

# PL 578 Status report at license expiry

4 November 2016



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# 1 Key history

Production license 578 is located in the northern North Sea, approximately 60 km west of Florø and some 30 km northwest of the Gjøa field (Figure 1.1). The license was awarded to Idemitsu Petroleum (operator, 40 %), GDF SUEZ E&P (Engie) (30 %) and VNG (30 %) on 04.02.2011 as part of the APA 2010 licensing. The license application described the main prospect, Smalhans, a relatively deep Jurassic fault and incision trap. A number of leads within the Cretaceous were also described in the application.

The work obligation and decisions are listed in Table 1.1

The PL 578 partnership initiated the preparatory work, prior to commencing seismic acquisition, immediately upon award. During the initial seismic acquisition a risk of conflicting interests between seismic acquisition and the coastal mackerel trolling fleet became evident. In order to avoid any dispute with the fishing industry the partnership decided to suspend the ongoing seismic acquisition after discussions with the authorities. Early July 2011 26 % of the planned acquisition had been completed. The acquisition was resumed and completed during the spring of 2012. A total of 1184 km<sup>2</sup> new 3D seismic data was acquired together with PL 270.

The 3D seismic acquisition delay and the time-consuming seismic processing delayed the progress of prospect evaluation to such a degree that the partnership was not able to make a DoD decision by the 4 February 2014 milestone. On 14 August 2013 the partnership therefore applied for a one-year extension of the remaining milestones, in order to complete the work programme and continue the normal progress. This extension was granted 13 November 2013.

The main Jurassic prospect, Smalhans, was thoroughly evaluated, but was in 2013 concluded not to be economically robust for drilling.

The focus shifted to the Cretaceous Tower prospect. The Tower structure (now called Tower North) is a part of the "Tower complex", which also includes Tower South, located in the Engie-operated PL 153. A large part of the Tower complex therefore lies within PL 153, and technical-economical evaluations demonstrated that an economical development would require a coordinated exploration, appraisal and development approach between the two licenses. On 18 December 2014 it was therefore applied for a two-year extension of the milestones. On 17 March 2015 the license was granted a one and a half year extension of the DoD, BoK and BoV milestones, while the PDO and the end of initial period milestones were extended with one year. In connection with the 2015 extension of the milestones the following activities were included in the PL 578 work program: a merge and reprocessing of approximately 540 km<sup>2</sup> of IPN1201 and ST0703, and a cooperation project with PL 153.

The reprocessing started in May 2015, and the final deliverables were delivered in January 2016. The objective was to improve imaging and definition of depositional systems in the Tower complex. The goal for the PL 578 and PL 153 cooperation project was to receive a common understanding of the whole Tower complex for the Kyrre, Agat and Åsgard successions, alignment on resources and risk and an optimization of a development solution. The project was completed in June this year.

License meetings have been held on a regular basis. Tables 1.2 and 1.3 give an overview of the meetings. In addition, work meetings have been arranged when required.

PL 153 operator Engie could not support advancing a common Tower complex project with PL 578 and the technical-economical evaluation of a the Tower North stand-alone project did not demonstrate sufficient economic potential to enable a recommendation for a positive drilling decision. Tower North was the only remaining target of interest in PL 578. Consequently, the partnership unanimously agreed to drop and surrender PL 578 at the 4 August 2016 DoD decision milestone.

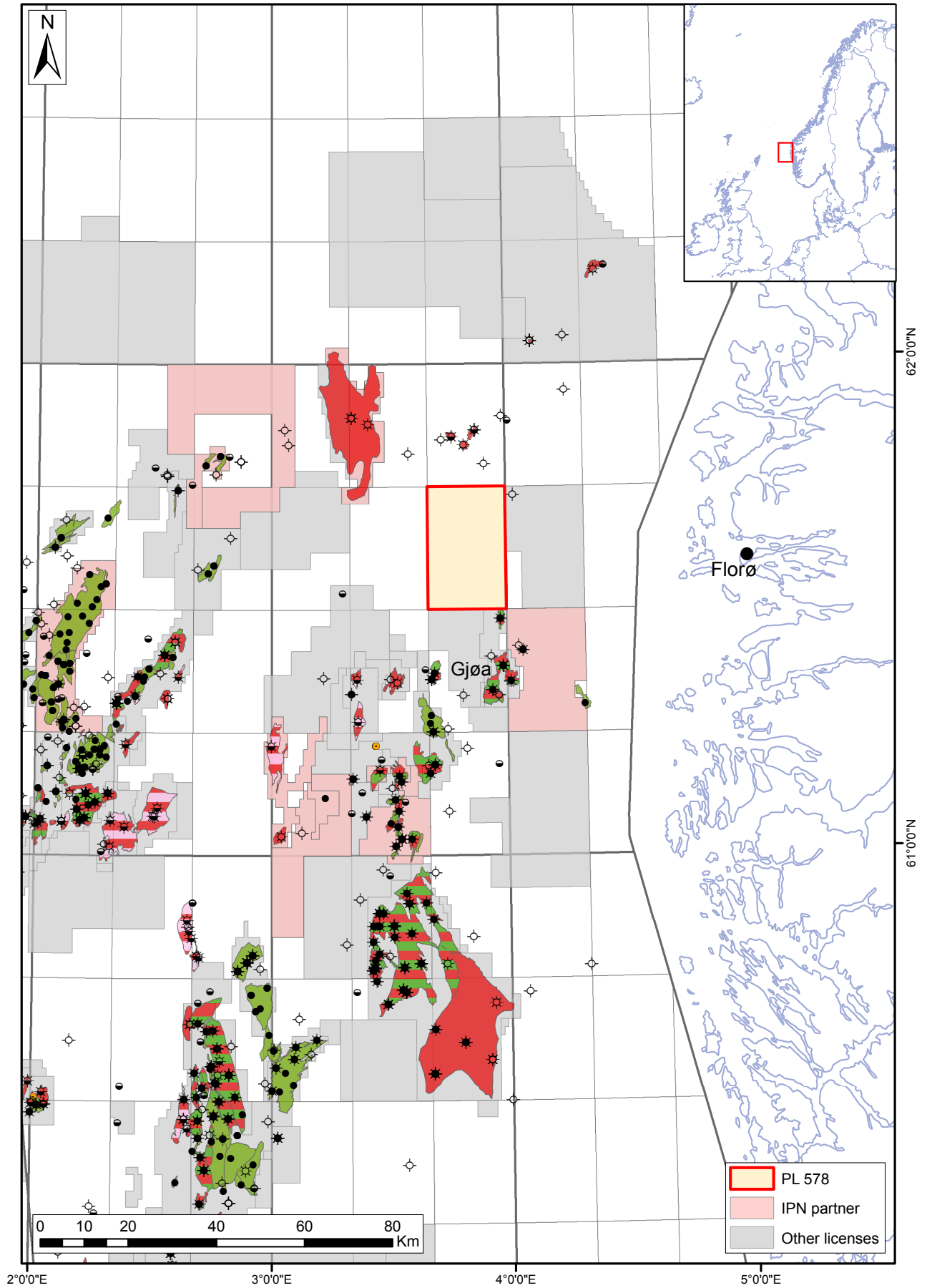


Figure 1.1 PL 578 location map.  
Outline of is indicated in red box

Table 1.1 PL 578 work obligations and decisions

Phase	Duration (yrs)	Activity/decision
1	3	Acquisition and processing of new 3D seismic Geological and geophysical studies <b>Decision:</b> Drill or drop
2	2	Drill exploration well <b>Decision:</b> Concretize (BoK) or Drop
3	2	Conceptual studies <b>Decision:</b> Continuation (BoV) or Drop
4	1	Prepare development plan <b>Decision:</b> Submit PDO or Drop

Table 1.2 PL 578 EC meeting overview

EC meeting	Date	Agenda
# 1	07.03.2011	1. Welcome & Introduction 2. Formalise PL 578 3. PL 578 prospectivity including partner presentation 4. Work program & Budget 5. 3D seismic status and plans 6. AOB.
# 2	14.06.2012	1. Introduction 2. 2012 Activities - IPN1101 & IPN1201 seismic survey, BPN9401 reprocessing (SIP), Rock physics study (SIP) status, Petroleum system (Torena) status, Subsurface geology status, Fieldtrip, Drilling preparations status, Planned activities autumn 2012 3. AOB
# 3	28.11.2012	1. Introduction 2. Summary of 2012 activities - IPN1101 & IPN1201 seismic survey (acquisition and processing), QC and editing of key geophysical well data, BPN9401 reprocessing (SIP), Rock physics phase 1 (SIP), Seismic interpretation, Reservoir facies/reservoir properties (UIO study and petrophysical evaluation), Drilling preparations (Environmental study, Metocean study & Collision risk analysis) 3. 2013 activities-proposal 4. AOB
# 4	21.11.2013	1. Introduction 2. IPN1101/1201 processing summary 3. PL 578 prospect and lead inventory - Smalhans, B2 and Upper Jurassic leads 4. Seismic inversion study 5. The way forward 6 AOB
# 5	12.06.2014	1. Introduction 2. Inversion study and seismic reprocessing 3. Smalhans prospect 4. Tower prospect 5. Technical economical evaluation - Smalhans and Tower 6. The way forward - discussion 7. AOB
# 6	25.09.2014	1. Introduction 2. Tower prospect - resources and technical and economical evaluation 3. The way forward 4. AOB
# 7	24.11.2014	1. Introduction 2. Smalhans & Tower prospects 3. The way forward 4. AOB
# 8	03.06.2015	1. Introduction 2. IPN1201MR15 reprocessing status 3. Tower project - a cooperation between PL 578 and PL 153 4. APA 2015 - Tower extension 5. AOB
# 9	27.11.2015	1. Introduction 2. IPN1201MR15 reprocessing status 3. Tower project - a cooperation between PL 578 & PL 153 - status 4. Seismic interpretation status 5. The way forward 6. AOB
# 10	13.06.2016	1. Introduction 2. IPN1201MR15 reprocessing 3. Tower project - a cooperation between PL 578 and PL 153 - Geology & Geophysics (Kyrre, Agat and Åsgard fms), reservoir engineering, technical economical evaluation 4. PL 578 Status 5. AOB

Table 1.3 PL 578 MC meeting overview

MC meeting	Date	Agenda
# 1	07.03.2011	1. Welcome & Introduction 2. Formalise PL 578 3. PL 578 prospectivity 4. Work program and budget 5. 3D seismic status and plans 6. AOB
# 2	30.06.2011	1. Introduction 2. Work program and budget 2011
# 3	09.11.2011	1. Introduction 2. Update of 2011 activities and the way forward 3. Work program and budget 2011 Budget update 2012 Work program and budget proposal 4. AOB
# 4	14.06.2012	1. Introduction 2. Work program and budget 2012 Revised budget 2013 Work program and budget proposal 3. AOB
# 5	28.11.2012	1. Introduction 2. Work program and budget 2012 Revised budget 2013 Work program and budget proposal 3. Partner forum related issues - cost sharing methods and hourly rates 4. AOB
# 6	21.11.2013	1. Introduction 2. Work program and budget 2013 Budget status 2014 Work program and budget proposal 3. Partner forum related issues - cost allocation method and hourly rate 2012 & 2013 4. AOB
# 7	12.06.2014	1. Introduction 2. 2014 Budget status 3. 2015 Proposed provisional work program and budget 4. AOB
# 8	24.11.2016	1. Introduction 2. License extension proposal 3. Work program and budget 2014 Budget status 2015 Work program and budget proposal 4. Partner forum related issues - cost allocation method and hourly rate 5. AOB
# 9	03.06.2015	1. Introduction 2. 2015 Budget status 3. 2016 Proposed provisional work program and budget 4. AOB
# 10	27.11.2015	1. Introduction 2. Work program and budget 2015 Budget status and revision 2016 Proposed work program and budget Partner forum 3. AOB
# 11	13.06.2016	1. Introduction 2. 2016 Work program and budget status 3. Operator's drill or drop recommendation 4. 2017 Proposed provisional work program and budget 5. AOB

## 2 Database

### 2.1 Seismic database

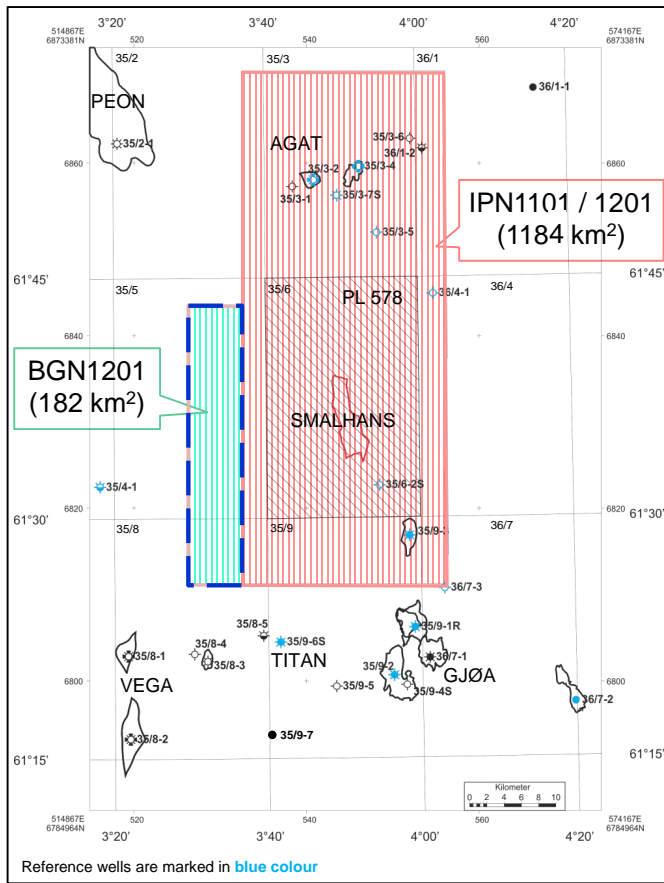
As part of the license work program, PL 578 acquired new seismic 3D data in 2011/2012 (Figure 2.1) Acquisition and processing of IPN1201 was a cooperation project between IPN-operated PL 578 and VNG-operated PL 270, with Idemitsu as project operator. Data ownership and cost split are shown in Figure 2.2. The survey covers the entire PL 578 license area, in addition to PL 270 acreage. The processing, including pre stack time migration (PSTM) and pre stack depth migration (PSDM), was carried out by CGG and was completed in 2013. For PL 578, the main focus of the 2013 processing was the Jurassic Smalhans prospect.

The data quality of IPN1201 was, however, not optimal for the Cretaceous Tower complex prospects. Therefore, in 2014 the license decided to carry out a merge and reprocessing of the IPN1201 and ST0703 surveys, to improve data quality and to ensure coverage of the whole Tower complex with a co-processed dataset. The main objective of the reprocessing was to improve structural imaging and definition of the potential Lower Cretaceous sand systems (Agat and Åsgard fms). The name of the reprocessed and merged dataset is IPN1201MR15. The processing was carried out by Schlumberger Geosolutions in Stavanger. The IPN1201MR15 processing, including PSTM and PSDM imaging, utilized de-ghosting processing to convert the conventional data into broadband data. The broadband processing gave significant uplift in seismic quality and imaging, as reduction of wavelet side lobes enhanced interpretation confidence and velocity picking analysis. In addition, the broadband processing, which preserves the low frequent response of the seismic data, was crucial for stabilizing the inversion results (e.g. sand cube, relative and absolute Vp/Vs and Acoustic Impedance (AI) data). The first PSTM data became available late 2015, and the final PSDM data in January 2016. The detailed seismic interpretation and updated prospect evaluation of the Tower complex was carried out on the new IPN1201MR15 dataset.

