License relinquishment report

PL559

[redacted] | April 25, 2014

License history

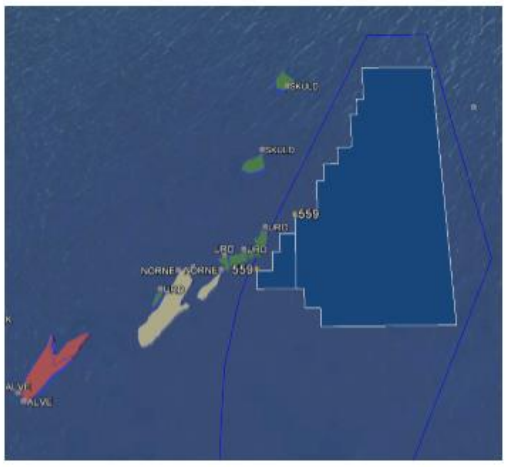
PL 559 license was awarded within APA 2009 licensing round. It contained parts of blocks 6608/10 and 6608/11. Initially, the license partnership comprised Rocksource ASA (60%, Operator), VNG Norge (30%) and Skagen 44 (10%). The Work Program included reprocessing existing 3D seismic data and making DoD decision within the first two years. Structural complexity of the area set high requirements on the data quality. Therefore, the partnership decided to rather acquire a new 3D seismic data set, which was done in 2010. In September 2011, the Phoenix well 6608/11-7 was drilled and it turned out to be dry.

In December 2012, Atlantic Petroleum (former Emergy Exploration) acquired 10% license share from VNG. In Mai 2013, Explora Petroleum acquired 10% share from Rocksource.

Since the dry Phoenix well was drilled, a post-well analysis and a number of geophysics and geology studies were undertaken. The goal was to assess the remaining prospectively in the license. Based on the subsequent technical assessment, the license partnership decided to relinquish the license. The license has fulfilled the Work Program commitments.

Licence history

- Awarded within APA2009 – part of blocks 6608/10 and 6608/11
- Initial partners:
  - Rocksource (60%)
  - VNG (30%)
  - Skagen44 (10%)
- Atlantic Petroleum (former Emergy Exploration) acquired 10% from VNG in Dec. 2012
- Within 2 year: Reprocess 3D seismic, decide on DoD
  - Partners decided to acquire new 3D
- Within 4 years: Drill 1 well and decide on PDO
  - Drilled 6608/11-7
- Within 6 years: Submit PDO
- Extension period: 20 years



Database

The license database included all publically available seismic data and well data shown in Figure 1.

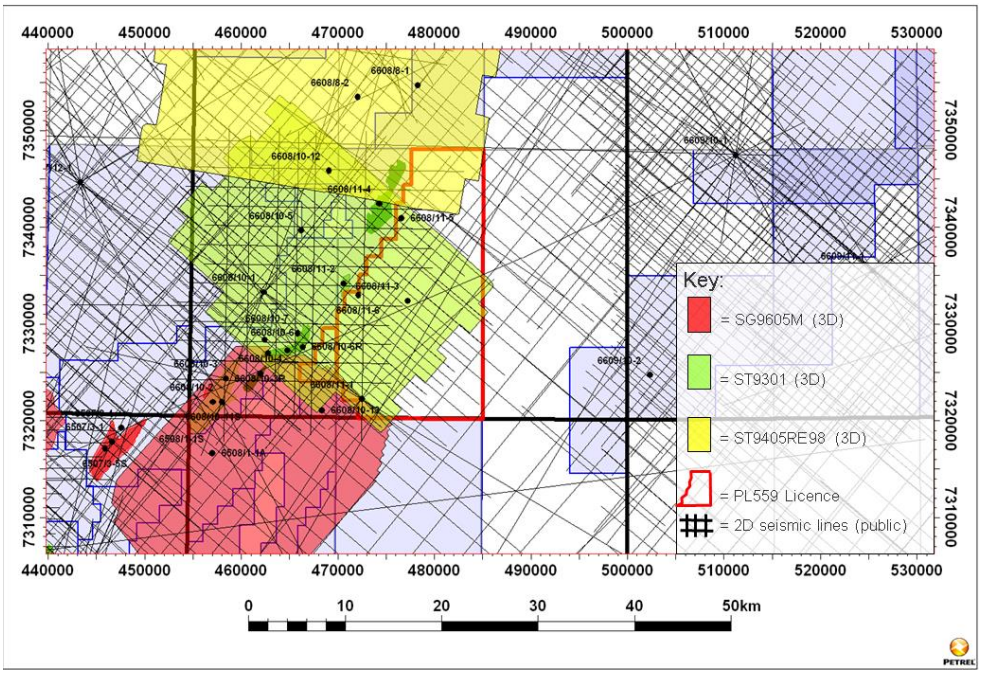


Figure 1 Data coverage.

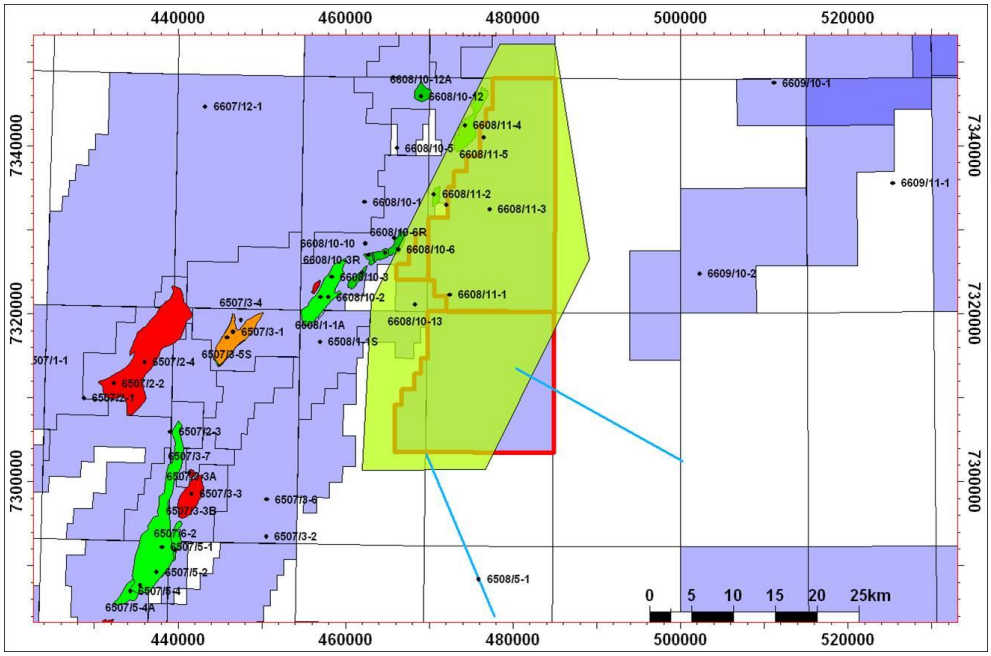


Figure 2 RS1002 survey (PL559 + PL515)

