MAERSK OIL

Relinquishment Report for PL510

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RELINQUISHMENT REPORT PL510

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KEY LICENCE HISTORY

Production Licence 510 (PL510), located on the Halten Terrace, is comprised of parts of blocks 6406/5 and 6406/6 (Figure 1). The licence is surrounded by fields and discoveries including the Tott condensate discovery (6406/5-1), located to the southwest, and the Linnorm gas discovery (6406/9-1) to the southeast. Both of these discoveries are analogous to the PL510 prospects.

PL510 was originally formed in January 2009, after a 2008 APA application award to Centrica Resources Norge AS (Operator, 40%), North Energy ASA (20%), Faroe Petroleum Norge AS (20%) and E.ON Ruhrgas Norge AS (20%). The work programme included reprocessing of 3D seismic, followed by a drill or drop decision. The work commitment was fulfilled by reprocessing the HWE95M seismic cube. However, by June 2011 all the partners except North Energy ASA made a 'drop' decision and departed the licence. Maersk Oil and Edison subsequently farmed into the licence with a drill commitment in January 2013, with Maersk Oil taking on operatorship. At the same time an extension to the licence deadlines and initial period was granted, deferring the deadline for a decision on continuation (BoV) to 23 January 2015. A second extension was granted in January 2015 due to rig availability issues, deferring same deadline to 23 January 2016. This consequently postponed the 'Plan for Development and Operation' until 23 January 2017.

The current licence group and respective equities are:

- Maersk Oil Norway 50% (operator)
- Edison International Norway Branch 30%
- North Energy 20%

Maersk Oil has held regular EC/MC meetings in addition to various well operation meetings, since entering the licence. All meetings are documented on L2S.

The licence contains 6 prospects all targeting the same HPHT Jurassic play; Tvillingen Sør, Tvillingen Nord, Breitind, Kvasstind Nord, Kvasstind Sør and Botnkrona. The licencees chose to drill the Tvillingen Sør prospect to test the geological concept of stacked Jurassic reservoirs.

6406/6-4 was spudded on the 6th January 2015 but was TD'ed at 1955m MD after difficulties running the 16" liner. The well was plugged and abandoned by 4th March 2015. 6406/6-4S was re-spudded on 11 August 2015 and completed successfully on 30 October 2015.
The well discovered 25m of gas condensate in the Garn Formation with a hydrocarbon water contact encountered at 3990m TVDSS. The deeper Ile, Tofte and Tilje Formations were all found to be water bearing with shows throughout the Garn and Ile Formations. The well was TD'ed at 4443m TVDSS, in the Tilje Formation, before being permanently plugged and abandoned. Economic analysis concluded that the limited size of the discovery means no commercially viable development scenarios exist.

The results from Tvillingen Sør have shown that the stacked pay concept is also unlikely to work in the remaining PL510 prospects, and consequently the predicted volumes have been reduced accordingly. Based on this volumetric update the remaining prospects are considered sub-economic, even when a cumulative hub development scenario is invoked.

The decision to drop PL510 is unanimous in the partnership and the Ministry of Petroleum and Energy was notified of this decision on the 8th January 2016. Approval of the relinquishment of PL510 was received in March 2016.

