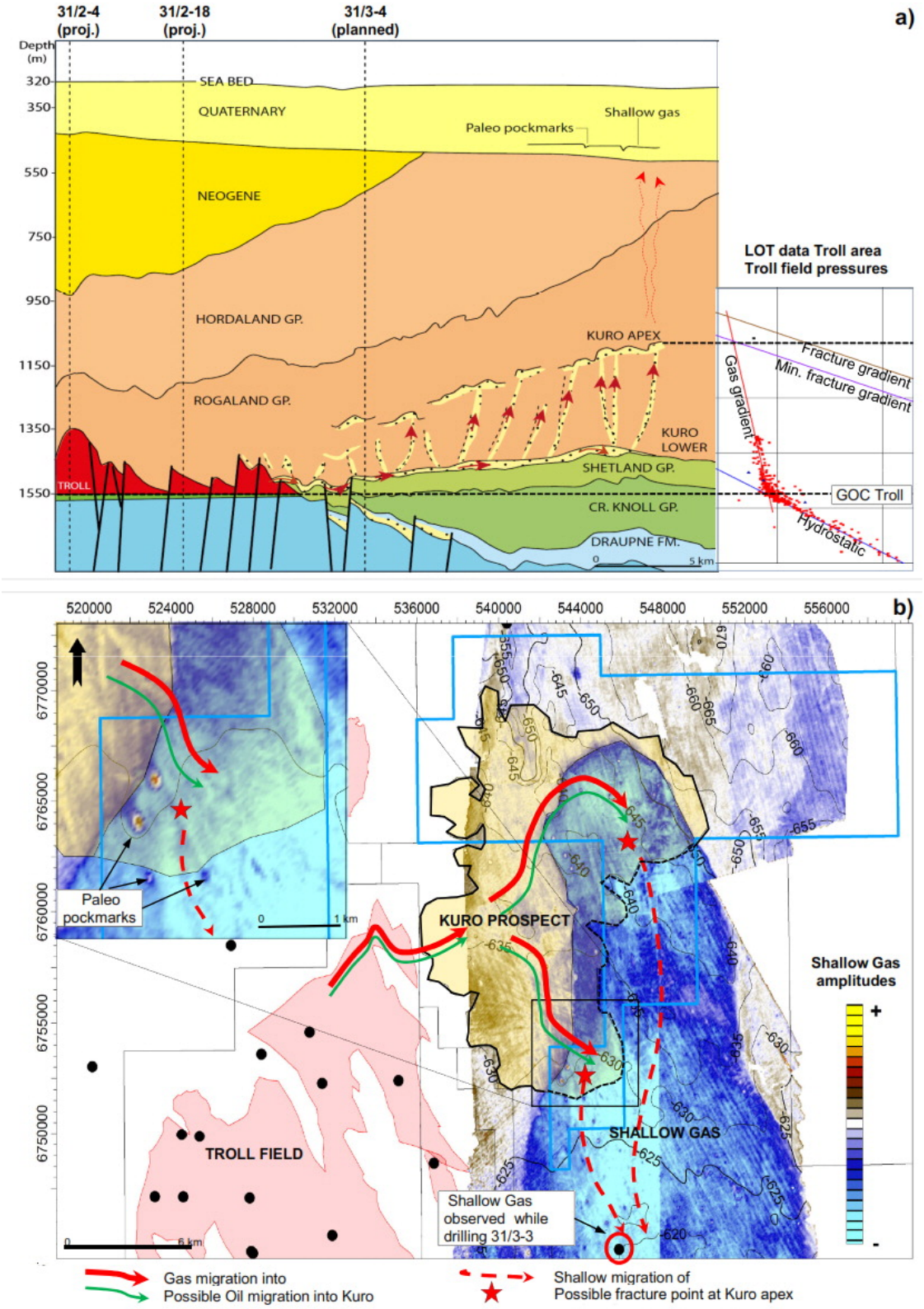


**Fig. 4.1 Migration model for the Kuro model**. *a) Migration into the Kuro prospect is by direct communication with the Troll field. Gas migrates further into the injectite complex and fill the complex. However when the column height is close to ~550 m, which matches the crest of the Kuro prospect, the fracture opening pressure is reached at the crests of the Kuro prospect and gas leaks creating the shallow gas anomaly (shown in b). b) Amplitude map from top of a large possible shallow gas anomaly. The lowest point of the anomaly coincide with the mapped Kuro apex. Shallow gas was observed in this zone in 31/3-3. The anomaly get shallower southwards. An alternative Kuro apex is also located below the amplitude anomaly. Many paleo pockmarks >250 m in diameter are imaged in the seismic data. Paleo-pockmarks are also identified on different levels in the overburden, showing the episodic release of gases. (Figure 2.17 in the APA 2012 application)*