In May/June 2010, Western Geco acquired a 3D seismic data set for the license (Figure 2). It covered 899 km² and included two 2D tie lines. Structurally complexity in the license dictated a detailed processing, which emphasized multiple removal, anisotropic migration and detailed velocity picking and modelling.

The CSEM database available within the license area is very comprehensive. Two 2D CSEM lines (Grap) were available within the area. The partnerships bought also the EDDA 3D data set which covered most of the license area. In addition, a composite line was acquired by Petromarker which tied the nearby Falk discovery to prospects in the license.

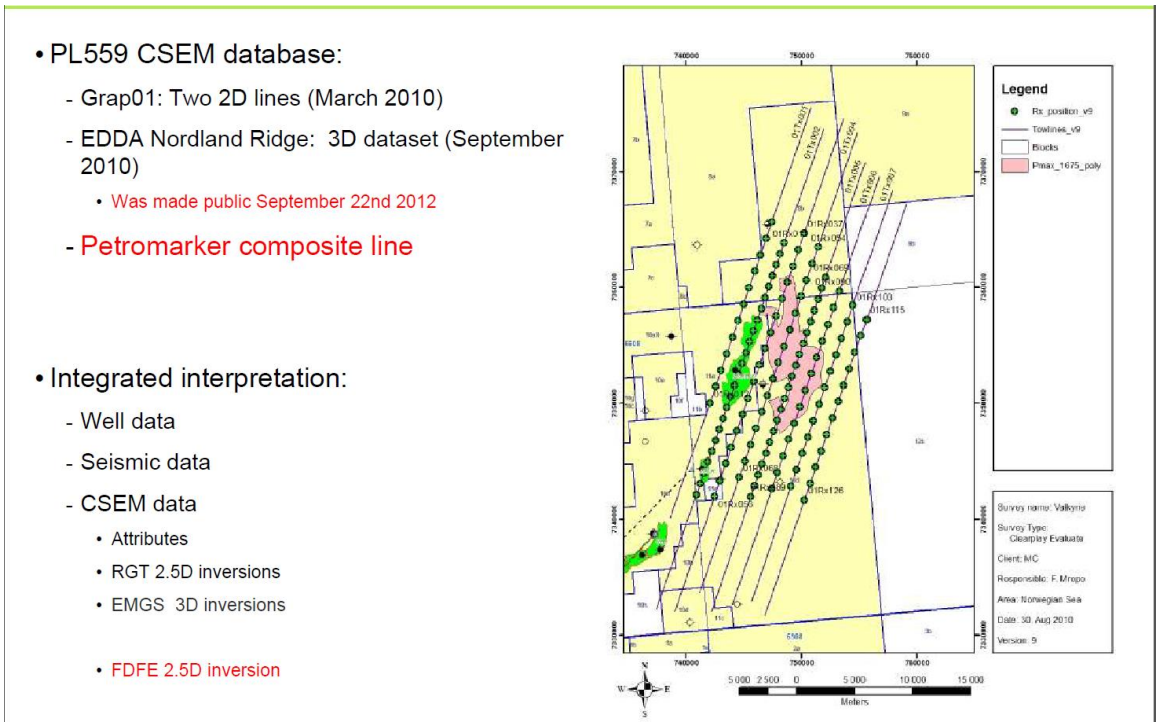


Figure 3 CSEM coverage

Review of the geological framework

The license is regionally situated in the Nordland II area of the Trøndelag Platform/Nordland Ridge, to the west of the Helgeland Basin (Figure 5). The basin fill stratigraphy comprises Permian to Cenozoic strata. The area has undergone multiple phase of tectonic extensions and compressions. This has created a number of mini-basins preferentially placed for Middle to Late Jurassic syn-rift deposition. Pre-rift sedimentation in Lower Jurassic (Båt group) is also present

across the region with proven reservoir targets. The structural development is thought to have exerted a major impact on reservoir distribution, source and migration as well as trap formation. Prospectivity was defined in several intervals: Triassic Grey Beds, Jurassic Båt, Fangst and Viking Groups (Intra Melke). Initially, a large number of prospects and leads was identified (Figure 4). Due to the proximity of the proven source (Spekk), the most western prospects in the license were considered to be most attractive. The eastern prospects depended on either more complicated migration from the west, or dependence on migration from Helgeland Basin (no proven commercial HC source). Before drilling 6608/11-7, the most prospective targets were Delilah (Intra-Melke) and Phoenix (Åre). After the well, focus shifted towards Hendricks (Åre/Ile) as the most interesting remaining prospect.