The seismic database is listed in Table 2.1 and also shown in Figure 2.3.

Details regarding acquisition and processing of IPN1201, IPN1201R13 and IPN1201MR15 can be found in 2011-2016 EC meeting presentations (Table 1.2).

In addition, Engie and Idemitsu had access to the ST0703MR13 seismic data reprocessed by PL 636 in 2013.



- A joint venture between PL 578 (IPN Operator) and PL 270 (VNG Operator). IPN was the survey Operator.
- Monarch Geophysical Services was technical advisors and managers (Main contact with boat and management of client representatives).
- Fugro was the seismic contractor company operating the hi-tech C-class vessel named Geo Caspian.
- The survey was acquired in 2 phases due to seismic restrictions
  - 11/07/11 to 05/08/11 (26 days – 26% of survey acquired)
  - 17/04/12 to 29/05/12 (43 days – 74 % of survey acquired)
- Technical specifications:
  - 2 source arrays
  - 14 streamers with 50 m distance
  - Streamer length of 6 km (5.5 km in 2011)
  - 2012: outer streamer fan mode
- IPN1201 was operated with 2 guard vessels.

Figure 2.1 IPN1201 acquisition summary

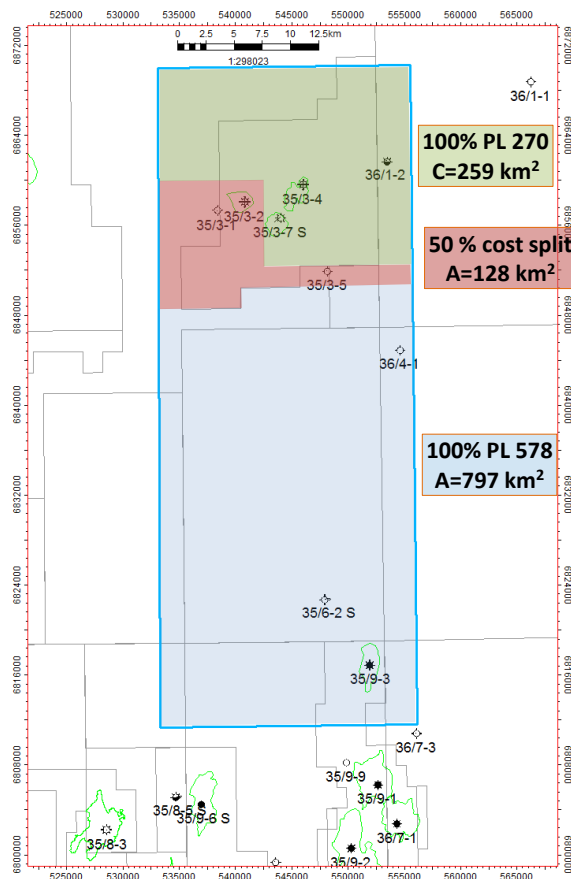


Figure 2.2 IPN1201 ownership

Table 2.1 PL 578 Seismic database

Survey name	Ownership	Type	Area (km <sup>2</sup> )	Comments
IPN1201	PL 578 & PL 270	3D	1470	Part of survey reprocessed by PGS 2013
IPN1201MR15	PL 578	3D	540	Merge and reprocessing of IPN1201 and ST0703
BGN1201	PL 635	3D	182	Trade agreement no 6102
BPN9401R12	PL 578	3D	380	PSTM and PSDM

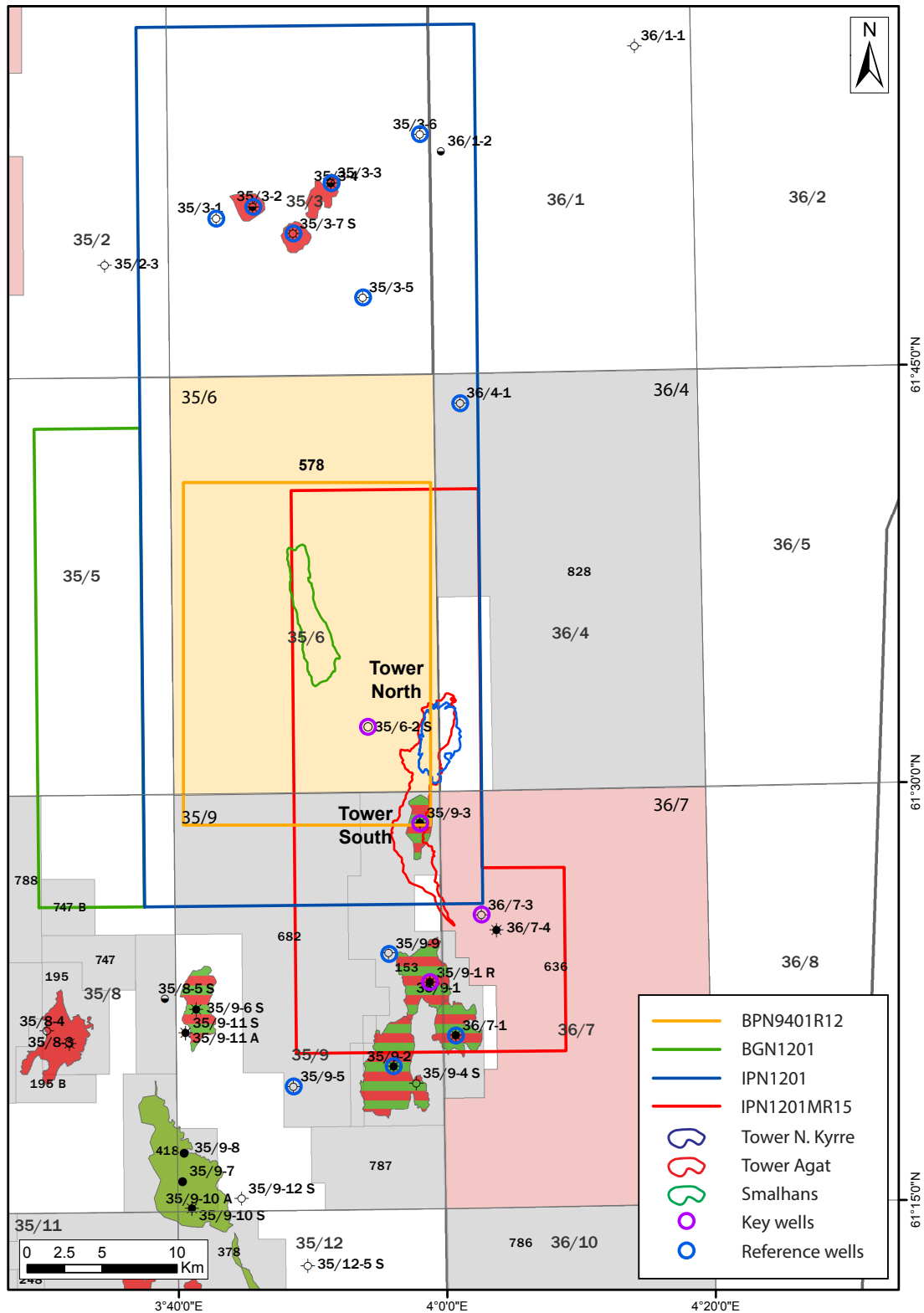


Figure 2.3 PL 578 seismic and well database

## 2.2 Well database

The PL 578 licensees have access to all relevant exploration wells in the eastern part of northern North Sea (Figure 2.3 and Table 2.2). The only well drilled after the application and incorporated in the license database was 35/9-9. The well was drilled by PL 153 in 2013 and is classified as a dry well.

Table 2.2 PL 578 Well database

Well name	TD (depth TVD RKB/age)	Comments
35/3-2 (Agat Field)	4400 m Pre-Devonian Basement	Gas and condensate discovery. Hydrocarbon shows were encountered in Lower Cretaceous and Lower Jurassic sandstones. Two zones in the Lower Cretaceous sandstones were tested, producing water and gas/condensate respectively. A possible 8.8 meters of net hydrocarbon bearing thin sand stringers were penetrated in the Lower Jurassic sequence.
35/3-4 (Agat Field)	4089 m Pre-Devonian Basement	Gas and condensate appraisal of 35/3-2 discovery. Hydrocarbon shows were encountered in Lower Cretaceous and Lower-Middle Jurassic sandstones.
35/3-5	4114 m Pre-Devonian Basement	Dry well with weak shows. A minor show was noted at the top of the Agat Formation. Minor oil shows with associated formation gas peaks were recorded in sandstones in the Lower Cretaceous Formation. Minor shows were recorded in siltstones below 3685 m (Åsgard Formation), but these were not associated with gas peaks.
35/3-6	3366 m Late Jurassic	The 25 m thick Agat Formation consisted of carbonate cemented sandstone with traces of hydrocarbons. Otherwise the well encountered no hydrocarbon bearing intervals.
35/3-7 S	3971 m Middle Jurassic	Gas discovery in the Agat Formation as proven by pressure data and gas samples. Moderate visible oil shows were primarily related to the core chips from the gas-bearing reservoir.
35/6-2 S (Grosso)	3583.2 m Lower Cretaceous Åsgard Formation	Dry well. Lower Cretaceous Agat and Upper Cretaceous Kyrre formations reservoirs were wet. Agat Formation reservoir cemented but much sandier than anticipated. Failure due to lack of trap (leakage of hydrocarbons updip to east). No shows in Kyrre Formation reservoir.
35/9-1 (Gjøa Field)	2348 m Pre-Devonian Basement	Gas and oil discovery. Gas in Middle Jurassic Fensfjord and Krossfjord formations, with separate gas column in Middle Jurassic Brent Group; gas and oil in Lower Jurassic Dunlin Group (in communication with the Brent Group).
35/9-2 (Gjøa Field)	2877 m Pre-Devonian Basement	Gas and oil discovery in Late Jurassic Draupne Formation sandstones, Sognefjord and Middle Jurassic Fensfjord formations, not in communication with 35/9-1 Viking Group discovery. Middle Jurassic Brent and Lower Jurassic Dunlin groups reservoirs are water bearing.
35/9-3 & 3 T2	2770/2781 m Pre-Devonian Basement	Gas discovery in laterally extensive Upper Cretaceous Kyrre Formation sandstones with excellent reservoir properties; gas and oil discovery in laterally discontinuous Lower Cretaceous Agat Formation sandstones with poor reservoir properties and poor vertical connectivity. Analysis of the cores using the Hydrocarbon Core Scanner indicated possible presence of residual oil within the gas column in the Kyrre Formation. Sidetrack of the 35/9-3 well from 1872 m to TD due to mud losses during drilling. One core taken in the first well and 4 cores in the sidetrack.
35/9-5	3531 m Middle Jurassic	Dry well. Very little sand preserved in the Agat Formation at the 35/9-5 location. There were no shows to confirm hydrocarbons in the Agat Formation or in any other part of the well.
35/9-9	3338 m Triassic	Dry well. Reservoir quality sands were penetrated in Fensfjord, Ness, Etive and Cook formations. All were water wet.
36/4-1	2714 m Pre-Devonian Basement	Dry well. Primary target failed due to absence of Upper Jurassic reservoirs (Heather Formation shale deposited on basement). Secondary target Upper Cretaceous Kyrre sandstone reservoir present with shows but failed due to lack of trap.
36/7-2	1435.0 m Pre-Devonian Basement	Heavy oil in shallow (900 m TVD) Upper Jurassic sandstones.
36/7-1 (Gjøa Field)	2839 m Pre-Devonian Basement	Oil and gas discovery in Upper Jurassic Viking Group Draupne Formation sandstones, Sognefjord and Middle Jurassic Fensfjord formations. Secondary target in Brent Group was water-bearing. Excellent reservoir quality in Sognefjord Formation.
36/7-3	2946.8 m Middle Jurassic Heather Formation	Dry well. Targets were stratigraphic traps in Lower Cretaceous Agat, Upper Cretaceous Kyrre and Lower Cretaceous Åsgard formations sandstones. Reservoirs were encountered at all levels with excellent reservoir quality in Kyrre Formation sandstones. Previously it was thought that the well lay in a migration shadow but new FIT data suggest that this area has been charged and therefore seal/retention is now considered the reason for failure.

## 2.3 Special studies

The new seismic data and well data have been integrated into regional and sub-regional models to form the basis of the interpretative framework for the PL 578 evaluation. Proprietary reports related to seismic data, reservoir quality, petroleum system analysis and drilling preparations are listed in Table 2.3. All reports are available on L2S. The results of the geology and geophysical evaluations have been presented in different EC meetings (Table 1.1) and the presentations are available on L2S.

Table 2.3 PL 578 special studies and reports

Title of report	Company	Vintage	L2S date
Field report 3 D marine seismic survey NCS Blocks 35/6 and 35/3 for Idemitsu Petroleum Norge AS Project No. FGAS.111006A Geo Caspian	Fugro	2012	20120813
Field report 3 D marine seismic survey NCS Blocks 35/6 and 35/3 for Idemitsu Petroleum Norge AS IPN 1201 Project No. 111006B M/V Geo Caspian	Fugro	2012	20120813
Field guide: Deep - marine canyon and fan deposits, Eocene Ainsa Basin, Pyrenees, Spain	Idemitsu	2012	20120917
PL 578 Re Processing of 3D BPN9401	Seismic Image Processing	2012	20121007
Environmental screening of PL 578 in Block 35/6	Acona	2012	20121015
Petroleum system analysis of the Smalhans prospect in PL 578, Block 35/6 on the eastern flank of the Sogn Graben, Norwegian North Sea	Torena	2012	20121015
Rock physics phase 1	Seismic Image Processing	2012	20121113
Formation of potentially porosity preserving grain coats in Brent and Dunlin sandstones from wells close to the Smalhans prospect, PL 578	University of Oslo	2012	20121205
Vessel traffic survey and collision analysis	SAFETEC	2013	20130418
Metoccean report for PL 578	Meteorologisk institutt	2013	20130418
IPN1201 Processing report	CGG	2014	20140430
PL 578 – North Sea, Offshore Norway: Seismic inversion and reservoir characterisation. Summary report	PGS Reservoir	2014	20141015
PL 578 – North Sea, Offshore Norway: Seismic inversion and reservoir characterisation. Report figures	PGS Reservoir	2014	20141015
PL 578 – North Sea, Offshore Norway: Seismic inversion and reservoir characterisation. Rock Physics report figures	PGS Reservoir	2014	20141005
Addendum to Torena AS report 2012_01 Petroleum system analysis of the Tower prospect in PL 578, block 35/6 on the eastern flank of the Sogn Graben, Norwegian North Sea	Torena	2014	20161025
Data processing report for Idemitsu Petroleum Norge AS. Area: PL 578, PL 153 and PL 636 (IPN1201MR15)	Schlumberger Geosolutions	2016	20160609
IPN1201MR15 AVO Inversion and Reservoir Characterization report	Idemitsu	2016	20161025

## 3 Review of geological and geophysical studies

### Geological studies

A study to evaluate the potential Brent and Dunlin groups' reservoir rocks in the area around the Smalhans prospect for identification of possible porosity-preserving grain coatings was carried out in 2012 by the Department of Geosciences at the University of Oslo. Hydrothermal experiments were performed on natural sandstone core samples taken from depth not yet buried to temperatures where coatings are known to form. This was done in order to enable simulation of deeper burial of the same rocks through experiments. The relationship between coating formation and the existence of precursor coatings and minerals species were studied. This relation could possibly relate coating formation to processes going on in different depositional environments. The fact that no reservoir potential was found in Dunlin sandstones in the Agat field (and only two out of seven samples from the Gjøa area indicated possible reservoir potential at 4000 m) may indicate that most Dunlin sandstones have a low reservoir potential in the area. The porosity-preserving potential of these micro-quartz coatings and their lateral distribution in Middle Jurassic sandstones (and possibly also in the Lower Jurassic sandstone) are still unexplored. Brent sandstones seems to be the best reservoir prospects in the Gjøa area, but permeability issues related to the kaolinite-to-illite reaction at depth is an unknown factor.