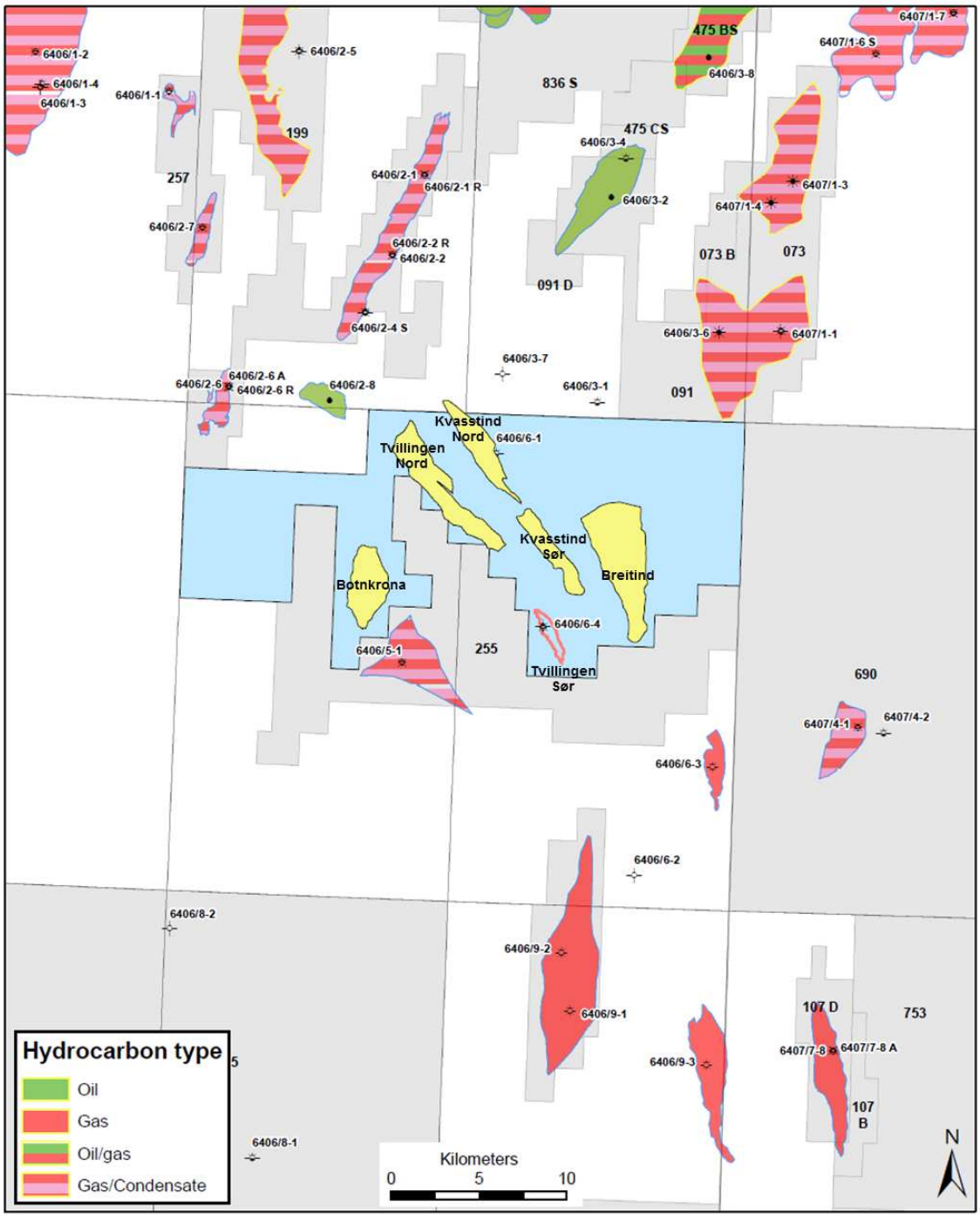

Figure 1. PL510 location map

DATABASE

Blocks 6406/5 and 6406/6 are covered by several public domain 3D data sets of varying vintage which were compiled into a "Mega Survey" seismic cube by PGS in 2005. This dataset was used for regional mapping while more detailed prospect evaluation was based on the 3D seismic datasets WIN09M01 and WIN09M02 (reprocessing and merge of vintage 3D surveys) as shown by Figure 2.