Figure 4 Regional setting of the license

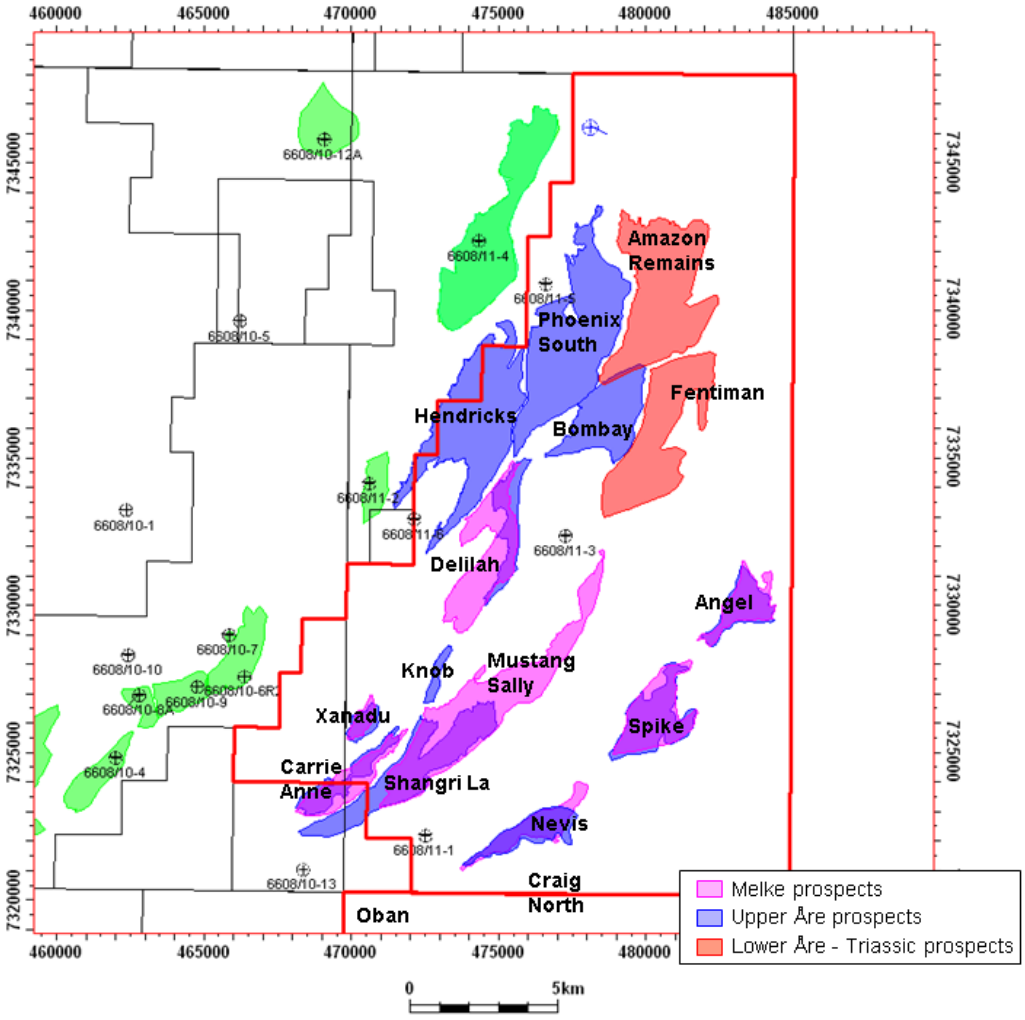


Figure 4 Initial prospects and leads

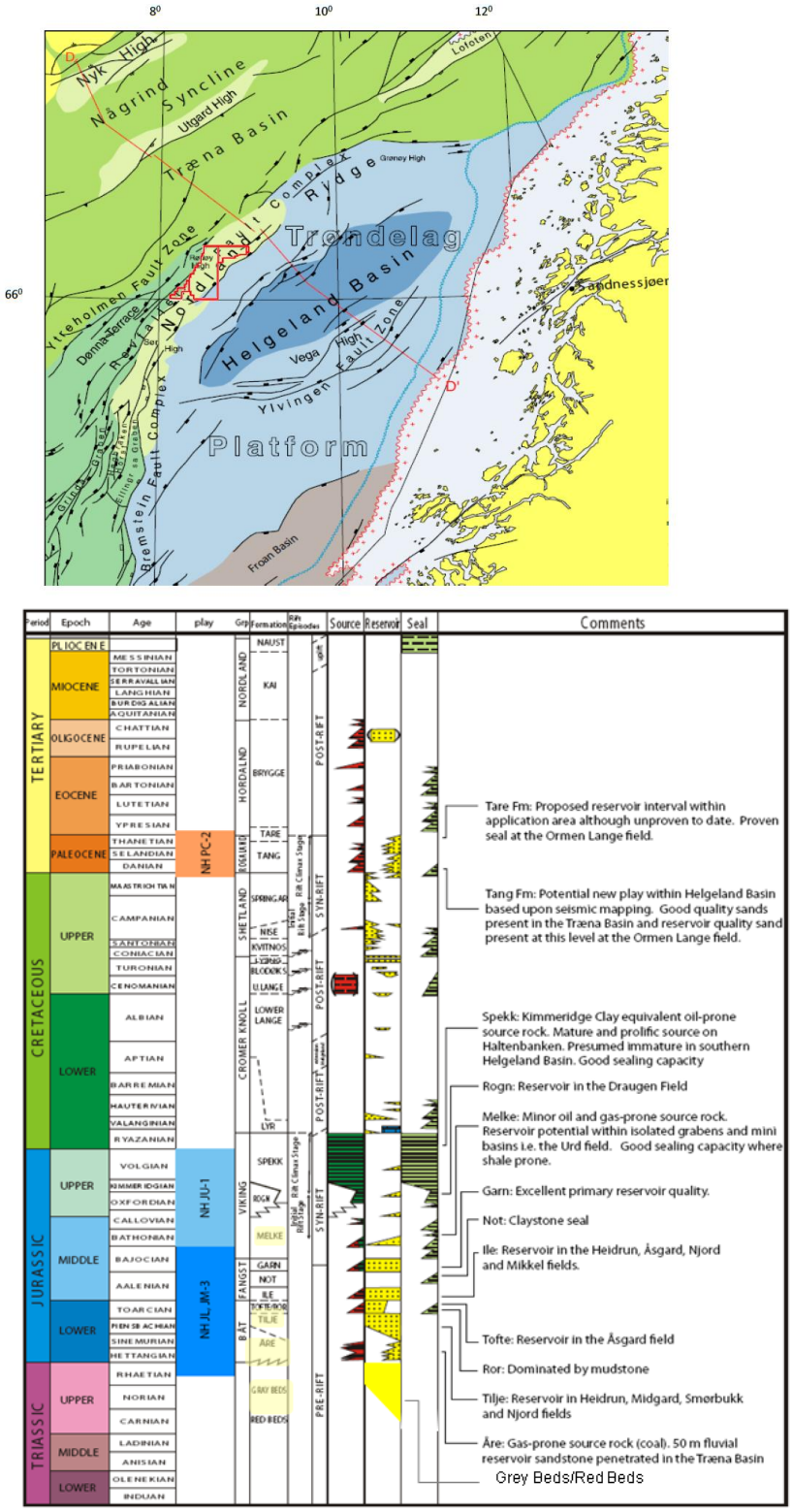
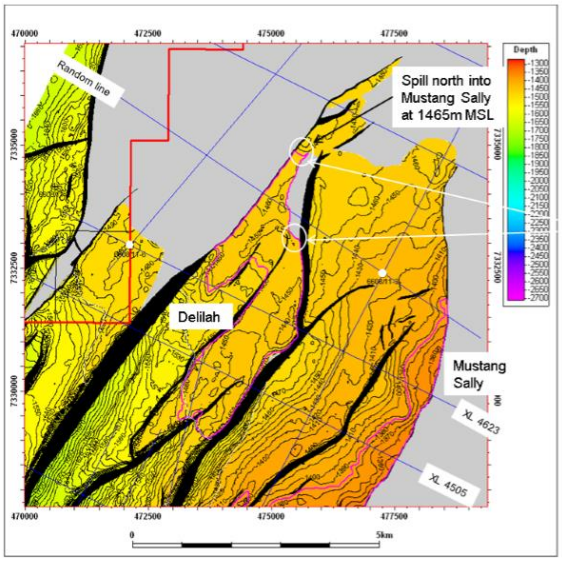