A petroleum system analysis of the Smalhans prospect in PL 578 was carried out by Torena in 2012. The results of the analysis indicate that Smalhans most likely is a gas-phase prospect with a moderate gas/condensate-ratio (GCR), possibly with a thin oil leg, although surplus charge suggests that a possible oil leg has spilled out of the prospect. Moderate to high overpressure seems anyway to yield a pure gas-phase accumulation with no oil leg. A main uncertainty concerns the GCR of the gas.

As an addendum to the Torena 2012 report a petroleum system analysis of the Tower North prospect in PL 578 was carried out in 2014. The Tower North prospect is likely to have been charged by two carrier bed systems, *i.e.* (1) along Top Agat Fm directly into the prospect, and (2) along Base Upper Jurassic followed by vertical leakage from beneath, at or close to the prospect. Assuming that an aliquot of the expelled hydrocarbons migrate and accumulates in the prospect it will occur as a two-phase accumulation under the given reservoir conditions, as seen in the 35/9-3 T2 discovery today. The size of the oil leg is difficult to assess, but the significant charge volumes and the strong shows in the Agat Fm in 36/7-3 suggests that the Tower prospect is filled to spill.

A license field trip was arranged to the Ainsa Basin, Spain in September 2012. Guide was Johan Petter Nystuen from the University of Oslo. The scope of the excursion was to obtain knowledge about deep-marine canyon to fan systems, as demonstrated from outcrops in a well-exposed and well-documented sedimentary basin. The Eocene Ainsa Basin in the southern Pyrenées was chosen due to good exposures of turbidite fan deposits and associated basin mud facies, as observed from the basin platform, through deep-marine canyons cutting through shallow-marine platform successions to proximal and distal deep marine fan locations and the basin floor area beyond these.

## Geophysical studies

In 2012 Seismic Image Processing (SIP) carried out reprocessing of 380 km<sup>2</sup> of the BPN9401 3D survey with focus on Smalhans. The key objective was to improve existing seismic data for early interpretation of key risk elements. An additional objective was to improve the understanding of seismic velocities and quality to support/improve the upcoming processing of the new IPN1201 seismic data.

In addition, SIP in 2012 carried out a rock physics study with the objectives to determine whether changing fluid types in reservoir section would yield a measurable difference on acoustic logs and to develop optimum rock physics indicators (RPI) to enhance these differences.

Petroleum Geo-Services was awarded a project to perform a simultaneous AVO/AVA seismic inversion study across PL 578. The objectives for the study was to discriminate between different lithologies and fluids, based on seismic data combined with well data. Originally the concentration was on the two main target levels: deeply seated Jurassic structures and the shallower, but quite deeply buried, gas filled deep-marine sand deposits and prospects of the Early to Late Cretaceous Agat Fm. During the course of the project it was concluded that Jurassic targets have a very subtle AVO response, which makes inversion results difficult to use in this case, while the Agat Fm targets were prioritized and considered to be the most prospective in this area. The inversion volumes are robust and consistent with the input data quality and handle the complicated geology and large variation in amplitude and frequency over the 1.9 seconds (TWT) inversion window. The low-frequency model (and therefore absolute volumes) rely on the quality of well and seismic velocity data. There are significant uncertainties in the low-frequency model, and these uncertainties should be considered when interpreting the results. The lithology prediction model derived from the well data is marginally consistent with the inversion volumes and makes prediction of anomalies based on the correlation between the rock physics model and the inversion volumes at each depth uncertain.

A 2015 re-processing and merge of the ST0703 and IPN1201 surveys, including time and depth processing, was carried out by Schlumberger Geosolutions (Chapter 2.1).

An in-house elastic (AVO) inversion study has been carried out based on the new reprocessed dataset (IPN1201MR15). The main goal was lithology and fluid predictions of the Agat and Åsgard fms, focusing on the Tower complex area. The inversion indicated presence of sand and HC. The reliability of the results is questionable due to several reasons: the anomalies are only partly concordant with structural closure some anomalies are also present outside the Tower structure. Furthermore, seismic tuning effects and residual gas may contribute to misinterpretation.

## Drilling preparations

A screening study was initiated to get an overview of relevant environmental aspects. PL 578 is located close to the coast, and the distance to the closest shore is approximately 30 km. There is short drift time to important areas of vulnerable resources, including significant bird cliffs. Planning of drilling activities outside the breeding period for sea birds (April – August) could be considered as a mitigating measure. Strict requirements for oil spill response (including short response times) should be expected. Systems for early detection of oil spills, such as oil detecting radar, and presence of NOFO-system on location during drilling were recommended.

A vessel traffic and collision study showed that a Smalhans well location would be situated in an area of low shipping density. The analysis showed that the collision impairment frequencies estimated for a rig at a Smalhans location is exceeding the acceptance criteria set by the Norwegian Petroleum Safety Authority. However, steps could be made to reduce the risk further. If possible traffic surveillance from the Ekofisk radar or Statoil marine (or another vessel traffic systems) should be considered. It was recommended to conduct a survey to confirm if it is possible to identify any so called “regular runners” in the most contributing routes, i.e. vessels or vessel operators that traffic the area repeatedly.

A Metocean report, including statistics and return value estimates for waves, wind and currents were generated by Meteorologisk institutt in 2012.

## 4 Prospect update report

### 4.1 Smalhans prospect

Smalhans is a well-defined north-south trending Jurassic horst cut by two east west trending incisions of Late Jurassic age (Figure 4.1 and Figure 4.2). The structure has a small four-way dip closure, but this closure was considered to be too small to be of any commercial interest. Detailed seismic interpretation showed that the trap may have been modified by the Late Jurassic to Early Cretaceous incisions in a similar way as has Gjøa, and thereby possibly being able to hold potentially larger volumes than the pure structural closure would suggest.

A reinterpretation of the prospect was carried out based on the IPN1201 3D survey. The new seismic data support total truncation of the Brent Group but not the Dunlin Group sequence.

Middle Jurassic trap definition: The structure has a well-defined fault closure with an erosional component towards the south. Middle Jurassic sandstones are not directly tied into the prospect (correlated based on an interpreted maximum flooding surface (MFS) reflector below), giving some uncertainty to be assigned to the trap geometry.

Middle Jurassic seal: Top seal is the mudstones of the Heather Formation. The reservoir is juxtaposed against Cretaceous deposits over the eastern bounding fault of unknown, but possibly distal part of sandstones penetrated in well 35/6-2 S (Åsgard Fm). Towards the south, the prospect is dependent on a lateral seal towards the Upper Jurassic incision (deeper than minimum filling) filled with unknown, but most likely fine-grained material. The trap is also dependent on basal seal towards the Cook Fm for deeper than mode filling.

Middle Jurassic reservoir presence: The "normal" southerly-derived Brent system is interpreted not to be present in this area, so the prospect relies on an easterly source. These easterly-derived Middle Jurassic sandstones are recorded in several nearby wells (e.g. 35/9-1 and 2, 35/3-4), but regional palaeographic interpretation indicates that this system terminates into mudstones close to the Smalhans prospect. There is recorded a gradual thinning of the middle Jurassic sandstones from east towards the west.

Middle Jurassic reservoir quality: Based on the nearby wells the reservoir quality seems to be moderate to good in the Middle Jurassic sandstones (e.g. 35/3-4, 35/9-1). Based on the study from The University of Oslo, the easterly-derived Brent system has the potential of chlorite/micro-quartz coating and thus may show a more than normal porosity preservation towards depth.

Lower Jurassic trap definition: The trap is a fault-closure bounded by an erosion to the south. The top Cook Fm reflector is not well calibrated to wells (based on the relative position to an overlying interpreted MFS, and thus somewhat uncertain). The relationship between the Upper Jurassic unconformity and Cook reflector is very important for the trap definition.

Lower Jurassic seal: The top seal is the mudstones of the Drake Fm. The Drake Fm is a proven cap rock in several areas, including the Titan discovery and also the Oseberg and Knarr fields. The reservoir is juxtaposed against Cretaceous deposits of unknown origin over an eastern bounding fault. Towards the south, the prospect is dependent on a lateral seal towards an Upper Jurassic incision (deeper than minimum filling), filled with unknown, but most likely fine-grained material. Internal barriers may give different gas-water contacts in the Dunlin sandstones.

Lower Jurassic reservoir presence: In the relevant nearby wells, reservoir is present in all except for 35/3-4. There is some uncertainty since the top of the reservoir can not be straightforward correlated into the prospect area.

Lower Jurassic reservoir quality: Some of the wells penetrating the Dunlin sandstone show very poor reservoir quality even at moderate burial depths (e.g. 35/3-5 and 36/7-1). There is recorded a large variability and no trends in both reservoir thickness and net/gross in the area. The reservoir parameters are set low to reflect this large uncertainty.

Source rock and HC dynamics: Upper Jurassic source is proved by several nearby discoveries. The Smalhans prospect is located in an optimal position to be charged by huge volumes of hydrocarbons generated in the Sogn Graben,

probably on the fill-spill route to Gjøa. Since Brent Gp is not present in the source area, the prospect relies on Cook Fm and/or Upper Jurassic Viking Gp sandstones as carrier beds. A probable gas-cloud above the prospect may be taken to imply migration into the structure.

Table 4.1, Table 4.2 and Table 4.3 give the results of the 2014 Smalhans evaluation. For the combined case (Brent and Dublin groups) the current numbers for the recoverable resources (mean case) are 4.9 MSm<sup>3</sup> oil equivalents (oe), while the corresponding number in the APA 2010 application was 6.2 MSm<sup>3</sup> oe for the combined case. The current chance of success (COS) is 41 % versus 35 % in the application. The main risks as currently are reservoir presence and quality.