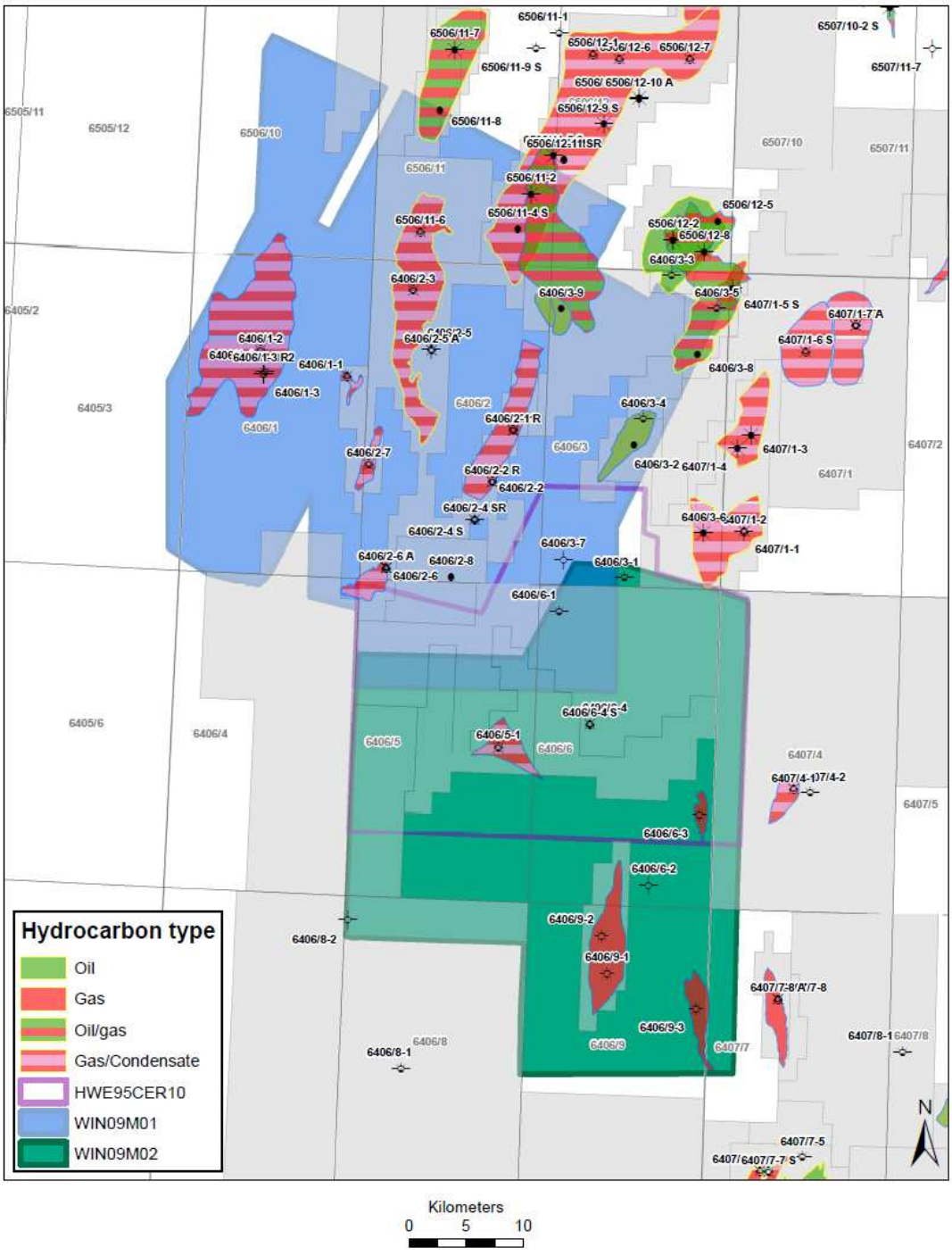

Figure 2. PL510 seismic database

The well database includes all the released wells which fall within the seismic 3D coverage. A comprehensive petrophysical evaluation of the Jurassic has been done for all these wells to aid understanding of reservoir architecture and quality. In addition, information on production data from producing fields on the Halten Terrace has been used to link petrophysical data to reservoir production characteristics.
The key offset wells for the PL510 prospects are shown in Table 1.

Table 1 Key offset wells.

Well name	Content	Completion year	TD Formation
6406/3-7 (Antares)	Dry	2006	Åre Formation
6406/3-1 (Epsilon)	Gas shows	1984	Triassic Red Beds
6406/6-1 (Eta)	Shows	1985	Tilje Formation
6406/5-1 (Tott)	Gas condensate in the Garn Formation	2002	Tilje Formation
6406/6-3 (Mjøsa)	Gas in the Garn Formation	2013	Åre Formation
6406/6-2 (Onyx West)	Dry	2007	Tilje Formation
6406/9-1 (Linnorm)	Gas in Ile, Tofte and Tilje Formations	2005	Åre Formation
6406/9-2 (Linnorm)	Gas in Ile, Tofte and Tilje Formations	2007	Åre Formation

The two wells drilled by the PL510 licence (6406/6-4 and 6406/6-4S) are also now part of the database.

REVIEW OF GEOLOGICAL FRAMEWORK

For details of the structural and stratigraphic setting of the licence please refer to the Tvillingen Sør Discovery Report, delivered to NPD in April 2016.

The prospects in PL510 all target the Jurassic HPHT play: Hydrocarbons sourced by the Upper Jurassic Melke and Spekk Formation shales (with some possible contribution from the Lower Jurassic Åre Formation coals), Middle to Lower Jurassic stacked marginal to shallow marine reservoirs including the Garn, Ile, Tofte, Tilje and Åre Formations. Intra-formational seals include the marine Ror and Not Formation shales while the late Jurassic and early Cretaceous shales provide an overall top seal to the system. Peak hydrocarbon expulsion occurred during the early Cretaceous and continues to this day. The prospects are all structural traps, either horsts or tilted fault blocks, that formed during the late Jurassic – early Cretaceous rifting event (Figures 3 and 4).