Figure 5 Regional setting and stratigraphy

Pre-well prospect overview

Pre-well (6608/11-7), the main prospects were Delilah (Figure 6) and Pheonix. Target in Delilah was Inter-Melke sandstone, deposited by localized gravity flows from the uplifted intra-basinal high. The sediment traps were set up by topography (Figure 7)



- Large fault-controlled mini basin, containing a series of half-grabens
- Many internal compartments
- Intra Melke and upper Båt Group are main targets (as in Urd)

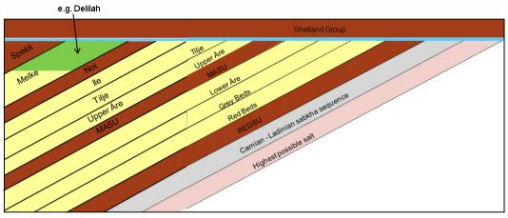
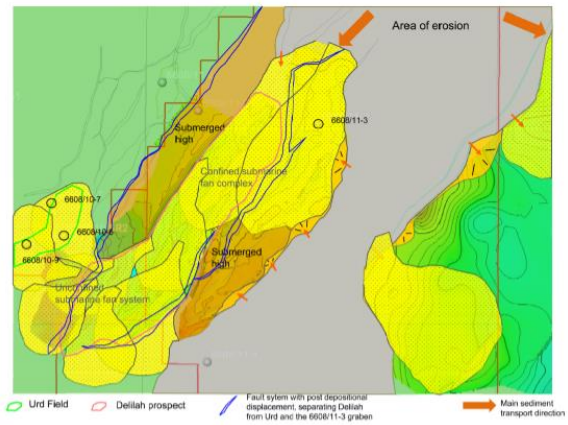


Figure 6 Delilah prospect overview. Map at Top Tilje (near base reservoir)



- Localized gravity-flow deposits derived from the uplifted intra-basinal high. Sediment traps set up by topography.
- Present in Urd and Norne fields and displaying good quality.

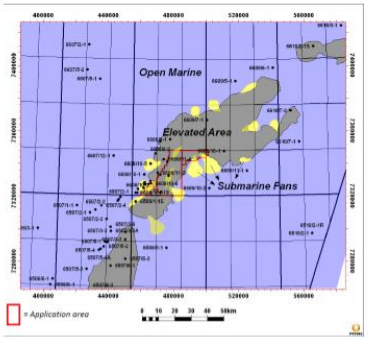


Figure 7 Intra-Melke depositional model

Mapped on the public seismic data (Figure 8), the Delilah trap seemed to comprise the whole mini basin, resulting in potentially large HC volumes. After the new seismic data set (RS1002) was acquired, a spill point was mapped at the northern tip of the prospect. The remaining volumes were not considered commercially interesting.