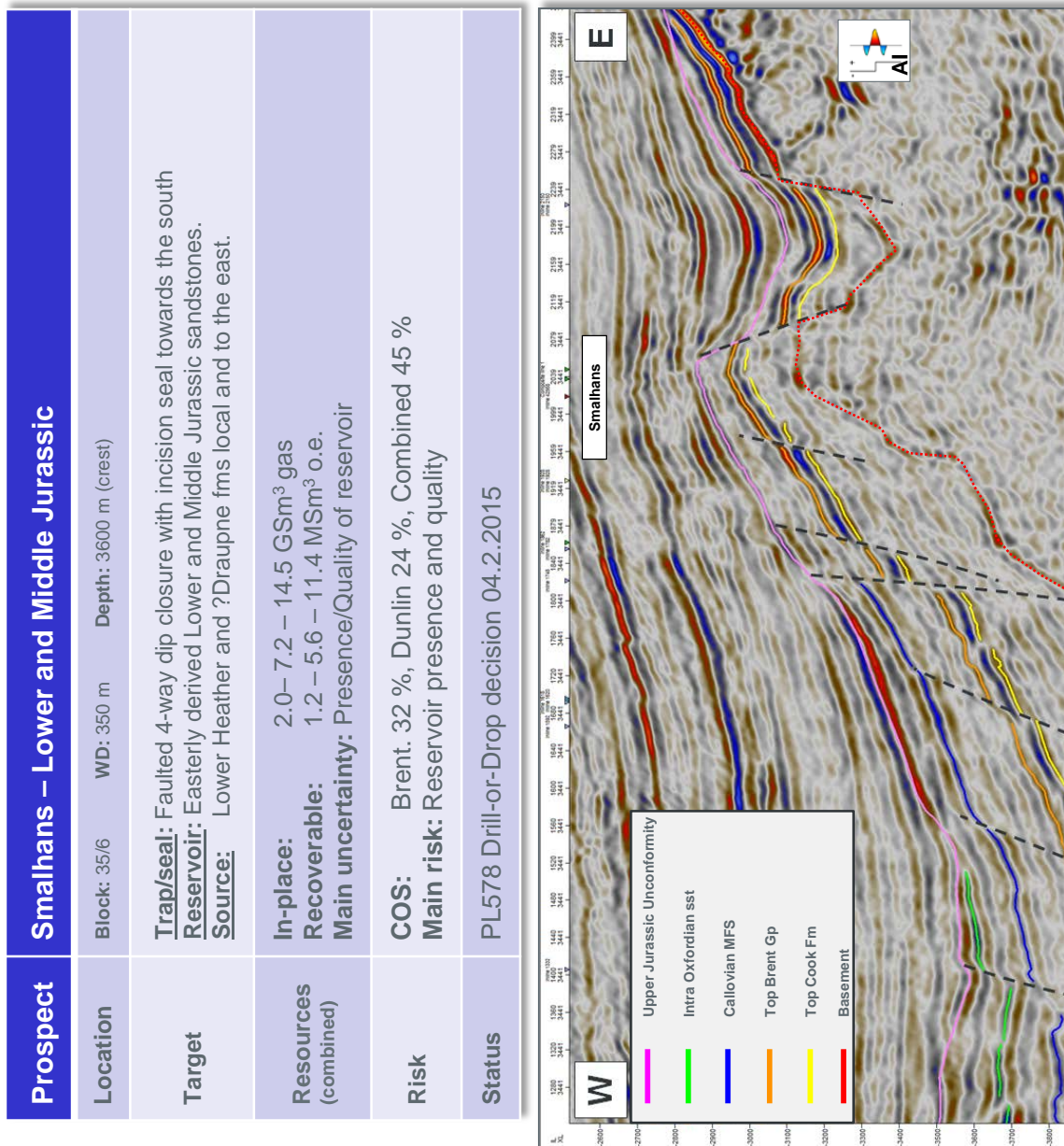


Figure 4.1 Smalhans map and seismic line

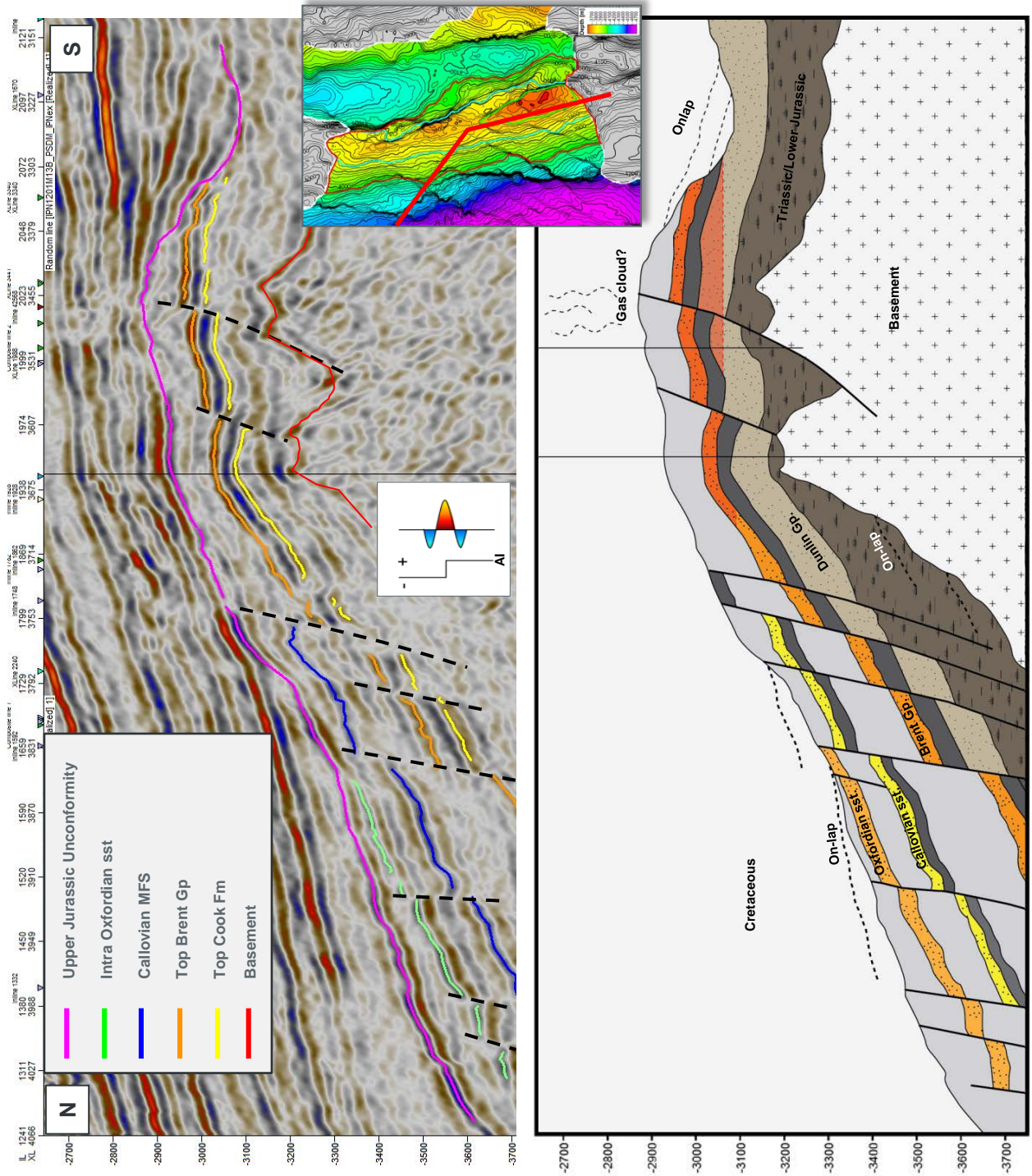


Figure 4.2 Smalhans prospect concept

**Table 4.1 Prospect data, Smalhans, Brent Group**

Updated 2014 numbers in orange colour.

Block	Prospect name		Discovery/Prosp/Lead		Prosp ID (or New!)	NPD approved?
35/6	Smalhans		Prospect		<i>NPD will insert data</i>	<i>NPD will insert data</i>
Play (name / new)	Structural element		Company/ reported by / Ref. doc.		Year	
<i>NPD will insert data</i>	Måløy Terrace		Idemitsu Petroleum Norge AS/APA2010 /EC meeting #5		2010/2014	
Oil/Gas case	<b>Resources IN PLACE</b>					
	Main phase			Ass. phase		
	Low	Base	High	Low	Base	High
Oil 10 <sup>6</sup> Sm <sup>3</sup>						
Gas 10 <sup>9</sup> Sm <sup>3</sup>	2,2	6,6	12,4			
	<b>Resources RECOVERABLE</b>					
	Main phase			Ass. phase		
	Low	Base	High	Low	Base	High
Oil 10 <sup>6</sup> Sm <sup>3</sup>				0,3	1,2	2,4
Gas 10 <sup>9</sup> Sm <sup>3</sup>	1,2	4,0	7,8			
	Which fractiles are used as:		Low:	P90 / P100*	High:	P10 / P0*
Type of trap	Water depth (m)		Reservoir Chrono (from - to)		Reservoir Litho (from - to)	
Truncated fault block	325		Middle Jurassic		Brent	
Source Rock, Chrono	Source Rock, Litho		Seal, Chrono		Seal, Litho	
Jurassic	Draupne, Heather		Lower Cretaceous		Cromer Knoll	
Seismic database (2D/3D):	IPN1201, BGN1201, BPN9401R2					
	<b>Probability of discovery:</b>					
Technical (oil+gas case)	0.28		Prob for oil/gas case		0,1 / 0,9	
Probability (fraction):	Reservoir (P1)	Trap (P2)	Charge (P3)	Retention (P4)		
	0.49	0.9	0.9	0.7		
<b>Parametres:</b>	Low*	Base	High*	Comments		
Depth to top of prospect (m)		3600				
Area of closure (km <sup>2</sup> )	3	12	29			
Reservoir thickness (m)	10	25	60			
HC column in prospect (m)	100	250	500			
Gross rock vol. (10 <sup>9</sup> m3)	0,06	0,41	1,22			
Net / Gross (fraction)	0,3	0,6	0,9			
Porosity (fraction)	0,08	0,15	0,2			
Water Saturation (fraction)	0,1	0,2	0,4			
Bg. (<1)	0,00303	0,00323	0,0034			
Bo. (>1)						
GOR, free gas (Sm <sup>3</sup> /Sm <sup>3</sup> )	1500	3000	5000			
GOR, oil (Sm <sup>3</sup> /Sm <sup>3</sup> )						
Recovery factor, main phase	0,4	0,6	0,8			
Recovery factor, ass. phase	0,3	0,5	0,7			
Temperature, top res (deg C) :	130	Pressure, top res (bar) :				
<b>For NPD use:</b>						
Innrapp. av geolog:		Registrert:		Map OK:		Nr:
Dato:		Dato:		Dato:		

Table 4.2 Prospect data, Smalhans, Dunlin Group

Updated 2014 numbers in orange colour.

Block	Prospect name	Discovery/Prosp/Lead	Prosp ID (or New!)	NPD approved?		
35/6	Smalhans	Prospect	<i>NPD will insert data</i>	<i>NPD will insert data</i>		
Play (name / new)	Structural element	Company/ reported by / Ref. doc.		Year		
<i>NPD will insert data</i>	Måløy Terrace	Idemitsu Petroleum Norge AS/APA2010 /EC meeting #5		2010/2014		
Oil/Gas case	<b>Resources IN PLACE</b>					
	Main phase			Ass. phase		
	Low	Base	High	Low	Base	High
Oil 10 <sup>6</sup> Sm <sup>3</sup>						
Gas 10 <sup>9</sup> Sm <sup>3</sup>	1,2	3,1	5,4			
	<b>Resources RECOVERABLE</b>					
	Main phase			Ass. phase		
	Low	Base	High	Low	Base	High
Oil 10 <sup>6</sup> Sm <sup>3</sup>				0,1	0,5	0,9
Gas 10 <sup>9</sup> Sm <sup>3</sup>	0,6	1,6	3,0			
	Which fractiles are used as:		Low:	P90 / P100*	High:	P10 / P0*
Type of trap	Water depth (m)	Reservoir Chrono (from - to)		Reservoir Litho (from - to)		
Truncated fault block	325	Lower Jurassic		Dunlin		
Source Rock, Chrono	Source Rock, Litho	Seal, Chrono		Seal, Litho		
Jurassic	Draupne, Heather	Lower Cretaceous		Cromer Knoll		
Seismic database (2D/3D):	IPN1201, BGN1201, BPN9401R12					
	<b>Probability of discovery:</b>					
Technical (oil+gas case)	0,24			Prob for oil/gas case		0,1 / 0,9
Probability (fraction):	Reservoir (P1)	Trap (P2)	Charge (P3)	Retention (P4)		
	0,48	0,8	0,9	0,7		
<b>Parametres:</b>	Low*	Base	High*	Comments		
Depth to top of prospect (m)		3680				
Area of closure (km <sup>2</sup> )	3	6	13			
Reservoir thickness (m)	50	100	200			
HC column in prospect (m)	100	170	270			
Gross rock vol. (10 <sup>9</sup> m <sup>3</sup> )	0,13	0,42	0,77			
Net / Gross (fraction)	0,10	0,25	0,50			
Porosity (fraction)	0,08	0,13	0,18			
Water Saturation (fraction)	0,10	0,30	0,50			
Bg. (<1)	0.00303	0.00323	0,004			
Bo. (>1)						
GOR, free gas (Sm <sup>3</sup> /Sm <sup>3</sup> )	1500	3000	5000			
GOR, oil (Sm <sup>3</sup> /Sm <sup>3</sup> )						
Recovery factor, main phase	0,30	0,50	0,70			
Recovery factor, ass. phase	0,20	0,40	0,60			
Temperature, top res (deg C) :	130	Pressure, top res (bar) :				
<b>For NPD use:</b>						
Innrapp. av geolog:		Registrert:		Map OK:		Nr:
Dato:		Dato:		Dato:		

**Table 4.3 Prospect data, Smalhans, Dunlin + Brent groups**

Updated 2014 numbers in orange colour.

Block	Prospect name		Discovery/Prosp/Lead		Prosp ID (or New!)	NPD approved?
35/6	Smalhans		Prospect		<i>NPD will insert data</i>	<i>NPD will insert data</i>
Play (name / new)	Structural element		Company/ reported by / Ref. doc.			Year
<i>NPD will insert data</i>	Måløy Terrace		Idemitsu Petroleum Norge AS/APA2010/EC meeting #5			2010/2014
Oil/Gas case	Resources IN PLACE					
	Main phase			Ass. phase		
	Low	Base	High	Low	Base	High
Oil 10 <sup>6</sup> Sm <sup>3</sup>						
Gas 10 <sup>9</sup> Sm <sup>3</sup>	1,8	6,4	12,5			
	Resources RECOVERABLE					
	Main phase			Ass. phase		
	Low	Base	High	Low	Base	High
Oil 10 <sup>6</sup> Sm <sup>3</sup>				0,2	1,1	2,4
Gas 10 <sup>9</sup> Sm <sup>3</sup>	0,9	3,7	7,6			
	Which fractiles are used as:		Low:	P90	High:	P10
Type of trap	Water depth (m)		Reservoir Chrono (from - to)		Reservoir Litho (from - to)	
Truncated fault block	325		Lower - Middle Jurassic		Dunlin - Brent	
Source Rock, Chrono	Source Rock, Litho		Seal, Chrono		Seal, Litho	
Jurassic	Draupne, Heather		Lower Cretaceous		Cromer Knoll	
Seismic database (2D/3D):		IPN1201, BGN1201, BPN9401R12				
Probability of discovery:						
Technical (oil+gas case)		41		Prob for oil/gas case		0,1 / 0,9
Probability (fraction):		Reservoir (P1)	Trap (P2)	Charge (P3)	Retention (P4)	
<b>Parametres:</b>		Low*	Base	High*	Comments	
Depth to top of prospect (m)						
Area of closure (km <sup>2</sup> )						
Reservoir thickness (m)						
HC column in prospect (m)						
Gross rock vol. (10 <sup>9</sup> m3)						
Net / Gross (fraction)						
Porosity (fraction)						
Water Saturation (fraction)						
Bg. (<1)						
Bo. (>1)						
GOR, free gas (Sm <sup>3</sup> /Sm <sup>3</sup> )						
GOR, oil (Sm <sup>3</sup> /Sm <sup>3</sup> )						
Recovery factor, main phase						
Recovery factor, ass. phase						
Temperature, top res (deg C) :		130	Pressure, top res (bar) :		580	
<b>For NPD use:</b>						
Innrap. av geolog:		Registrert:		Map OK:		Nr:
Dato:		Dato:		Dato:		

## 4.2 Tower North and Tower complex

The Tower North prospect, located in the south-east corner of PL 578, is identified by two separate structural four-way closures. The shallowest closure, which consists of the intra-Kyrre sandstone fan system (upper and middle Kyrre sandstone units), has the highest probability of discovery, whereas Agat Formation sandstone system has the expected highest volume potential. Figure 4.3 shows the prospect summary of the Tower Kyrre North, and Figure 4.4 shows the prospect summary Tower Agat North and Tower Agat South. All three segments combined constitute the Tower complex. The Tower complex prospect concept and summary is illustrated in Figure 4.5.

Inversion and AVO attribute analysis have been key to the prospect evaluation of Tower. The Kyrre sandstones closure is mapped on excellent seismic data, and has a distinct depth-conformable AVO anomaly (Figure 4.6). The strong AVO anomaly is interpreted to represent gas, thus Tower Kyrre is interpreted as a gas prospect. The risking of Tower Kyrre North is as follows:

The Tower Kyrre North trap definition is well-defined as a faulted 4-way dip structure based on high quality 3D seismic data. Some small uncertainty in depth conversion remains, but the structure is present, regardless of velocity model applied.

The Tower Kyrre North seal has some risk, as the structure is cut by some small faults, but the 35/9-3 T2 discovery strongly support a working top seal. Kyrre North has a strong DHI support, with a small risk of being low-saturation gas only.

The Tower Kyrre North reservoir presence is proven by the nearest wells, 35/9-3 T2, 35/6-2 S and 36/7-3. The distinct soft seismic amplitude and the good tie to nearby wells with sandstones drilled support sand distribution.

The Tower Kyrre North reservoir quality is expected to be good, due to its relative shallow depth and by the distinct soft amplitude response. Furthermore, similar good-quality intra-Kyrre sandstones are proved in all nearby wells.

The Tower Kyrre North hydrocarbon-dynamics and source rock presence and quality carry low risk, as the source rock is proved by the 35/9-3 T2 discovery and other nearby discoveries. Charge is strongly supported by the gas discovery in nearby well 35/9-3 T2. Widespread distribution of intra-Kyrre sandstones (including Silius channels/canyons) provide an excellent carrier bed system. Alternative/additional charge is also possible along faults from the underlying Agat Fm. The presence of gas is highly supported by an DHI anomaly conformable to structure.

Compared to the intra-Kyrre level, the data quality at the Agat Fm level is more challenging. This is most noticeable at the crestal part, where the Agat Formation is thinning and where the faulting and structural deformations are most intense. The Tower North Agat closure is evaluated as an oil prospect with a gas cap. Inversion and attribute analysis of the new IPN1201MR15 data do, however, strengthen the presence of sands and hydrocarbons within the Tower Agat North prospect (Figure 4.7). However, the PL 578 licensees still deem a deep hydrocarbon-filling (down to structural spill) and sandstone distribution within Tower North as quite uncertain. The licensees considered that the sandstone distribution to be locally either very thin and/or compartmentalized, which affect the volume potential and geological risk in a negative direction.

The risking of Tower Agat North is as follows:

Tower Agat North trap definition is well-defined by a faulted four-way dip structure based on good quality 3D seismic data. There is a slight uncertainty in size, but no risk for the presence of a minimum trap geometry.

Tower Agat North top seal is proven by the 35/9-3 T2 discovery. The top seal should have sufficient capacity to retain a large hydrocarbon column. No thief sands above the main Agat sandstone are observed.

Tower Agat North reservoir presence has moderate risk. Tower North is assumed to be a paleo-structural high, which has been filled in with sediments at the time of Agat deposition. Observations in the new IPN1201MR15 seismic, including AVO and inversion results, support the presence of sands over the apex area and on the flanks (except for a small area on the east flank).