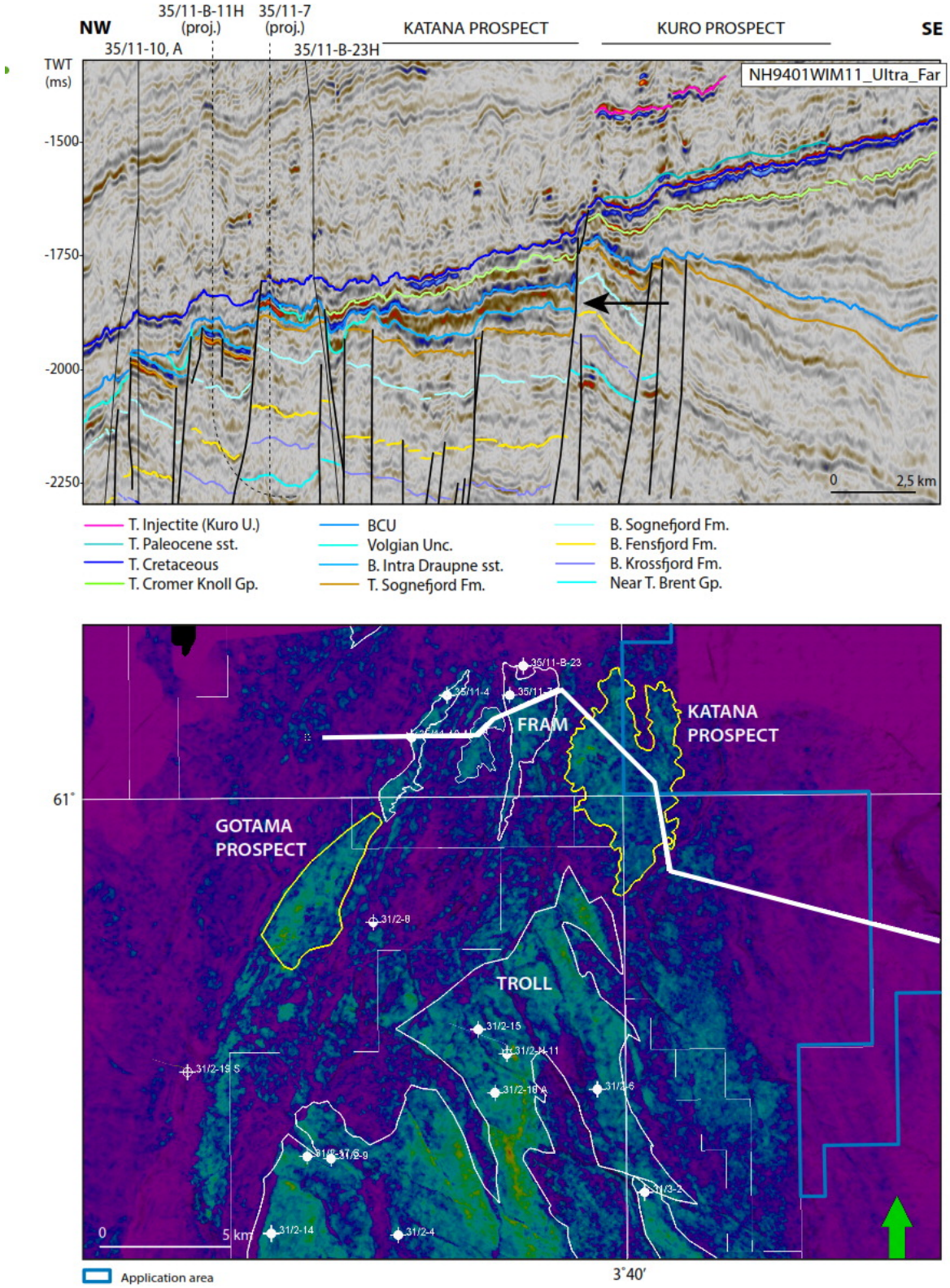


**Fig. 4.2 Seismic anomalies on Katana and Gotama prospects, Fram East and Troll Fields.**. *NH9401WIM11 Ultra Far offset seismic line (top) and map (base) demonstrating the correlation between hydrocarbon filled Late Jurassic reservoirs and ultra far offset anomalies. The Katana interval is marked with an arrow on the seismic section. The map shows the sum of positive amplitudes 0-80 ms below BCU, this captures both the Intra Draupne and Sognefjord response. (Figure 2.7 from the APA 2012 application)*

The 2D structural reconstruction study carried out over the Katana prospect suggest that the Katana graben was submerged and turbidite deposits most likely constitute the reservoir.
Detailed automatic seismic mapping (PaleoScan) in the target area has not revealed any geometrical patterns that are distinct for gravitational processes.
Seismic to well-tie for the Uppermost Jurassic strata is difficult due to the truncations of the Upper Jurassic unconformities that takes place towards the wells located on the highs. However seismic mapping integrated with bio-stratigraphy constrained well correlation suggest that the seismic anomaly in Katana is Volgian in age. The current well data base only have one well (35/11-11) with a sandstone of Volgian age. The thickness of the Volgian sandstones is far thinner than the Fram Oxfordian (35/11-15S). Finding an efficient reservoir is considered as the main risk for the Katana prospect.