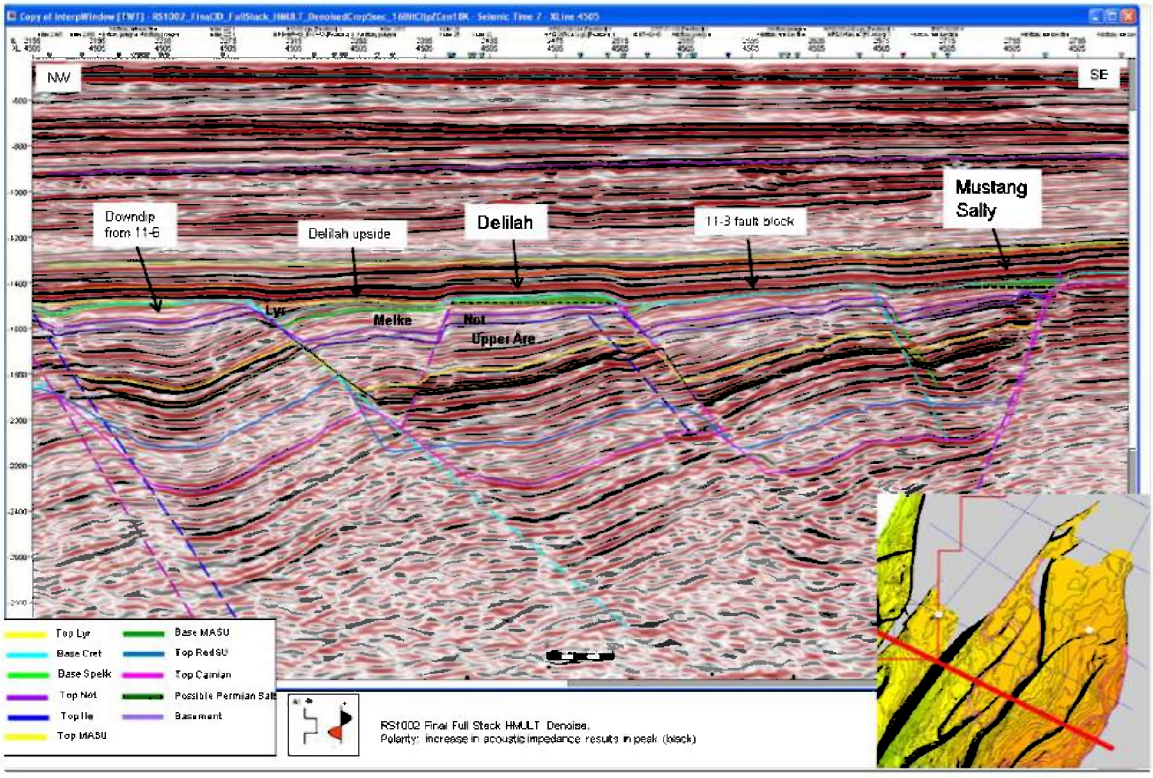


Figure 8 Seismic section across Delilah

The Phoenix prospect consisted of two segments – Phoenix Fire (renamed to Amazon) and Phoenix Ashes (renamed to Phoenix). The well 6608/11-7 tested Phoenix Ashes prospect, which is a sub-crop trap with reservoir within the upper Åre formation. Shales/coals in the lower part of Åre and upper parts of Grey Beds forms the seal of the prospect. It comprises a series of eroded rotated fault blocks which are capped by Upper Cretaceous sediments. The upper Åre has been encountered by most wells in the area with generally good reservoir properties. The formation was deposited in coastal plain setting (Figure 10). The subtropical climate of the early Jurassic led to increased erosion of the hinterland areas and an upward increase in sediment supply (towards upper Åre).

The target in Amazon was lower part of Åre formation and potentially Triassic Grey Beds. The segment is a bounded rotated fault block which sub-crops the Base Cretaceous Unconformity to the north and east. The prospect is separated from Linerle discovery by faults. The CSEM analysis (discussed later) [redacted]

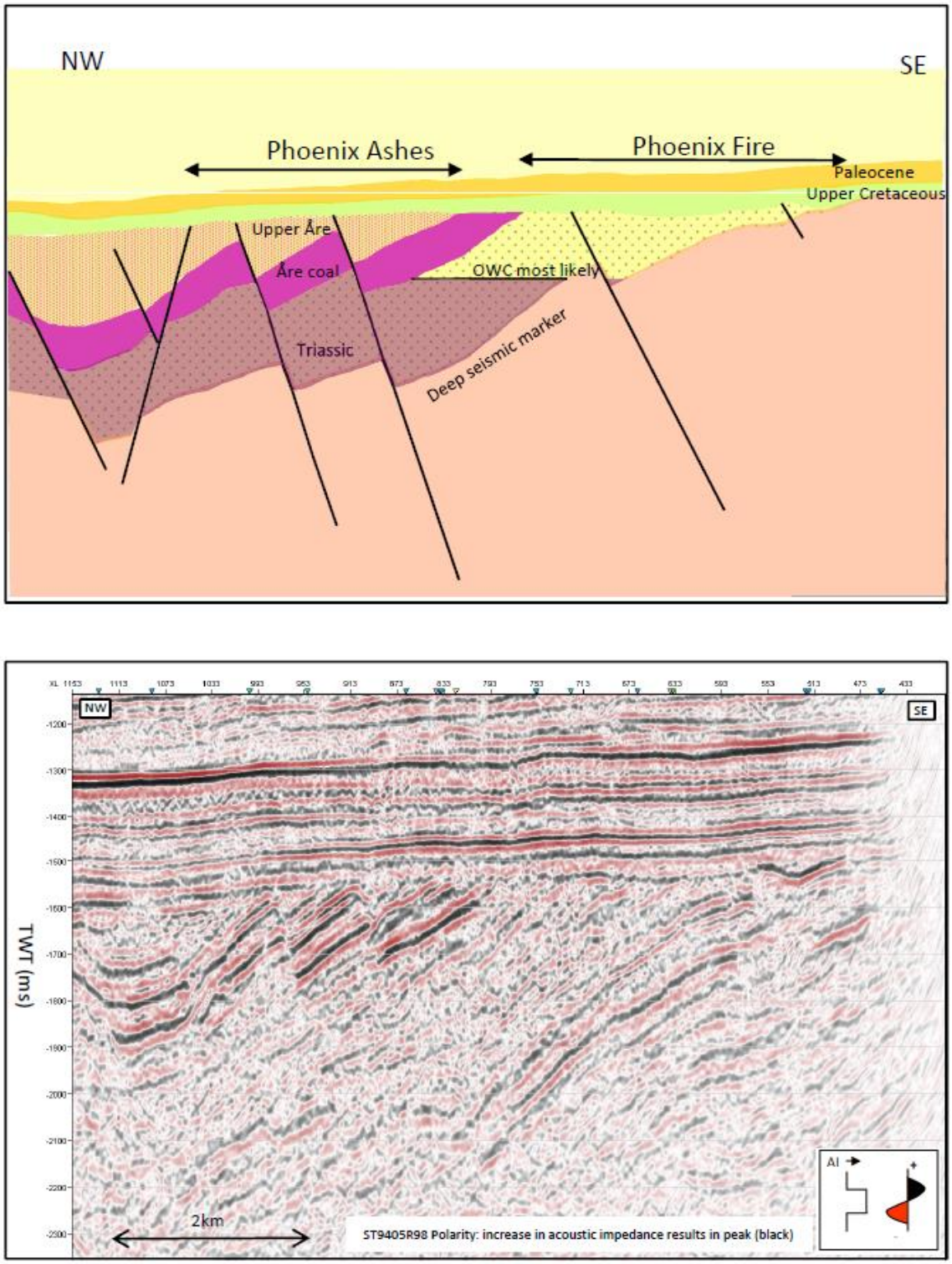
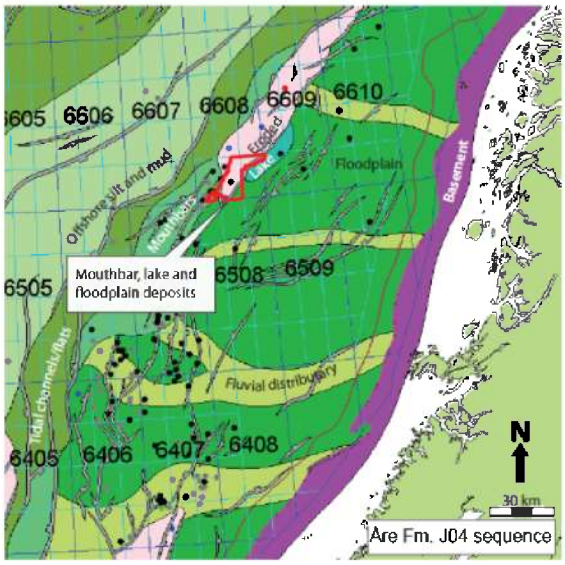


Figure 9 Structural setting and a seismic section for Pheonix Ashes and Fire



- Dominated by prograding coastal plains and floodplain sediments
- Westward prograding deltas.
- Alternates between mud-prone anc coal-bearing inter distributary bays to swamp units and sand units (fluvial and distributary channels).
- Moderate to good quality sands and well proven in the area.
- Main reservoir in Urd and contributor in Norne.