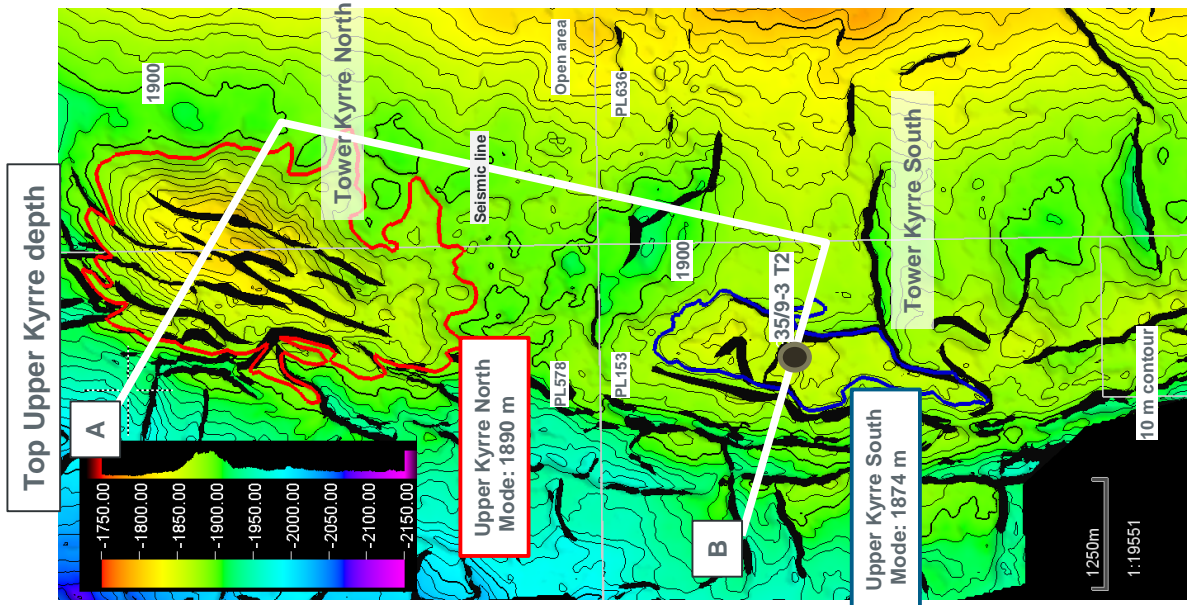
Tower Agat North reservoir quality risk is considered low. Nearby wells show good reservoir quality (35/6-2 S, 35/9-3 T2 and 36/7-3). Furthermore, seismic data suggest a distinct soft top sand response, which suggests good reservoir quality.

Tower Agat North source rock has no risk, as the source rock is proven by the 35/9-3 T2 discovery and other nearby discoveries. With regards to hydrocarbon dynamics no risk is assigned to the gas dynamics, whereas a moderate risk is assigned to the oil-case. Hydrocarbon migration of both oil and gas to the south part of Tower is proven by the 35/9-3 T2 discovery. Basin modelling performed by contractor Torenna shows that huge amounts of hydrocarbons migrated into the Tower prospect and probably spilled out to south east towards well 36/7-3 (paleo oil column?). However, the modelling suggests a more gas-prone setting than assumed in the relatively oil-prone resource estimation.

Tower Agat South is proven by the 35/9-3 T2 discovery. However, in evaluating a potential deeper OWC (e.g. deeper than 2648 m MSL oil down to (ODT) in 35/9-3 T2), Tower Agat South carries a significant seal risk. There is some depth uncertainty if the southern part of Tower Agat South structure is de-risked by the well. Thus, there is significant risk that structure has leaked due to Neogene uplift and tilt. Consequently, hydrocarbon indications from AVO/inversion could be a result of the presence of residual hydrocarbons. Furthermore, it may be that the well is simply testing an isolated fault-trapped segment and is not representative of the whole Tower South.

As the Tower North prospect was evaluated to be too small to justify an exploration well, PL 578 sought partnership with PL 153 to evaluate and mature the whole Tower complex as a drillable prospect. Exploration well 35/9-3 T2, located within the Agat Tower South structure, which proved gas and a thin 4 m oil column at Agat level, was crucial for the G&G evaluation of the Tower Complex (Figure 4.8). However, the 35/9-3 T2 well results are difficult to understand, as the well was drilled in the middle of a fault zone and the formation pressure points below the ODT at 2648 m MSL are very scattered. However, an alternative interpretation of the 35/9-3 T2 well suggests a deep oil-filling ( 2700 m +/-30 m) in the structure, more or less at the same depth as the structural spill of the Tower North prospect. This observation is also supported by the AVO and inversion results, which show a marked change in amplitude at the same depth within the Tower North and South segments (Figure 4.7 and Figure 4.9). Consequently, both Tower North and South (35/9-3 T2) could share a common deep OWC, which would make the volume potential for the whole Tower complex quite attractive. However, this view was not shared by the PL 153 operator and PL 578 partner Engie, and thus it was not possible to mature the combined Tower complex (North and South) into a drilling candidate.

Details regarding prospect evaluation of Tower Kyrre, Tower Agat North and Tower Agat complex (North and South) is found in 2015-2016 EC meeting presentations (Table 1.1).



Prospect	Tower Kyrre North	Tower Kyrre South
<b>Location</b>	Block : 35/6 & 36/4 WD : 350 m Depth : 1800 m	Block : 35/9 WD : 350 m Depth : 1840 m
<b>Target</b>	Trap/seal : 4-way dip closure Reservoir : Upper Cretaceous Kyrre Sst Source : Lower Heather and Draupne fms	Trap/seal : Faulted 4-way dip closure Reservoir : Upper Cretaceous Kyrre Sst Source : Lower Heather and Draupne fms
<b>Resources</b>	In-place : 3.3 – 5.3 – 7.5 GSm <sup>3</sup> gas Recoverable : 1.9 – 3.3 – 4.9 GSm <sup>3</sup> gas Main uncertainty : Net sand thickness. Approx. half volumes in open area (36/4)	In-place : 0.4 – 0.6 – 0.9 GSm <sup>3</sup> gas Recoverable : 0.2 – 0.4 – 0.6 GSm <sup>3</sup> gas Main uncertainty : Net sand thickness
<b>Risk</b>	COS : 80 % Main risk : Seal	Discovery
<b>Status</b>	Approved by GGC 20160428 2014 recoverable: 2.1- 3.4 - 4.7 GSm <sup>3</sup> gas	

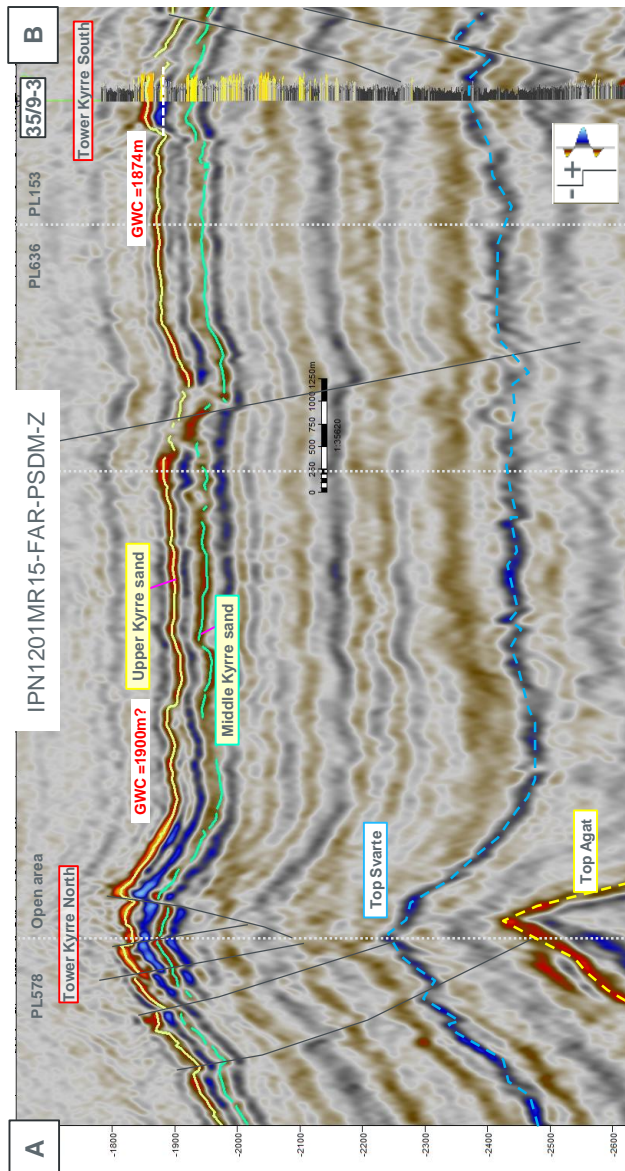
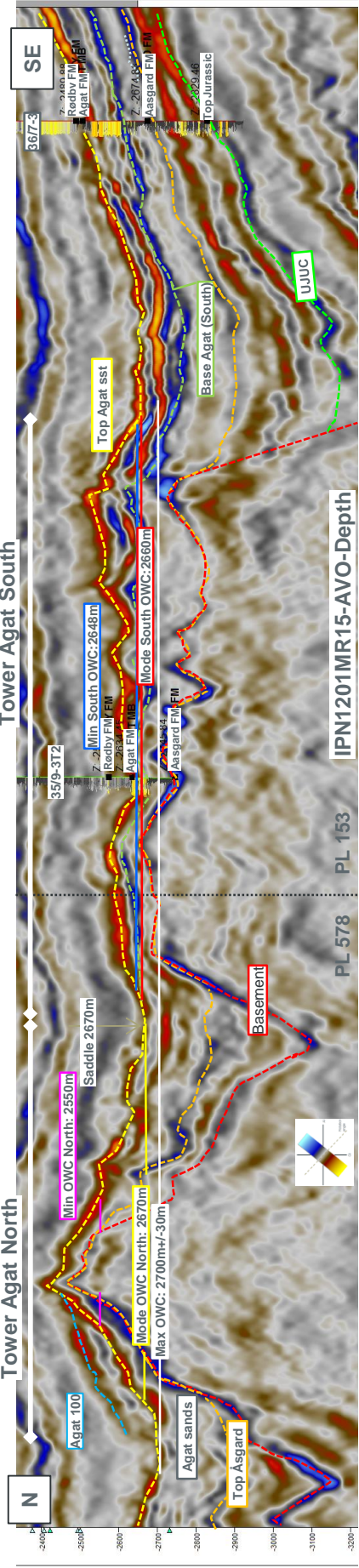
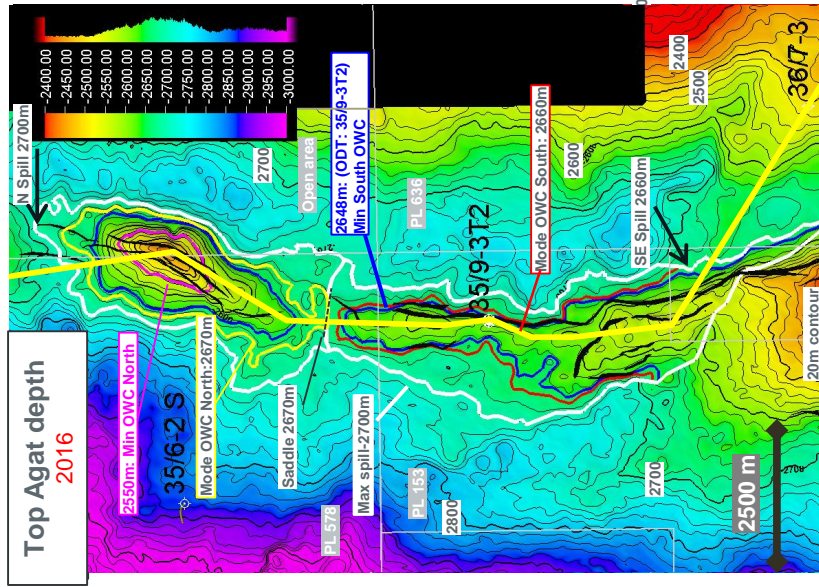


Figure 4.3 Tower Kyrre North prospect summary



Prospect	Tower Agat North	Tower Agat South
Location	Block : 35/6 & 36/4 WD :350 m Depth: 2440m	Block : 35/9 WD :350 m Depth : 2520 m
Target	Trap/seal : 4-way dip closure Reservoir : Lower Cretaceous Agat sst Source : Lower Heather and Draupne fms	Trap/seal : Stratigraphic pinch out trap towards Gjøa Reservoir : Lower Cretaceous Agat sst Source : Lower Heather and Draupne fms
Resources	In-place : 1.1 – 2.7 – 4.5 GSm <sup>3</sup> gas 1.5 – 7.7 – 16.6 MSm <sup>3</sup> oil Recoverable : 1.0 – 3.5 – 7.0 MSm <sup>3</sup> oe Main uncertainty: Hydrocarbon contact depth, size of gas cap and net sand thickness. 20-30% of volumes in open area	In-place : 2.8 – 4.7 – 6.7 GSm <sup>3</sup> gas 4.3 – 14.5 – 26.8 MSm <sup>3</sup> oil Recoverable : 3.3 – 6.5 – 10.7 MSm <sup>3</sup> oe Main uncertainty: Oil water contact depth
Risk	COS : 45 % (oil- prone case) Main risk : Reservoir presence and dynamics for oil	COS : 40 % (oil- prone case) Main risk: Seal, whether entire structure is derisked by 35/9-3T2 and the seal has failed due to uplift and tilt
Status	Approved by GGC 20160428	Approved by GGC 20160428