The Katana outline, still based on seismic amplitudes, only leaves one percent of the prospect area within the PL681 area.

The updated volumes for Kuro and Katana is given inTable 4.1. The updated prospect outlines are given in Fig. 4.3.

*Table 4.1 Updated resource potential for PL681. The changes in resource potential from the application is highlighted in yellow.*

| Discovery/ Prospect/Lead name | D/ P/ L | Unrisked recoverable resources | | | | | | Probability of discovery | Resources in acreage applied for % | Reservoir | | Distance to infra-structure (km) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Oil $10^6Sm^3$ | | | Gas $10^9Sm^3$ | | | | | Litho-/ Chrono-stratigraphic level | Reservoir depth (m MSL) | |
| | | Low | Base | High | Low | Base | High | | | | | |
| Katana | P | 1.4 | 3.3 | 5.8 | 0.2 | 0.5 | 1.0 | 10 | 1 | Draupne Fm/ Kimmeridgian-Volgian | 1680 | 10 |
| Kuro | L | 0.0 | | 95.0 | | | | <10 | 45 | Ty Fm/Paleocene | 1009 | 8 |
| Kenja | L | | 7.0 | | | | | NA | 100 | Sognefj.-Brent/ M.-U.Jurassic | 2132 | 26 |
| Aura | L | | 7.0 | | | | | NA | 100 | Sognefj.-Brent/ M.-U.Jurassic | 1945 | 22 |
| Kiku | L | | 4.0 | | | | | NA | 100 | Sognefj.-Brent/ M.-U.Jurassic | 1992 | 20 |
| Pyra | L | | 3.0 | | | | | NA | 100 | Sognefj.-Brent/ M.-U.Jurassic | 2121 | 26 |
| Chopstick | L | | 1.0 | | | | | NA | 100 | Sognefj.-Brent/ M.-U.Jurassic | 1966 | 24 |
| Mauja | L | | 1.0 | | | | | NA | 100 | Fensfjord/ Bathonian | 2141 | 24 |
| Katana Brent-Sognefjord | L | | 2.0 | | | | | NA | 85 | Sognefj.-Brent/ M.-U.Jurassic | 1940 | 10 |