Figure 10 Depositional setting of Åre formation

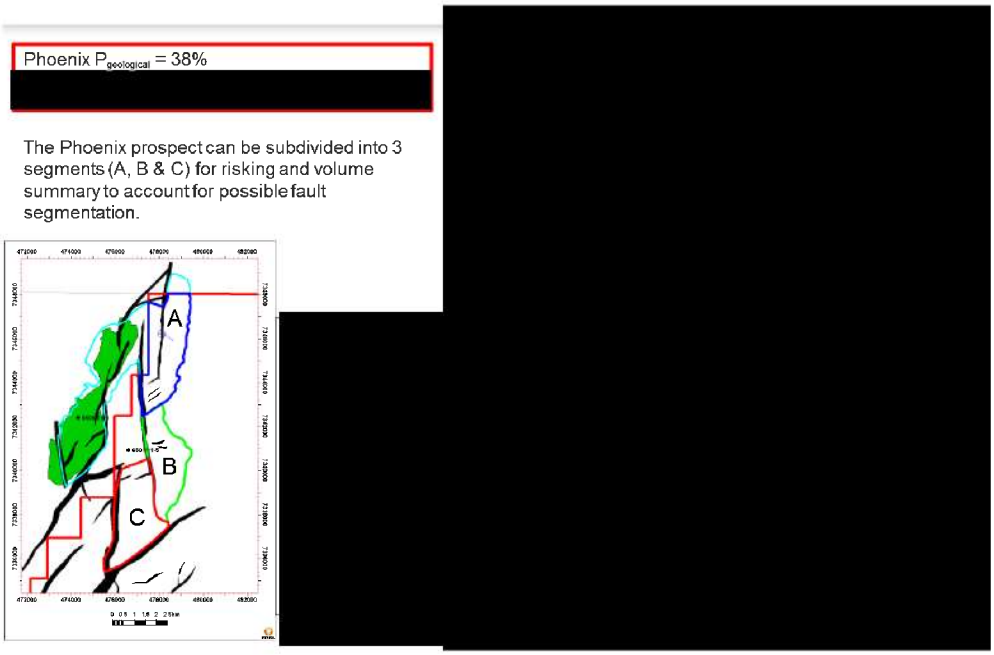
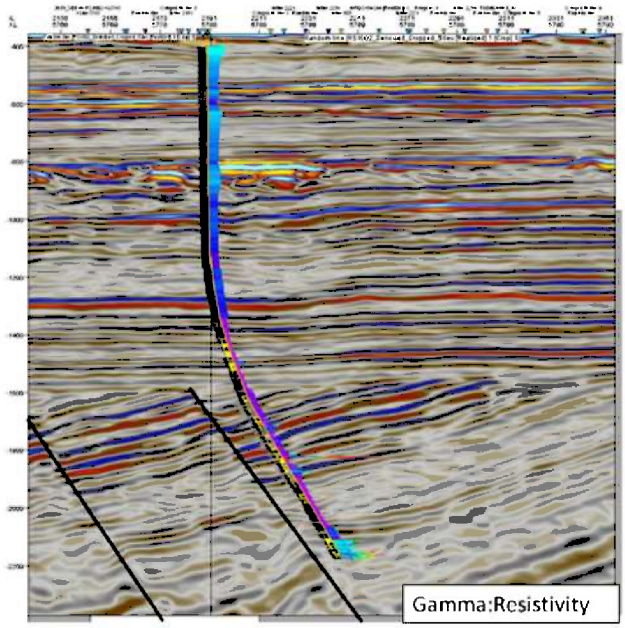


Figure 11 Risk and volumes for Phoenix prospect

Well 6608/11-7

The Pheonix well was drilled in September 2011. Geological prognosis was as expected. The reservoir sand had a poorer development than expected and there were no shows of HC in cored sands within the primary target. No significant resistivity increase was observed, which could [redacted] Some shallow gas was observed at 850m depth



Well result = dry hole

Operational summary

- Deviated well
  - *30° in primary reservoir section*
  - *40° below primary reservoir down to TD*
- Well TD 2435m MD rkb (100m below Top Carnian Marker – Triassic Red Beds)

Summary of well observations

- Geological prognosis largely as expected
- Shallow gas observed @ ~850m
- Poorly developed sands above 'shared' Linerle HC contact (1679m TVD)
- Lack of migration into prospect believed to cause well failure despite poor sand development
- Pressure gradient – on trend with Valkyrie Lower Åre water gradient.
- No HC shows detected in cored sands within primary target.
- No significant resistivity observed on horizontal logs
- Unable to acquire Triaxial data resulting in poor understanding of anisotropy factor for area.

Figure 12 6608/11-7 summary

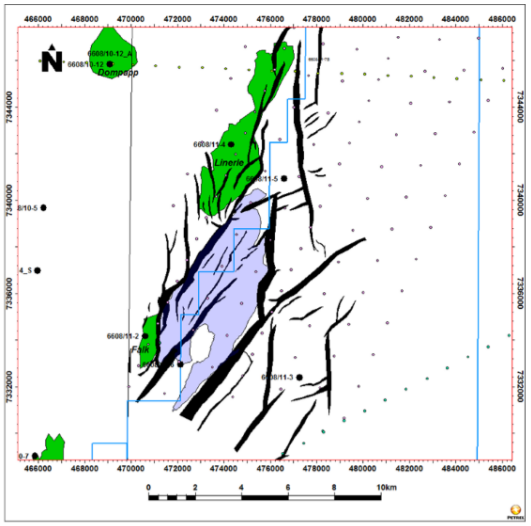
Before the well was drilled, one of the working models assumed that Linerle and Phoenix had a common oil-water contact. The post well pressure data evaluation showed that the Linerle water zone in Upper Åre was over-pressured compared to Phoenix. Phoenix Upper Åre water zone was on the trend with the water wet Lower Åre in the dry Valkyrie well (6608/11-5). These observations indicated that there was a pressure barrier between Linerle and Phoenix although 1-2 bar difference was quite small. Even though the sand development was poorer than expected, the major reason for the well failure was lack of migration into the prospect. The pressure analysis indicated that the migration from west into this area was not very likely. This shifted the focus towards prospect somewhat more south, where alternative migration routes were possible.