Figure 4.4 Tower Agat North and Tower Agat South prospects

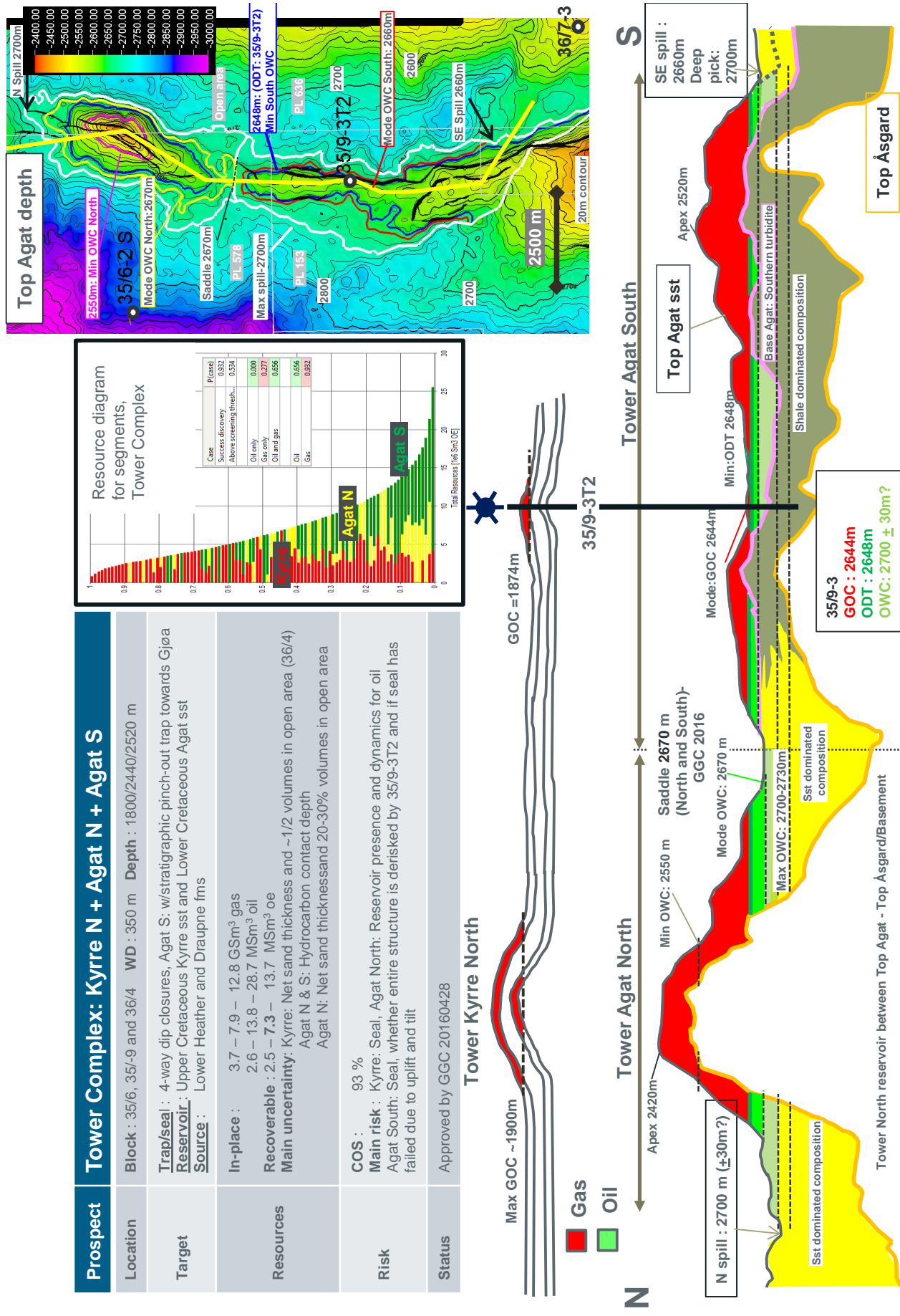


Figure 4.5 Tower complex summary and prospect concept

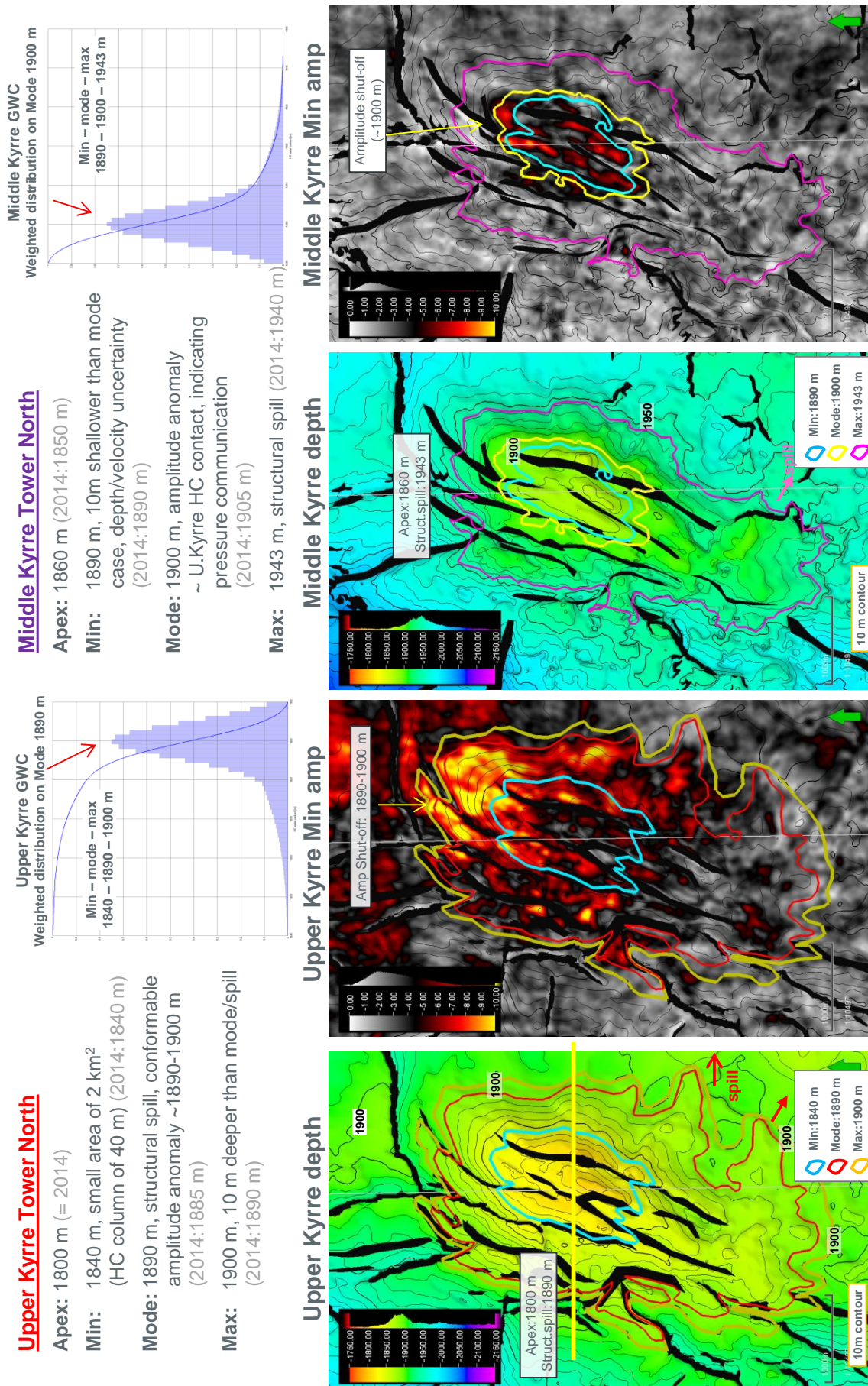


Figure 4.6 Tower Kyrre North AVO and hydrocarbon contact distribution

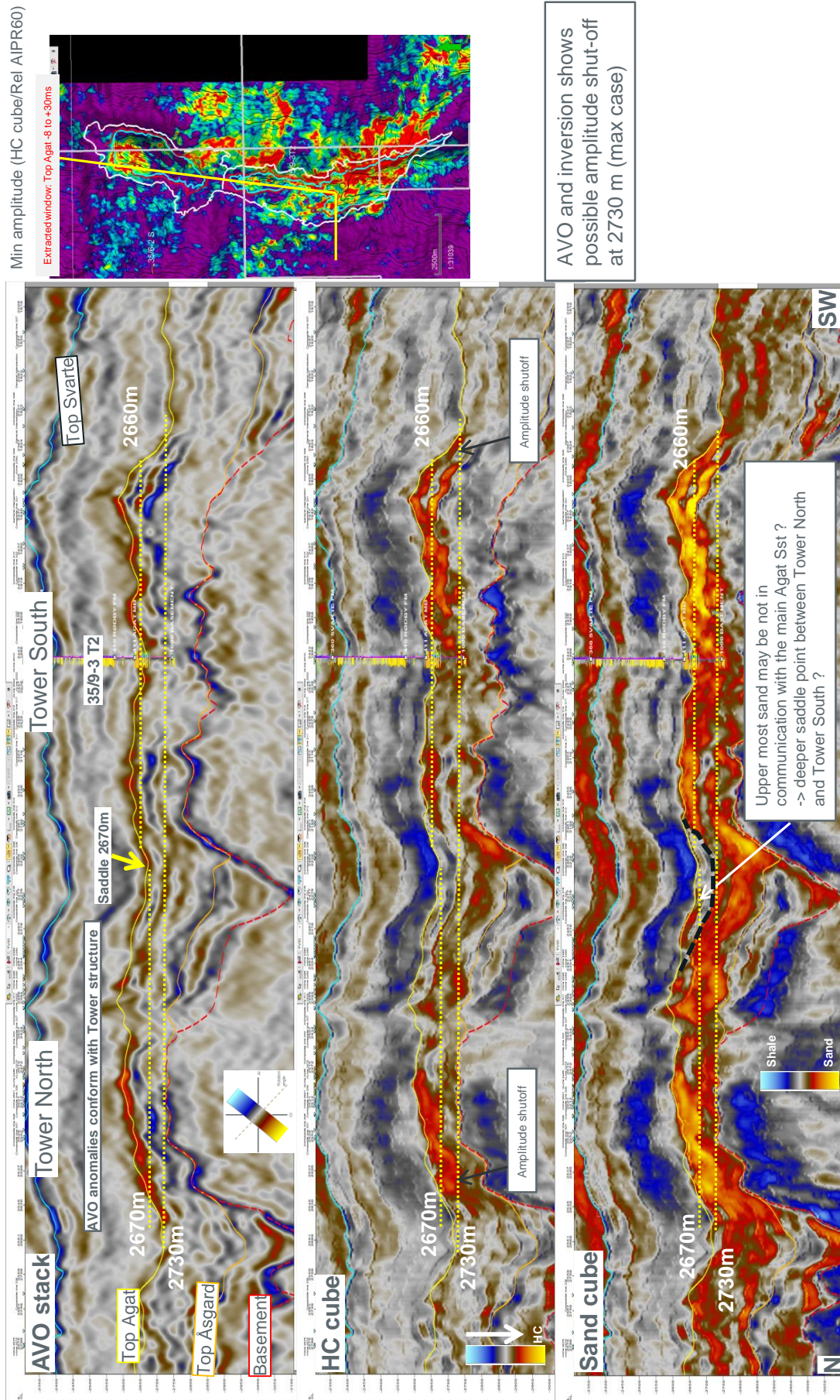
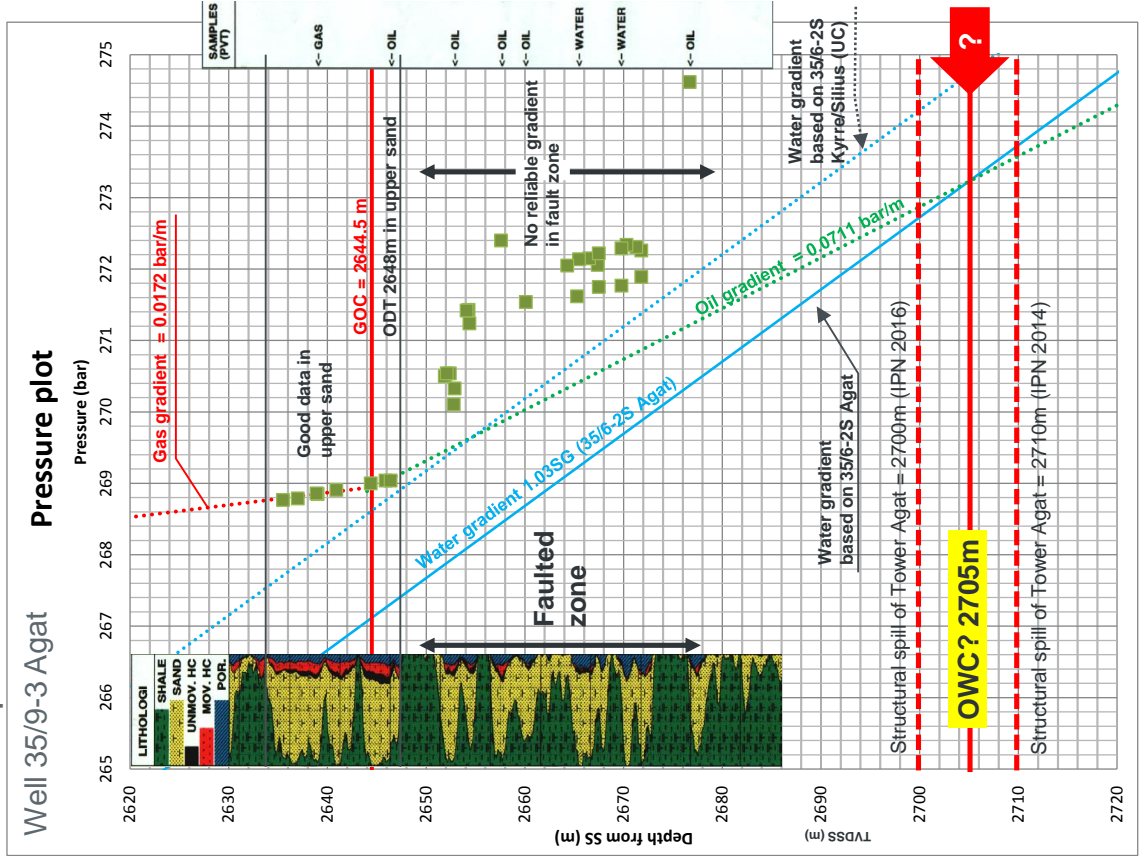


Figure 4.7 Illustration of inversion and AVO data at Agat level in north-south direction