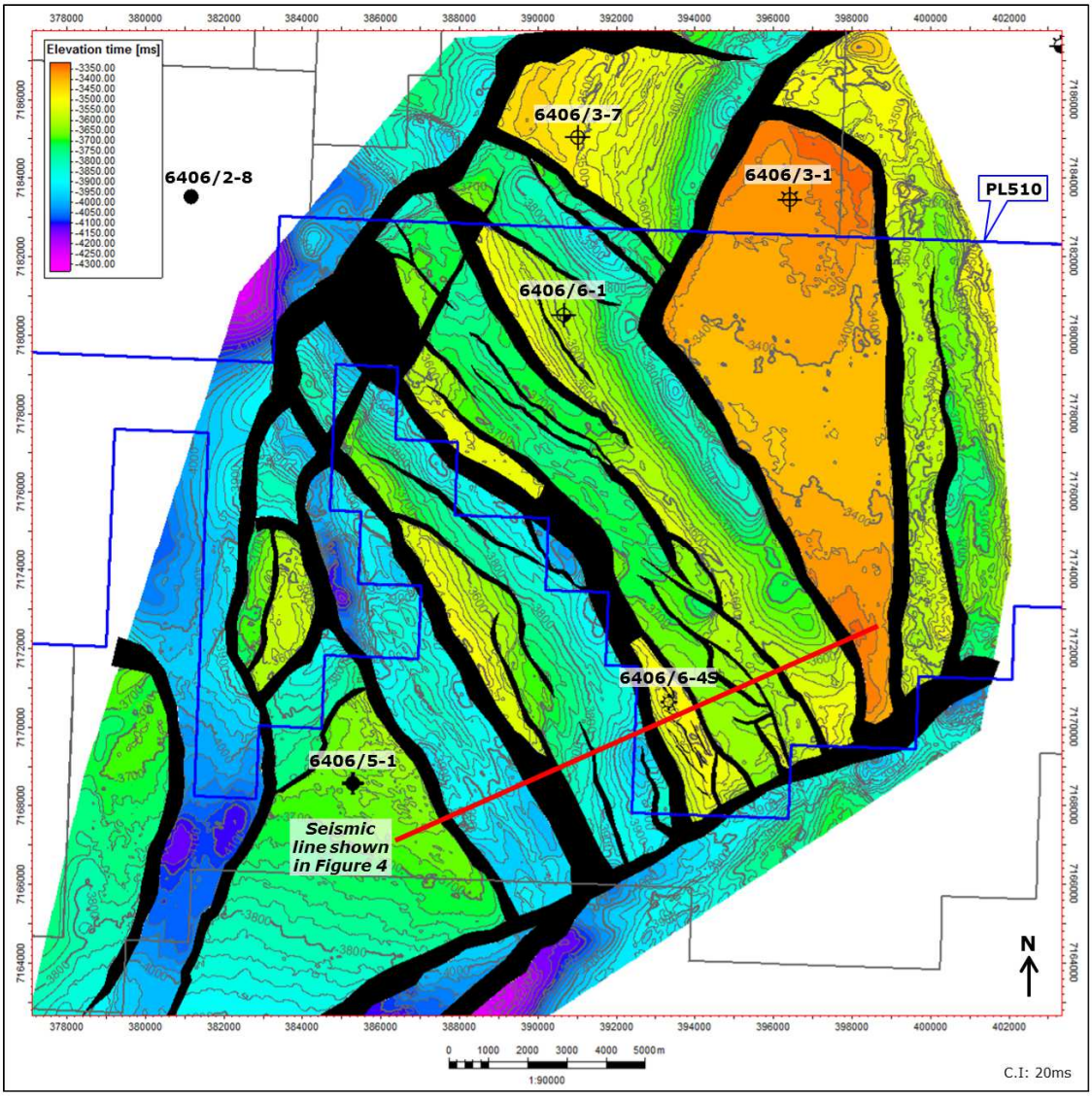

Figure 3. Top Garn Formation TWT map

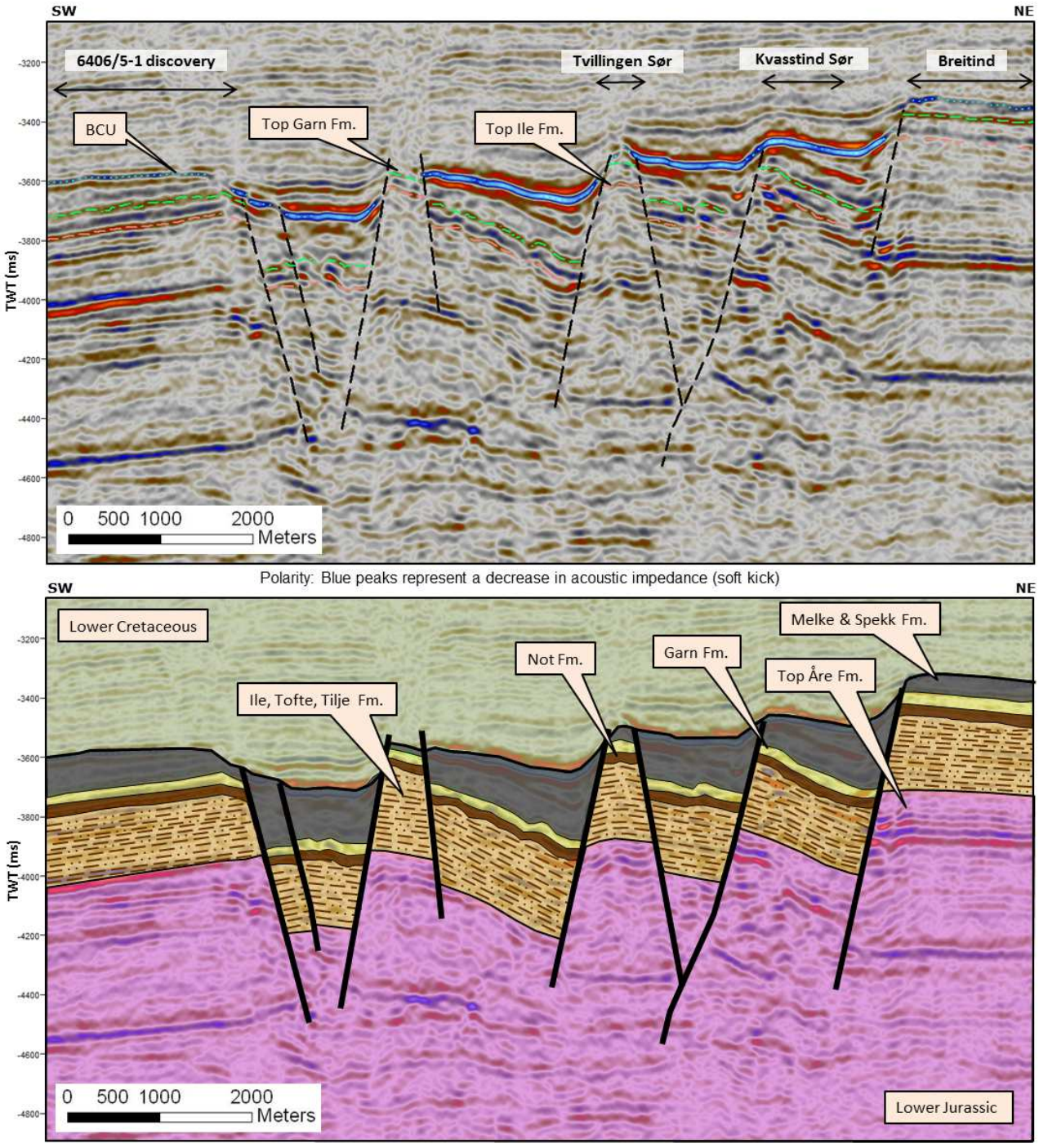

Figure 4. Seismic section through Tvillingen Sør and surrounding prospects

The pre-drill work programme for PL510 included reprocessing of 3D seismic. Fugro Seismic Imaging reprocessed 700 km2 of the HWE95M seismic cube focusing on noise reduction, removal of multiples and improved resolution of the Garn and Ile reflectors. The location of the reprocessed cube, HWE95CER10, is shown in Figure 2. In addition to this, the licence group also commissioned a pressure study completed by GeoPressure Technology and a sequence stratigraphy study by Geolink.

With Maersk Oil and Edison entering PL510 and a positive drill decision having been made the focus of the licence shifted towards well planning. Seal was identified as the key risk and fluid type as the main uncertainty. In order to address lateral seal risk, fault juxtaposition analysis and shale gouge ratio modelling were completed. The fault juxtaposition analysis resulted in the identification of potential down-dip leak points across bounding faults and therefore constraints to potential hydrocarbon columns. The shale gouge ratio calculations showed that, based on offset well stratigraphy, faults with throws of 130m would provide 30% of shale gouge and should theoretically seal (as per Weber 1987). The results of these analyses led to improved confidence in the prospect's ability to retain hydrocarbons. To address the concern that Cretaceous 'thief sands' could pose a risk to the Jurassic prospectivity, a study was completed which integrated seismic interpretation and amplitude analysis, pressure data and analogues from Mid Norway. The licence concluded that although the possibility of Cretaceous thief sands could not be fully excluded, it was unlikely that they would have sufficient reservoir quality to act as thief sands to the Jurassic reservoirs. This was mostly due to the location of PL510 in the Cretaceous depositional system, but also due to the depth of the potential sands - below the Cretaceous sand quality 'basement'.

In order to address the top seal risk, a detailed pore pressure study was completed by the operator. This included purchasing fluid inclusion reports for some of the key offset wells from Fluid Inclusion Technologies. This led to improved understanding of the fluid history and results of offset wells. The pore pressure study included top seal analysis and calculation of potential column heights. A breached top seal interpretation was invoked to explain the dry wells and smaller discoveries in the area. Tvillingen Sør was modelled to have sufficient seal capacity for the structure to be filled to spill. This pore pressure study was also integral to detailed well planning.