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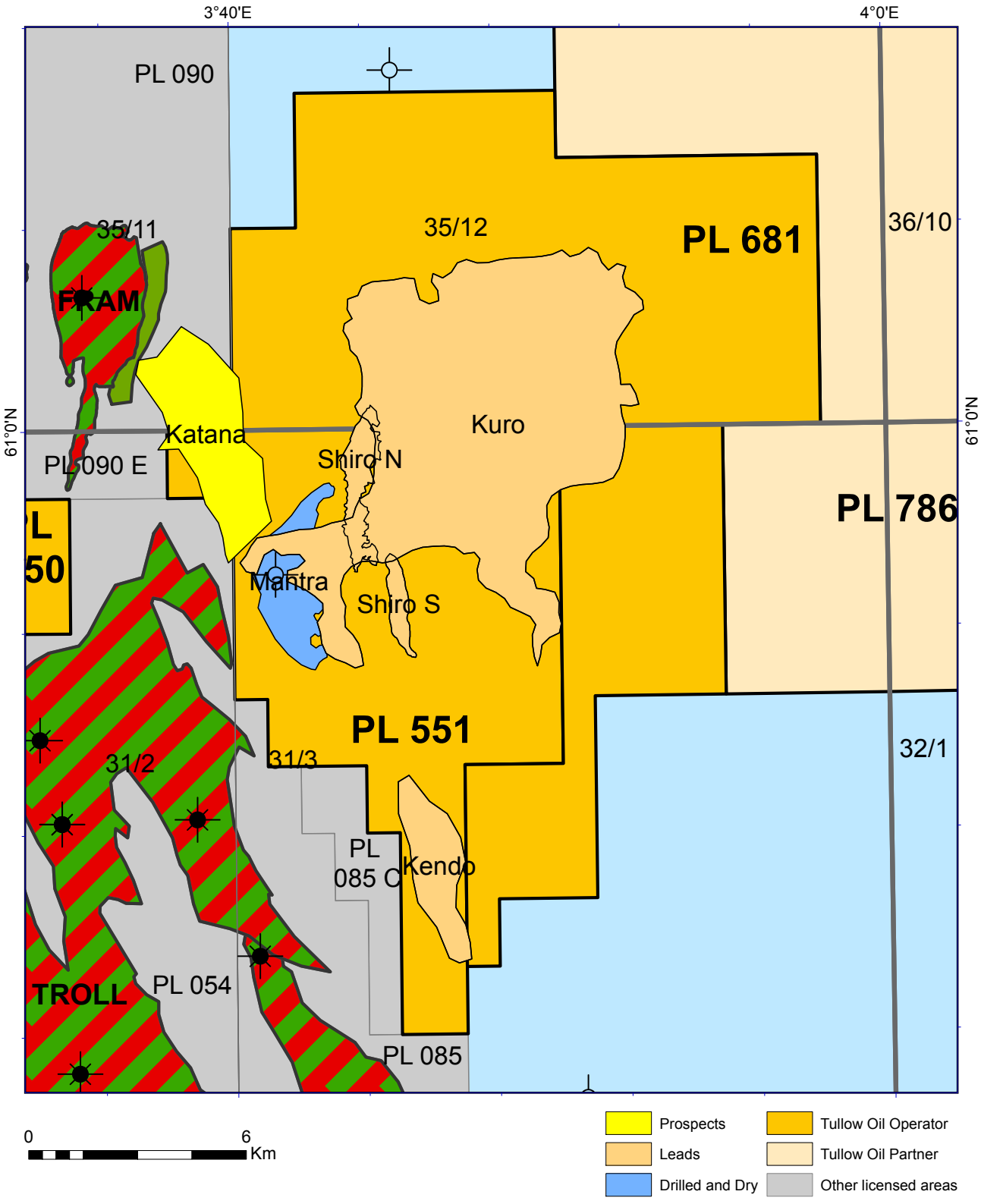


**Fig. 4.3 Current prospect and lead map**

# 5 Technical evaluations

No new evaluations regarding possible developments has been performed since the APA2012 application.

# 6 Conclusions

It has not been possible to define the extent of the Kuro prospect after the 31/3-4 well. Analysis of the EM data (CSEM) [redacted] The risked resources for Kuro would be close to zero and Kuro is only considered as a weak lead.

In the Katana prospect almost all of the revised resources are estimated to be outside the licence. The high prospect risk on a moderate accumulation size do not reflect a commercial potential to support a decision to drill an exploration well.

The partnership of the PL681 has in good cooperation evaluated and concluded on the exploration and commercial potential in the license, and a unanimous decision to drop the license was taken in February 2016.