# OWC estimation in 35/9-3T2 Agat based on MDT pressures



# 35/9-3 Agat discovery

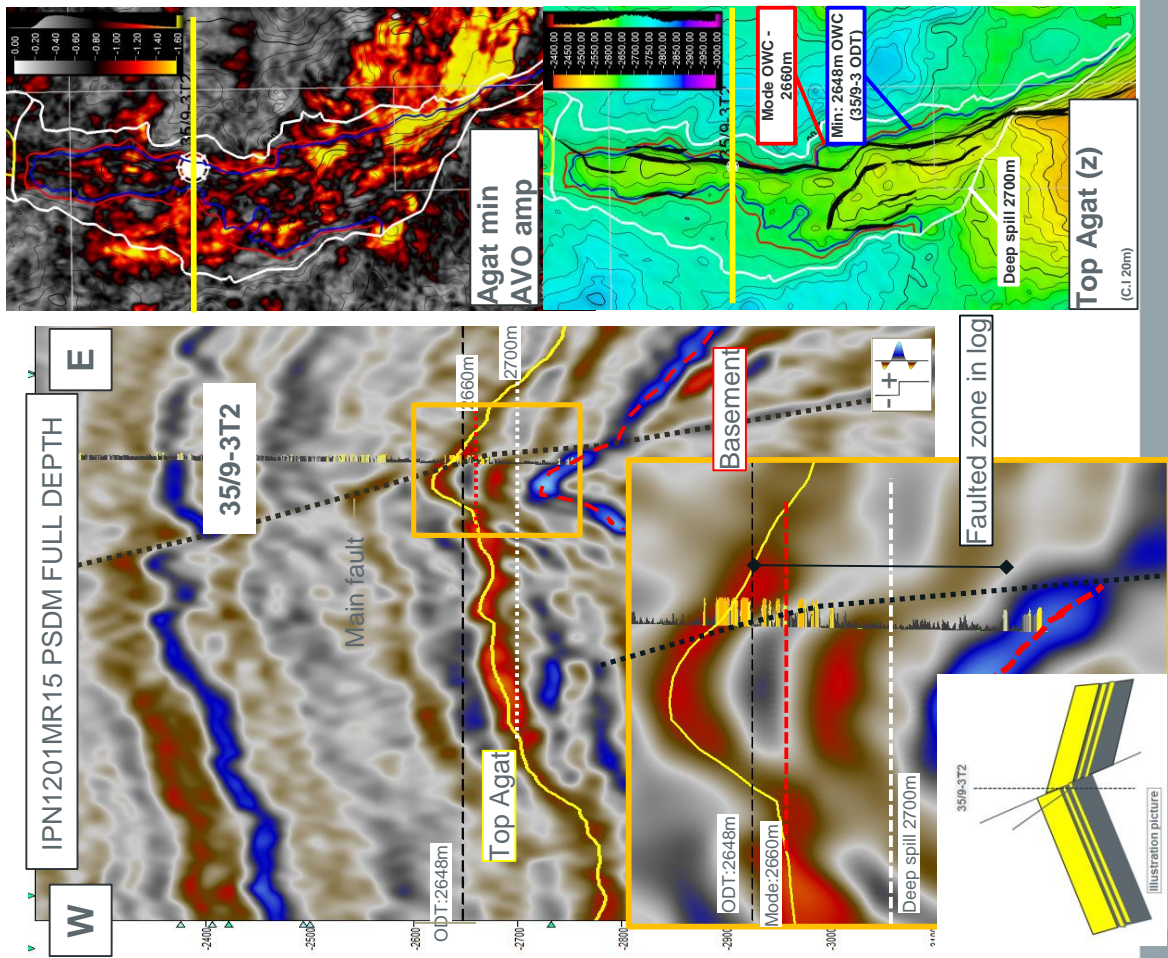


Figure 4.8 36/9-3 T2 Agat discovery and formation pressure points

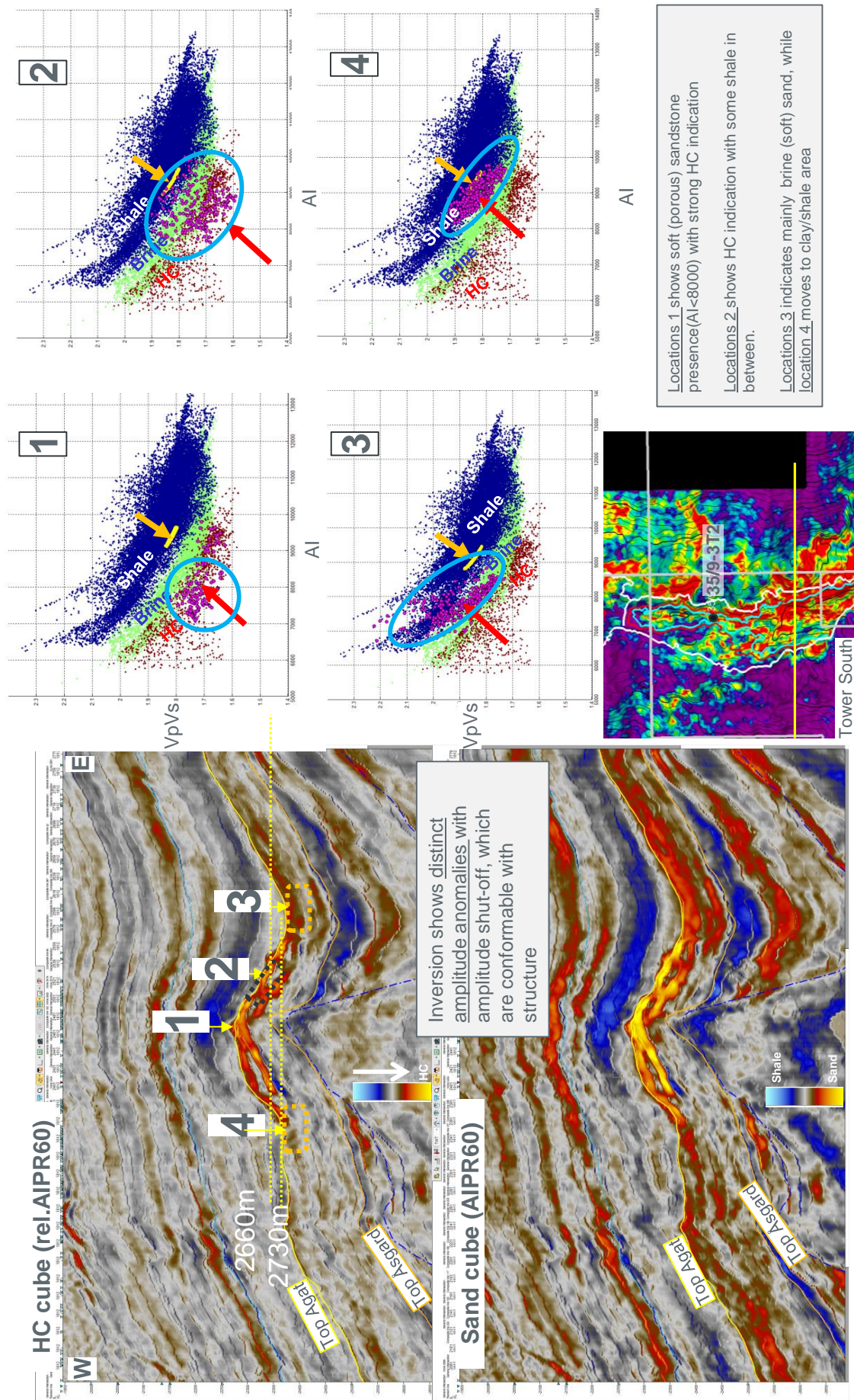


Figure 4.9 Tower South inversion results at cross-line 1812 IPN1201MR15

**Table 4.4 Prospect data, Tower North Agat Formation**

Block	Prospect name		Discovery/Prosp/Lead		Prosp ID (or New!)	NPD approved?
35/6	Tower North Agat		Prospect		<i>NPD will insert data</i>	<i>NPD will insert data</i>
Play (name / new)	Structural element		Company/ reported by / Ref. doc.		Year	
<i>NPD will insert data</i>	Måløy Terrace		Idemitsu Petroleum Norge AS/EC # 10 2016		2016	
Oil & Gas case	<b>Resources IN PLACE</b>					
	Main phase			Ass. phase		
	Low	Base	High	Low	Base	High
Oil 10 <sup>6</sup> Sm <sup>3</sup>	1.5	7.7	16.6			
Gas 10 <sup>9</sup> Sm <sup>3</sup>				1.1	2.7	4.5
	<b>Resources RECOVERABLE</b>					
	Main phase			Ass. phase		
	Low	Base	High	Low	Base	High
Oil 10 <sup>6</sup> Sm <sup>3</sup>	0.3	2.0	4.5			
Gas 10 <sup>9</sup> Sm <sup>3</sup>				0.6	1.6	2.8
	Which fractiles are used as:		Low:	P90/P100*	High:	P10/P0*
Type of trap	Water depth (m)		Reservoir Chrono (from - to)		Reservoir Litho (from - to)	
4 way dip closure	350		Lower Cretaceous		Agat sst	
Source Rock, Chrono	Source Rock, Litho		Seal, Chrono		Seal, Litho	
Jurassic	Heather /Draupne		Lower Cretaceous		Cromer Knoll	
Seismic database (2D/3D):	IPN1201, IPN1201MR15, ST0703R13					
	<b>Probability of discovery:</b>					
Technical (oil+gas case)	0.45		Prob for oil/gas case			
Probability (fraction):	Reservoir (P1)	Trap (P2)	Charge (P3)	Retention (P4)		
	0.72	1	0.7	0.9		
<b>Parametres:</b>	Low*	Base	High*	Comments		
Depth to top of prospect (m)		2420				
Area of closure (km <sup>2</sup> )	1.2	7.1	11.2			
Reservoir thickness (m)	38	70	116			
HC column in prospect (m)	130	250	310			
Gross rock vol. (10 <sup>9</sup> m3)	1.11	1.36	1.62			
Net / Gross (fraction)	0.3	0.5	0.8			
Porosity (fraction)	0.15	0.2	0.23			
Water Saturation (fraction)	0.1(g)/0.2(oil)	0.2(g)/0.3(oil)	0.4(g)/0.5(oil)			
Bg. (<1)	0.0045	0.0051	0.00625			
Bo. (>1)	1.28	1.35	1.42			
GOR, free gas (Sm <sup>3</sup> /Sm <sup>3</sup> )						
GOR, oil (Sm <sup>3</sup> /Sm <sup>3</sup> )	100	117	140			
Recovery factor, main phase	0.1	0.25	0.4			
Recovery factor, ass. phase	0.25	0.5	0.75			
Temperature, top res (deg C) :	100	Pressure, top res (bar) :				
<b>For NPD use:</b>						
Innrapp. av geolog:		Registrert:		Map OK:		Nr:
Dato:		Dato:		Dato:		

**Table 4.5 Prospect data, Tower North Kyrre Formation**

Block	Prospect name		Discovery/Prosp/Lead		Prosp ID (or New!)	NPD approved?
35/6	Tower North Middle Kyrre		Prospect		<i>NPD will insert data</i>	<i>NPD will insert data</i>
Play (name / new)	Structural element		Company/ reported by / Ref. doc.		Year	
<i>NPD will insert data</i>	Måløy Terrace		Idemitsu Petroleum Norge AS/EC # 10 2016		2016	
Gas case	<b>Resources IN PLACE</b>					
	Main phase			Ass. phase		
	Low	Base	High	Low	Base	High
Oil 10 <sup>6</sup> Sm <sup>3</sup>						
Gas 10 <sup>9</sup> Sm <sup>3</sup>	3.3	5.3	7.5			
	<b>Resources RECOVERABLE</b>					
	Main phase			Ass. phase		
	Low	Base	High	Low	Base	High
Oil 10 <sup>6</sup> Sm <sup>3</sup>						
Gas 10 <sup>9</sup> Sm <sup>3</sup>	1.9	3.3	4.9			
	Which fractiles are used as:		Low:	P90/P100*	High:	P10/P0*
Type of trap	Water depth (m)		Reservoir Chrono (from - to)		Reservoir Litho (from - to)	
4 way dip closure	350		Middle Cretaceous		Middle Kyrre sst	
Source Rock, Chrono	Source Rock, Litho		Seal, Chrono		Seal, Litho	
Jurassic	Heather /Draupne		Middle Cretaceous		Shetland	
Seismic database (2D/3D):	IPN1201, IPN1201MR15, ST0703R13					
	<b>Probability of discovery:</b>					
Technical (oil+gas case)	0.8		Prob for oil/gas case		0/0.80	
Probability (fraction):	Reservoir (P1)	Trap (P2)	Charge (P3)	Retention (P4)		
	1	1	1	0.8		
<b>Parametres:</b>	Low*	Base	High*	Comments		
Depth to top of prospect (m)		1800				
Area of closure (km <sup>2</sup> )	2.1	7.5	8.8			
Reservoir thickness (m)	55	80	90			
HC column in prospect (m)	40	90	100			
Gross rock vol. (10 <sup>9</sup> m3)	0.039	0.247	0.376			
Net / Gross (fraction)	0.45	0.5	0.6			
Porosity (fraction)	0.2	0.28	0.35			
Water Saturation (fraction)	0.1	0.2	0.4			
Bg. (<1)	0.0048	0.0053	0.0056			
Bo. (>1)						
GOR, free gas (Sm <sup>3</sup> /Sm <sup>3</sup> )						
GOR, oil (Sm <sup>3</sup> /Sm <sup>3</sup> )						
Recovery factor, main phase	0.6	0.8	0.9			
Recovery factor, ass. phase						
Temperature, top res (deg C) :	70	Pressure, top res (bar) :				
<b>For NPD use:</b>						
Innrapp. av geolog:		Registrert:		Map OK:		Nr:
Dato:		Dato:		Dato:		

## 4.3 Leads

### 4.3.1 Jurassic leads

In the 2010 application two Jurassic leads were mentioned. The Tommy lead was located on a fault block to the east of Smalhans. The lead had a well-defined Brent/Dunlin sequence resting on basement. Tommy was smaller than Smalhans and had a very uncertain limit towards north and south. The B2 lead was a small four-way dip closure at Upper Jurassic Unconformity level, north of Smalhans. The lead could be of interest as a northwards extension of Smalhans.

As a result of the IPN1201 interpretation project five different leads were identified (Figure 4). All of them have apex at or deeper than 3600 m.

The B2 lead is a four way closure with its apex at 3600 m. The anomaly area extends below the structural spill. The reservoir is presumed Oxfordian sandstone with a strong negative amplitude ("soft-kick").

The B2 West lead is a hanging-wall trap with apex at 4100 m. Definition of the closure is quite uncertain. The reservoir is Oxfordian sandstone with a good amplitude anomaly.

The B2 South lead is an unconformity trap with apex at 4200 m. The reservoir is Oxfordian sandstone with no apparent seismic anomaly.

Smalhans West is a hanging-wall and unconformity trap at Callovian maximum flooding surface (MFS) level, with an apex at 3900 m and no amplitude anomaly. The reservoir is juxtaposed to Middle Jurassic Brent Gp or Dunlin Gp rocks.

Sjampinjong is a gentle four-way closure at Upper Jurassic unconformity level, with its apex at 4200 m. The structure extends into the former Bayerngas-operated license PL 635, which was surrendered in 2015.

### 4.3.2 Cretaceous leads

The 2010 application indicates that sand-prone sequences of the Agat Formation are likely to infill a major incised valley system in block 35/6. Three branches, informally named Tobias, Bastian and Snakes, that all represent different different sedimentary entry-points, seem to converge in the central part of block 35/6. Each branch is probably filled with a complex sequences of gravity flow sediments.

Bastian, a Lower Cretaceous lead, is mainly located in the neighbouring block 36/4.

Tobias is the northern branch of the Agat channel system. The extent of the amplitude anomaly is relatively small.

The three branches converge into a very strong amplitude anomaly, referred to as the "Agat slope/basin floor fan", to the west of Smalhans. The main risk is estimated to be the possibility for identification of disconnected sand bodies that do not leak up-dip towards the east.

A small four-way dip closure at Upper Cretaceous level, named Tower, was mapped in the down-dip part of the Sofie fan, located immediately north of the 35/9-3 T2 gas discovery. A very strong amplitude, conformable to structure, suggest that this trap is gas-filled only. The small size and the thin reservoir units do, however, suggest sub-commercial gas volumes only. About 50 % of the Tower closure is located in block 35/6.

Based on the new seismic data, the Tower lead has been promoted into a prospect see chapter 4.2 for detailed information.

As a result of the latest evaluation, an Åsgard North lead has been identified in the Lower Cretaceous Åsgard Formation in the Tower North area (Figure 4.11). The lead has not been matured further, due to the very high risk on seal, and high risk on reservoir quality and presence.