The key uncertainty prior to drilling Tvillingen Sør was the hydrocarbon fluid type. Surrounding fields and discoveries exhibit a large range of fluid types from dry gas (5 stb/mmscf) to rich condensate (360 stb/mmscf). Geochemical data purchased from APT was integrated into a petroleum system analysis which attempted to address this uncertainty and concluded that a moderate to higher condensate gas ratio (CGR) was more likely than a dry gas.

As part of the well planning a biostratigraphy study was carried out by Ichron. The study used the key offset wells to create a biostratigraphic framework which could be updated real time during drilling, and allowed improved confidence in well picks. This was particularly relevant for the top reservoir approach as the Upper Jurassic is very thin above the fault blocks.

PL510 was located in an existing focus area for Maersk Oil when the licence was entered. Significant amounts of work had already been completed on a regional scale including play analysis, seismic interpretation of key horizons including reservoirs and source rocks, the construction of palaeogeography maps, biostratigraphy studies, fluid inclusion analysis and basin modelling. This provided a good background knowledge base and meant that new data and the results from studies could be integrated quickly and effectively.

PROSPECT UPDATE

When Maersk Oil entered the licence the main prospect was the areally largest horst structure named Breitind (Figure 1). The horst has a dry well at the northern end which is separated from a southern closure by a saddle. The theory was that the northern end had breached and leaked, reducing the overpressure in the structure and protecting the southern trap. However, the pore pressure study indicated that stacked columns were unlikely in this prospect which reduced the volumes considerably. Consequently, the partnership moved its focus to the Tvillingen Sør prospect which had the highest predicted volume range, and was expected to retain the possibility for stacked pay.

The Tvillingen Sør prospect was drilled in the autumn of 2015 and discovered a 25m gas condensate column (187 stb/mmscf) in the Garn Formation but the lower reservoirs were dry, with shows throughout the Garn and Ile Formations. The well was TD'ed in the Tilje Formation at 4443m TVDSS. Table 2 shows the pre-drill and post-drill resource range for Tvillingen Sør.

Table 2. Recoverable resource range for Tvillingen Sør

Recoverable Resources MMBOE	P90	Pmean	P10
Pre-drill	21	92	177
Post-drill	3.5	5.9	8.3

Reservoir parameters including thickness, net to gross and porosity came in within the respective pre-drill ranges. The Garn reservoir was thicker than predicted at 104m gross compared to the estimated 70m. Despite the large uncertainty on fluid type, the CGR of the discovered hydrocarbon was very close to the mode prediction pre-drill.

The post-drill analysis focused on identifying which element was likely responsible for the limited hydrocarbon column found in Tvillingen Sør: source, migration and seal were all evaluated as likely culprits.

Source and migration

Geochemistry and fluid data from the well were integrated with the basin/migration model. From this the following conclusions could be drawn:

- Tvillingen Sør had most likely been charged by the Melke Formation.
- The CGR can be explained if all the earlier, higher CGR charge the structure received has been lost, and only the most recent charge has been retained.
- The CGR and volumes can be explained by retention since 2 My.
- Tvillingen Sør had access to cross-fault charging as the volume found is larger than what could be charged from the source rock within the Tvillingen Sør horst alone.

Seal

There are two scales of faulting on the Tvillingen Sør structure: the main bounding faults with throws between 200m and 800m, which mostly detach on the underlying Triassic salt; and minor faults seen at the crest of the structure which are restricted to the Spekk, Melke and Garn Formations (figure 5), with smaller throws of approximately 40m.

There are diffuse, type 2 (as per Heggland 2005) gas clouds above the majority of the structures in the PL510 area, regardless of whether the structures hold hydrocarbons or not. There are also more defined type 1 gas chimneys above the small crestal faults above Tvillingen Sør, some of which correspond to the present day HCWC seen in the well.