Post-well prospectivity

After the well was drilled, a number of studies were initiated in order to assess the remaining prospectivity in the license. The major focus was [redacted] the light of the dry Phoenix well. Further, geophysical studies were undertaken in order to de-risk

the migration challenge. Both of these are shortly described in a separate section. This work led to a new evaluation of the Hendricks prospect.

Hendricks prospect is located west of Falk and Linerle discoveries. The segment is a rotated horst block uplifted to sub-crop against BCU. Ile, Tilje and Upper Åre constitute a combined reservoir interval. The base seal provided by a Mid-Åre-Sealing-Unit (MASU) which consists of coal and shale. Lateral seal has combined stratigraphic and structural components.



- Located in the vicinity of Linerle and Falk discoveries
- Rotated horst block – uplifted to subcrop against BCU
- Trap at Ile, Tilje and Upper Åre (combined reservoir interval)
- Base seal – MASU coals.
- Lateral seal – combined stratigraphic and structural.

Figure 13 Hendricks overview

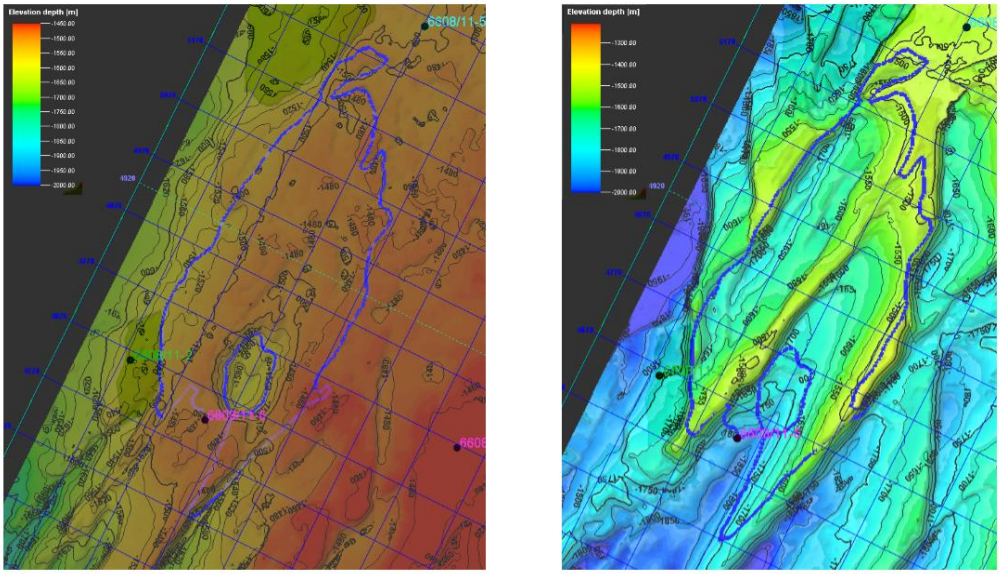


Figure 14 Top (BCU) and base (MASU) reservoir depth maps

The prospect polygon area covered 20 km². The structure was mapped on high quality seismic data. Top and base reservoir are easily identifiable seismic events on regional scale and they were tied to several wells in the area. Base on the core plug measurements, it was reasonable to expect 20-35% porosity and 1-100mD permeabilities within Hendricks Åre reservoir. Top seal consisted of 200m of Tertiary and Cretaceous shale. Faults to the east had significant throws and fault seal study indicates that even small faults in the region seal. Towards west, the fault zone is much more complex. The main risk in Hendricks remained to be migration. Since the dry Hauk well (6608/11-6) is within the closure, a filling scenario had to be assumed, which the partnership did not find convincing.

Scenarios	Dist. type	Mode	Mean	Std. dev.	F100	F90	F50	F10	F0	Overall probabi...
Failure										0.846
Success volume	MC(5000)	5.6	6.71	2.92	1.83	3.47	6.21	10.6	17.4	0.154
Unconditional segment	MC(5000)+		1.03	2.68	0.0	0.0	0.0	5.23	17.4	1.000

Figure 15 Risk and volumes in Hedricks

CSEM

Extensive modeling and inversions have been done for Delilah, Phoenix and Hendricks. Only the results for Hendricks are presented here. The data were inverted using in-house proprietary software. In order to assess several geological scenarios, synthetic models were generated and inverted using the same inversion parameters as in the case of real data. In addition, phase and amplitude attributes have been compared for both modelled and acquired data.

Elastic inversion

A pre-stack inversion on conditioned gathers was performed. Vp/Vs and AI were computed for the whole area. Based on rock physics, lithology and fluid classifications were done. Due to target depth and proximity to Linerle, Falk and (partially) Urd, which all contain heavy oil, oil with high density was assumed to be found in Hendricks too. Elastic properties of heavy oil are quite similar to those of brine, which makes HC discrimination very difficult. Elastic inversion results were however used to discriminate lithology.