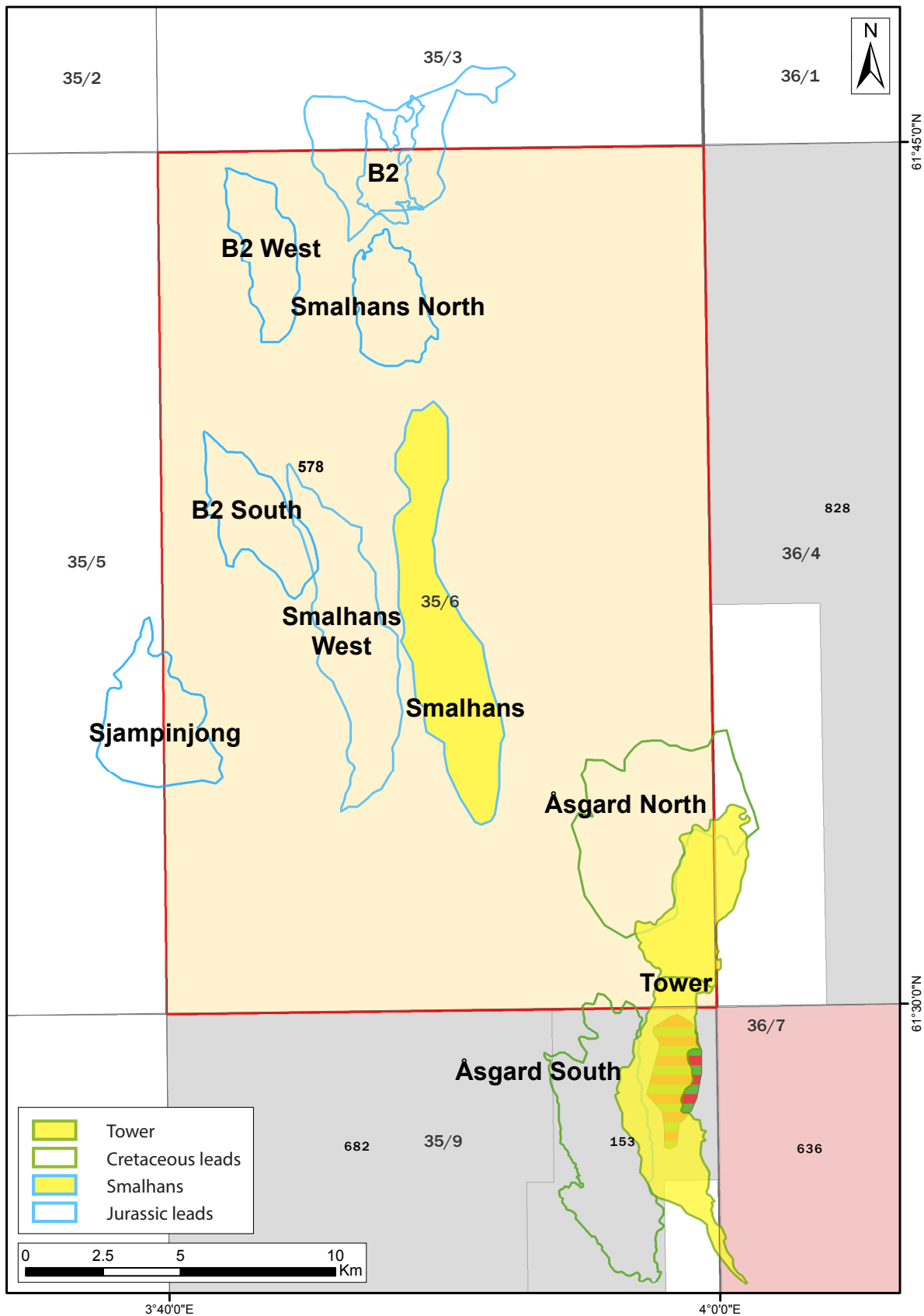


Figure 4.10 PL 578 Upper Jurassic leads

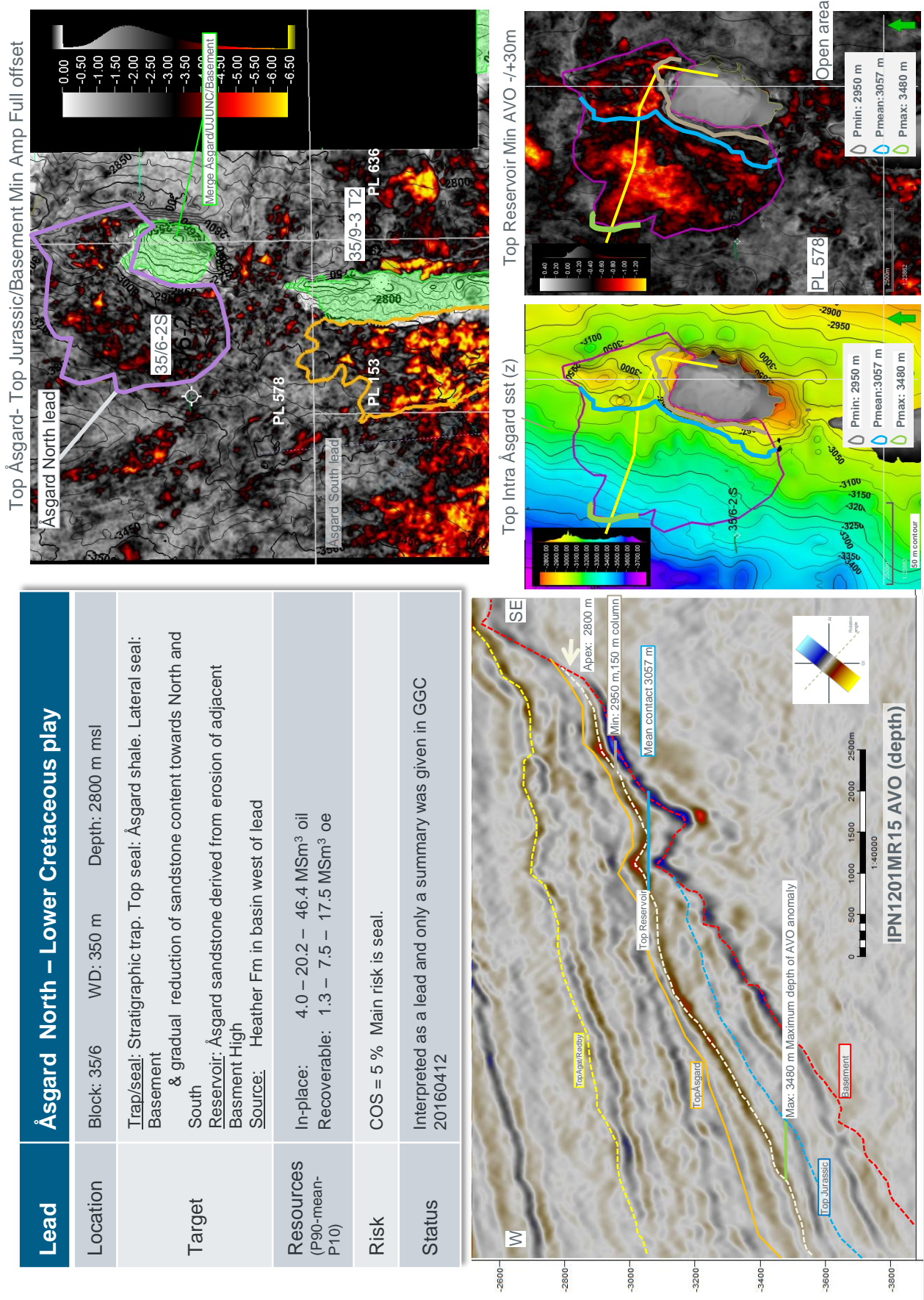


Figure 4.11 Åsgard North lead summary

## 5 Technical evaluation

### 5.1 Technical reservoir conditions

#### Tower North

The most likely development scenario for the Tower North prospect would be a combined Agat and Kyrre development, involving two highly deviated/horizontal oil producers in the Agat Fm between the water zone and the gas cap, and a horizontal well in the Kyrre Fm to ensure drainage of all sands across faults. The drainage strategy is pure pressure depletion in Kyrre Fm and natural aquifer support in Agat Fm. The pore volume of connected aquifer in the Agat Fm is estimated to be 2000-3000 times the produced oil and gas volume, and is connected across all the western flank of the reservoir. It is therefore assumed that the aquifer will ensure sufficient pressure support to the two producers in the Agat Fm. The Agat oil producers will be completed with remote operable sleeves, in order to co-produce the Agat gas cap, both for control of gas coning and for controlled acceleration of free gas production.

The reservoir quality of the Kyrre Fm is expected to be very good, with estimated permeabilities up to 1000 mD, N/G of 0.7-0.8 and porosity of 26 %. Compared to the Kyrre reservoir, the Agat reservoir quality is interpreted to be poorer and more variable. The estimated average permeability is expected to be in the range of 50-100 mD. The estimated N/G varies from 0.17 in lower Agat sandstones to 0.7 in upper sandstones, with porosities ranging from 18 to 22 %. The PVT and reservoir quality data are based on Agat discovery wells and the 35/9-3 well. The production profile (Figure 5.1) is based on the input described and an average gas/oil-ratio (GOR) of 117 Sm<sup>3</sup>/Sm<sup>3</sup> in Agat Fm. The reservoir pressure (water zone) is assumed to be hydrostatic.

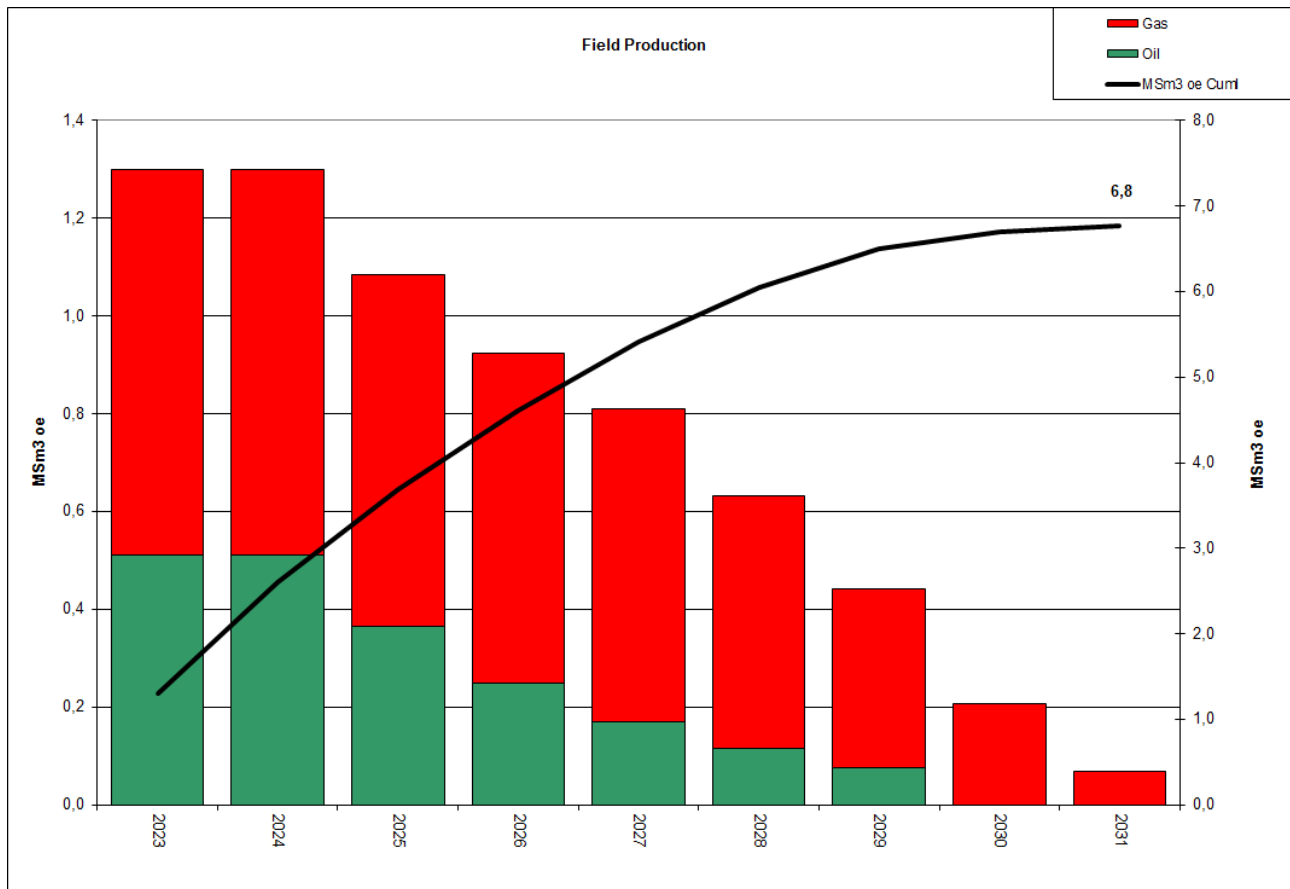


Figure 5.1 Tower North profile

Base case recovery is estimated to be 60 % for the Kyrre Fm gas, 25 % for the Agat Fm oil and 50 % for the Agat Fm gas. The gas cap production from Agat Fm will fill in the decline in Agat oil production, according to flow line capacity .

Both the Agat and Kyrre fms producers would be pre-drilled, and the production start-up is would be estimated to be 1 January 2023. An initial oil rate of 700 Sm<sup>3</sup>/d/w in the Agat Fm and a gas rate of 2 MSm<sup>3</sup>/d from Kyrre Fm would be expected. The mean recoverable resources are calculated 2.0 MSm<sup>3</sup> oil and 4.8 GSm<sup>3</sup> gas.

The main uncertainties from reservoir engineering point of view are reservoir quality, vertical and lateral communication in the Agat Fm and pressure support from the aquifer. The main uncertainty for the Kyrre Fm is communication across faults and lateral sweep. Regarding increased oil recovery (IOR), infill producers would be evaluated, based on production experience from production wells.

## 5.2 Technological assumptions and development plan

The Tower North prospect was planned as a field development solution with three subsea wells drilled from one template installed at 400 m water depth. One flowline would have been tied back to the existing Gjøa subsea Satellite F, in order to bring the oil and gas production to the Gjøa platform through existing flowlines (See Figure 5.2 for field development schematic). A moderate upgrade and modification of the existing Gjøa processing plant would have been required in order to receive hydrocarbons, as well as controlling the subsea facilities. Production start-up was planned in 2023, given sufficient spare capacity to include the Tower North production at Gjøa. Control and monitoring of the Tower installations as well as supply of chemicals and power would take place from Gjøa, through a new umbilical from the existing Gjøa subsea Satellite F.

Tower oil and gas processed at Gjøa was planned exported through existing pipelines: the Gjøa oil pipeline connects to the TOR II pipeline to Mongstad and the gas pipeline transport the gas to the UK via the FLAGS/SEGAL system. The field development assumptions would have been optimized if the understanding of the fluid, reservoir and structural characteristics been improved. Selection of production line sizes would also have been optimised.



## 6 Conclusions

Production license 578 was awarded on 04.02.2011, following an application in the APA 2010 licensing activity. The application described the main prospect Smalhans, a relatively deep Jurassic fault and incision trap. A number of leads within the Cretaceous were also described in the application.

Geological evaluations and interpretation were undertaken, based on the new IPN1201 3D seismic dataset in order to possibly mature Smalhans towards a drilling decision. The present evaluation of Smalhans did, however, indicate only a relatively moderate resource potential.

A one and a half year extension of initial license period was granted 17 March 2015. During this second extension period, a successful seismic re-processing of IPN1201 (PL 578) and ST0703 (PL 153) over the whole Tower complex was performed, with the objective to get a common dataset with optimal parameters for the Cretaceous sequences. This involved improving the seismic imaging and resolution of the Tower complex (Tower North in PL 578 and Tower South in PL 153). The new reprocessed seismic data set was interpreted in great detail.

Furthermore, a seismic inversion project was carried out. The new seismic evaluation, including the seismic data analysis and seismic inversion was carried out in cooperation with Engie as operator of PL 153 to reduce exploration and appraisal cost for the whole Tower complex. A revised mapping was combined with extensive geological evaluation, and a new basis for evaluating risks and resources for the entire Tower complex was created. The PL 578/ PL 153 license cooperation project included regular work meetings with PL 578 partner Engie. The project involved transfer of information and evaluations regarding G&G, reservoir engineering and field development.

However, PL 153 operator Engie could not support advancing a common PL 153 Tower complex project with PL 578. The technical-economical evaluation of a the Tower North stand-alone project does not demonstrate sufficient economic potential to enable a recommendation for a positive drilling decision, the only remaining target of interest in PL 578. Consequently, the partnership unanimously agreed to drop and surrender PL 578 on the 4 August 2016 DorD decision milestone.

## 7 References

- APA 2010 Application document
- Hand-out material from all relevant meetings - work meetings, Exploration Committee and Management Meetings available on "L2S".