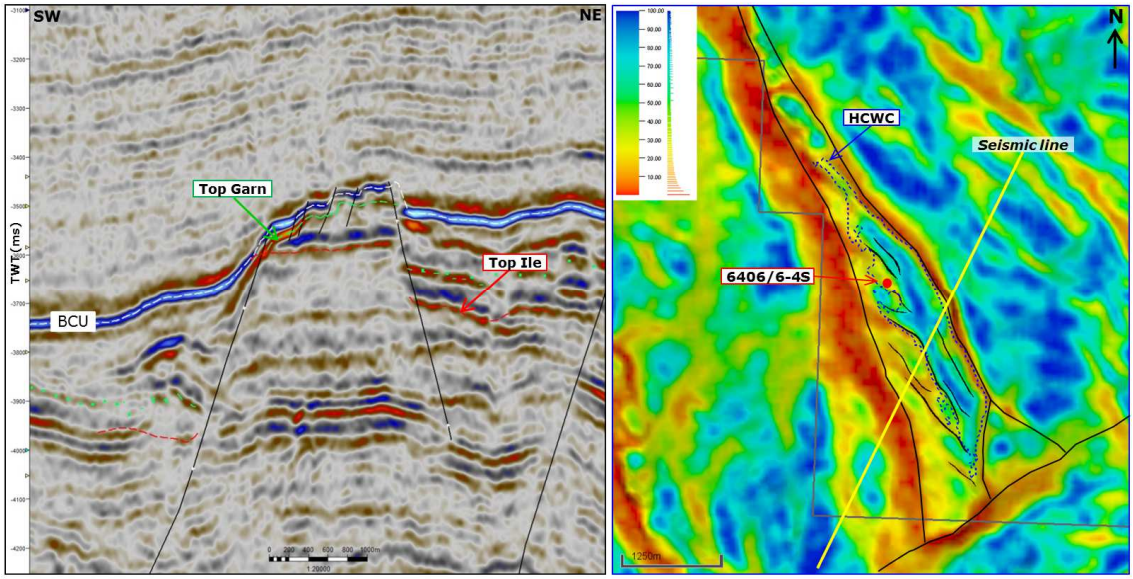

Figure 5. Seismic line through Tvillingen Sør and Edge detection of the BCU with OWC and fault polygons, illustrating crestal faulting

These seismic gas features, in addition to increased gas readings through the overburden while drilling, indicate that the Tvillingen Sør structure has leaked hydrocarbons at some point in time, probably via both the bounding and crestal faults. However, the fact that Tvillingen Sør is currently 4500 psi overpressured, means that these faults must be mostly sealing today. This is further supported by the high Leak Off Test (LOT) taken in the Melke Formation of Tvillingen Sør, showing that the fracture gradient is sufficiently higher than the pore pressure. This means that based on present-day seal capacity, the Tvillingen Sør structure should be able to hold a larger hydrocarbon column than it currently does. The pore pressure of the Jurassic reservoirs in Tvillingen Sør were very close to those predicted pre drill, being approximately 4500 psi overpressured. This is also in line with the regional trend of decreasing overpressure towards the east.

Once the Tvillingen Sør LOT and pore pressure data had been received the pre-drill pore pressure regional model was revisited. All of the offset HPHT pressure data was plotted together and by only plotting the shallowest Jurassic pore pressure measurement – a linear trend appears; a trend often seen when hydrocarbon column heights have been limited by a fracture gradient. However, the pore pressure gradient is significantly (approximately 1000 psi) below the present day fracture gradient (based on Leak Off Tests (LOT) and Formation Integrity Test (FIT) data).