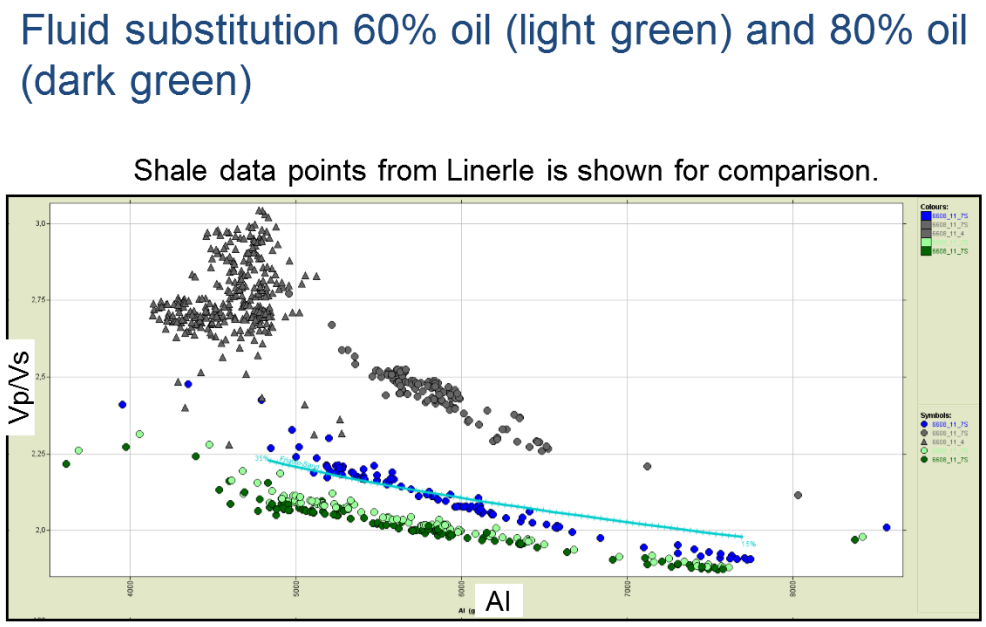


Figure 18 Heavy oil substitution. The results show that there is small difference in Vp/Vs and AI for oil and brine.

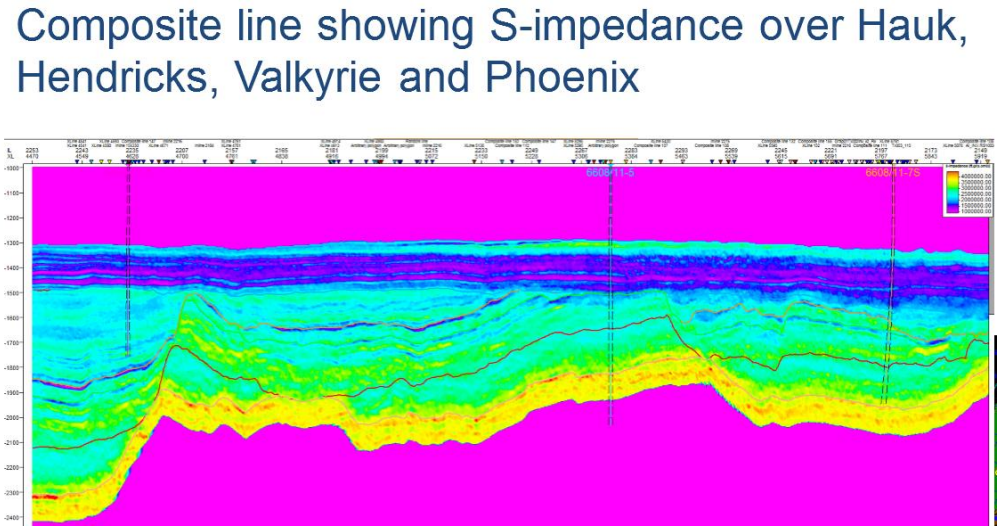


Figure 19 Lithology discrimation based on S-impedance

Technical evaluations

The key development assumptions included a subsea tieback to Norne. This would require a significant upgrade of topside/processing needed to accommodate expected heavy oil. Lack of deck space might require more equipment to be installed subsea. The most interesting scenario involved a common development with Linearle. This would reduce costs with respect to Norne upgrade and opex. It could also potentially lead to shared pipeline from subsea measurement center. Heavy oil might also require heated pipelines with pigging loop. There was a significant uncertainty with respect to number of wells due to uncertainty in oil quality and reservoir properties.

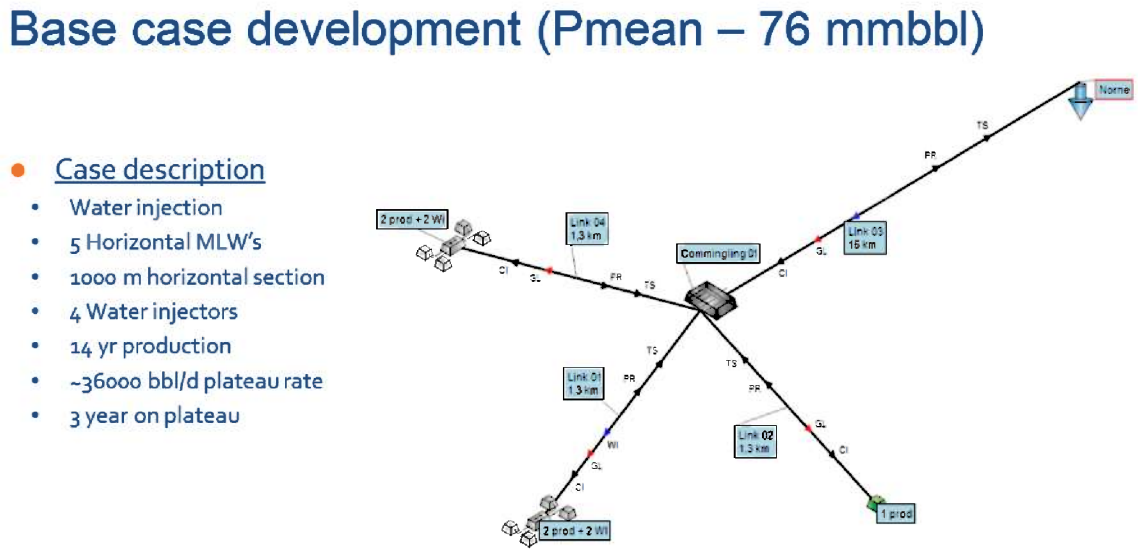


Figure 20 Development scenario

Conclusion

The main remaining target after the dry Phoenix well was Hendricks. Due to the proximity of the proven source (Spekk), the prospect to the West seemed to be the most attractive, and of those, Hendricks has the largest GRV and lowest risk. The eastern prospects depended on either more complicated migration from the west, or dependence on migration from Helgeland Basin (no proven commercial HC source) and thus are associated with a very high HC/Migration risk.

Migration for the Hendricks prospect still posed a major risk and significant effort made in order to produce a reliable DHI which could reduce the risk of charge and migration. [redacted] nor Elastic inversion could provide this. In combination with complicated development scenario due to heavy oil properties and uncertainty in reservoir quality, the risk in Hendrick remained high despite a number of extensive G&G studies. For these reasons, the partnership decided to relinquish the license.