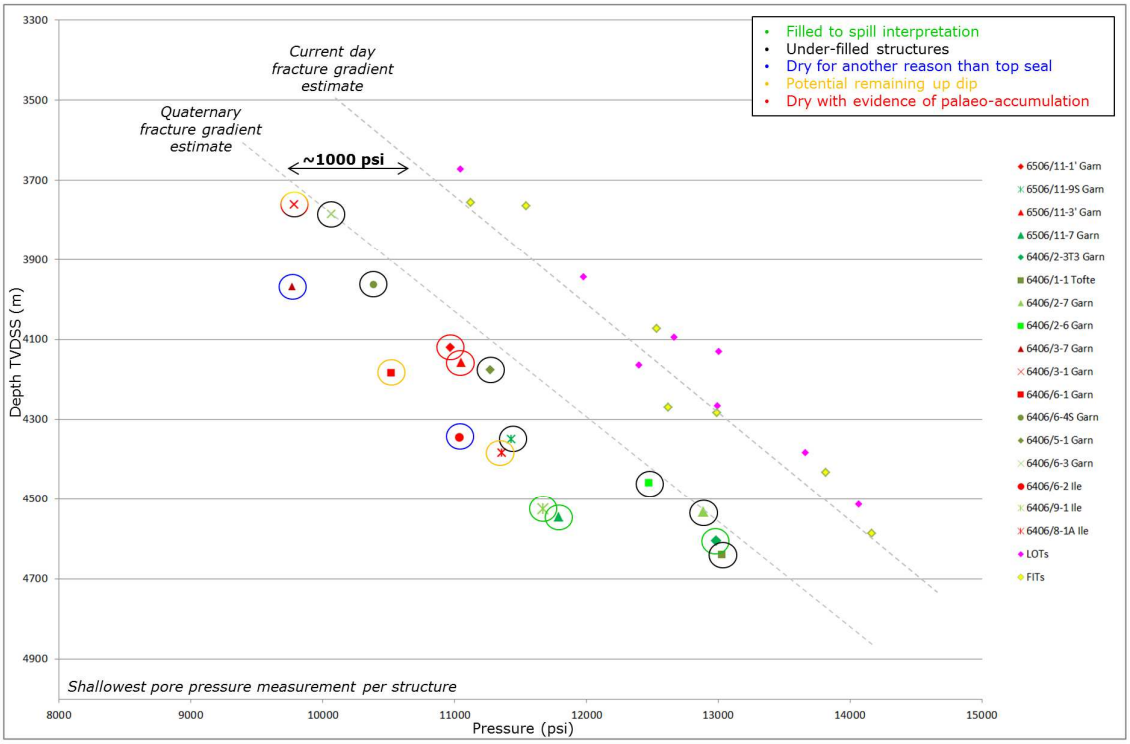

Figure 6. Regional pressure model illustrating the 1000 psi separation between current day pore pressures and fracture gradient estimations

Hermanrud and Bolas (2002) conclude that the fracture gradient in the Halten Terrace must have been lower in the past, causing many of the structures to leak, but has since increased, giving the apparent 'seal capacity' we see when performing pressure predictions. In Figure 6 this is illustrated by the dry and underfilled structures plotting closest to the modelled palaeo-fracture gradient. It is suggested that flexuring of the overburden during the Plio-Pleistocene, due to glacial loading or progradation of thick glacial sediment packages (Naust Formation), lowered the fracture gradient sufficiently to breach the shallower HPHT structures. The timing of this leakage also corresponds to the conclusions from the basin modelling – that the fluid type and volumes can only be explained by very recent charge (2 My). This model also explains why deeper structures (below 4400m MSL) and normally pressured structures in the Halten Terrace are more likely to have retained their columns as a larger reduction in seal capacity is required before their top seals breach.

Integrating the findings from the basin analysis, fault interpretation and pressure study has led to the conclusion that the Tvillingen Sør structure once held a larger hydrocarbon column than it does today. A lowering of the fracture gradient in the recent geological past led to the structure leaking via the bounding and crestal faults. Since then, the separation between the fracture gradient and the pore pressure (seal capacity) has increased, partly due to the overpressure being bled off through leakage, but also with the removal of the stress anistotropy with the melting of the ice/continued progration of the sediment. Therefore the faults are sealing once more, allowing hydrocarbons to accumulate in the structure.

TECHNICAL EVALUATIONS

The breached top seal model has a detrimental impact on the remaining PL510 prospects which are all located at similar depths to Tvillingen Sør. Maersk Oil has accordingly revised the recoverable resource range for the remaining prospects in PL510:

Table 3. Remaining PL510 prospectivity recoverable volumes.

	Recoverable Resources MMBOE		
Prospect	**P90**	**Pmean**	**P10**
Tvillingen Nord	7	28	56
Breitind	3	25	58
Kvasstind Nord	4	17	35
Botnkrona	2	10	23
Kvasstind Sør	2	6	12

These volumes are calculated assuming single columns in the Garn Formation.

The risk of finding hydrocarbons for the remaining PL510 prospects has been reduced given the findings of Tvillingen Sør. However, the risk of finding economic volumes has increased with seal as the critical risk factor.

The most cost-effective development option for Tvillingen Sør, given the CGR and CO_2 value of the fluid, would be a simple 'daisy-chain' sub-sea tie back to Tyrihans and then onto the Åsgard Transport hub. However, the Minimum Economic Field Size (MEFS) for this development concept is approximately 40 MMBOE which is far beyond the 6 MMBOE (Pmean) found in the Tvillingen Sør structure. Prior to drilling Tvillingen Sør, the PL510 development concept was one of a hub development: The Tvillingen Sør well aimed to prove the stacked pay concept and de-risk the remaining prospects. All the prospects could then, in a success case, be developed together as a hub. However, given that Tvillingen Sør volumes are not sufficient to cover a template cost it makes it very challenging to envision a scenario where Tvillingen Sør could be developed as part of a hub.

CONCLUSIONS

Since Maersk Oil and Edison entered the PL510 licence, the licencees have matured and drilled the Tvillingen Sør HPHT prospect. Unfortunately the well was unable to prove stacked pay, only finding a 25m gas condensate column in the Garn Formation. Economic evaluations of the size of the discovery has shown that the discovery cannot be developed economically. The post-well analysis concludes that a compromised top seal is the likely explanation for the limited hydrocarbon column. Given the depths of the remaining PL510 prospects, it is likely that they have also been affected by top seal breach in the past and have similar limited columns. Therefore the PL510 licencees regard all prospects in the licence to be sub-economic. This has led the partnership to a unanimous decision to relinquish the licence.

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Tvillingen Sør Discovery Report, 2016