



### Licence: PL456, Blocks 17/6 & 9 - Cyclops



Licence Data

Equity: Rocksource ASA 100% (op.)

Awarded: 29th Feb 2008 following APA 2007

Top Sandnes Fm map with volumetric polygons

Pmax = Purple

P50 = Blue 

P90 = Red

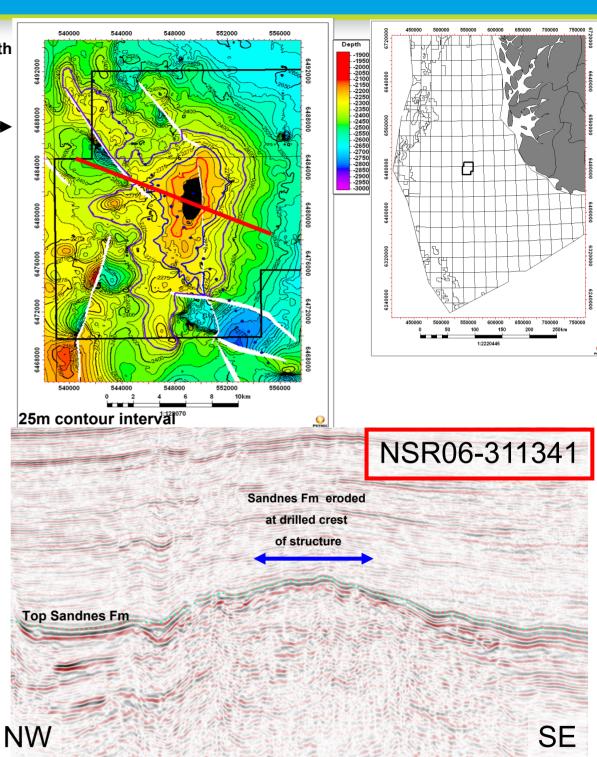
Eroded crest = Black fill

#### Work programme

- → 1st March 2008 1st March 2009: Further G&G work
- → 1st March 2009
  Decision on acquiring minimum 300km² 3D seismic data
- → 1st March 2011
  Decision on drilling an exploration well
- → 1st March 2013
  BOV decision and start of PDO writing
- → 1st March 2014 Submit PDO
- → Extension period 20 years from PDO submission

### Volumetric summary

- Mean oil case recoverable resources = 25.0 x10<sup>6</sup> SM<sup>3</sup>



#### Status:

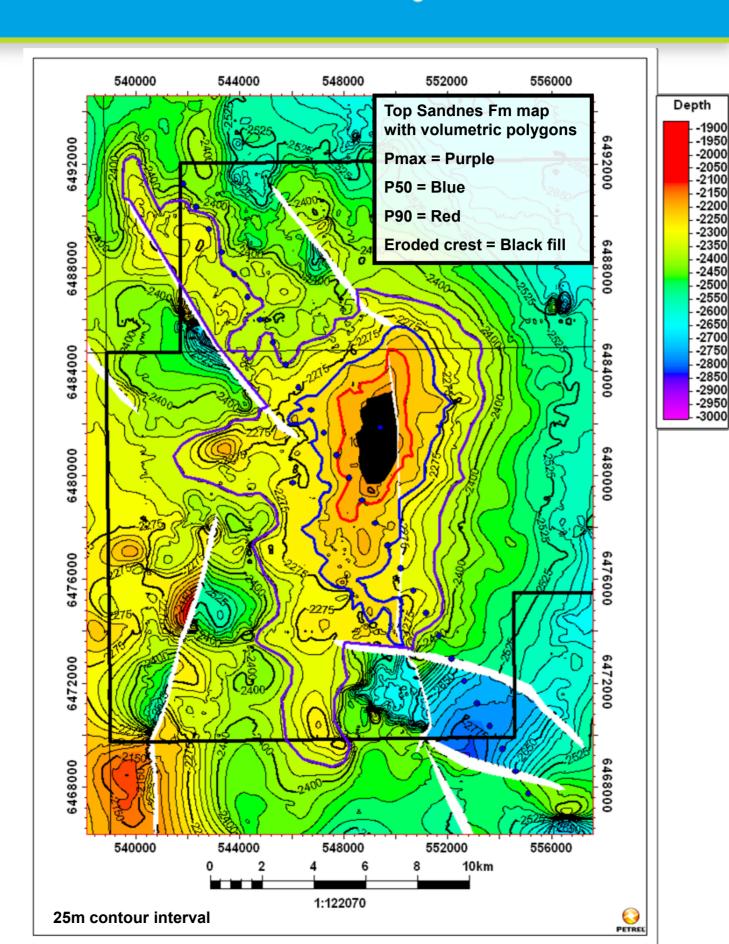
- CSEM acquisition complete
- CSEM processing and inversion complete
- G&G work complete including basin modelling and initial rock physics modelling

#### Meeting agenda

ROCKSOURCE

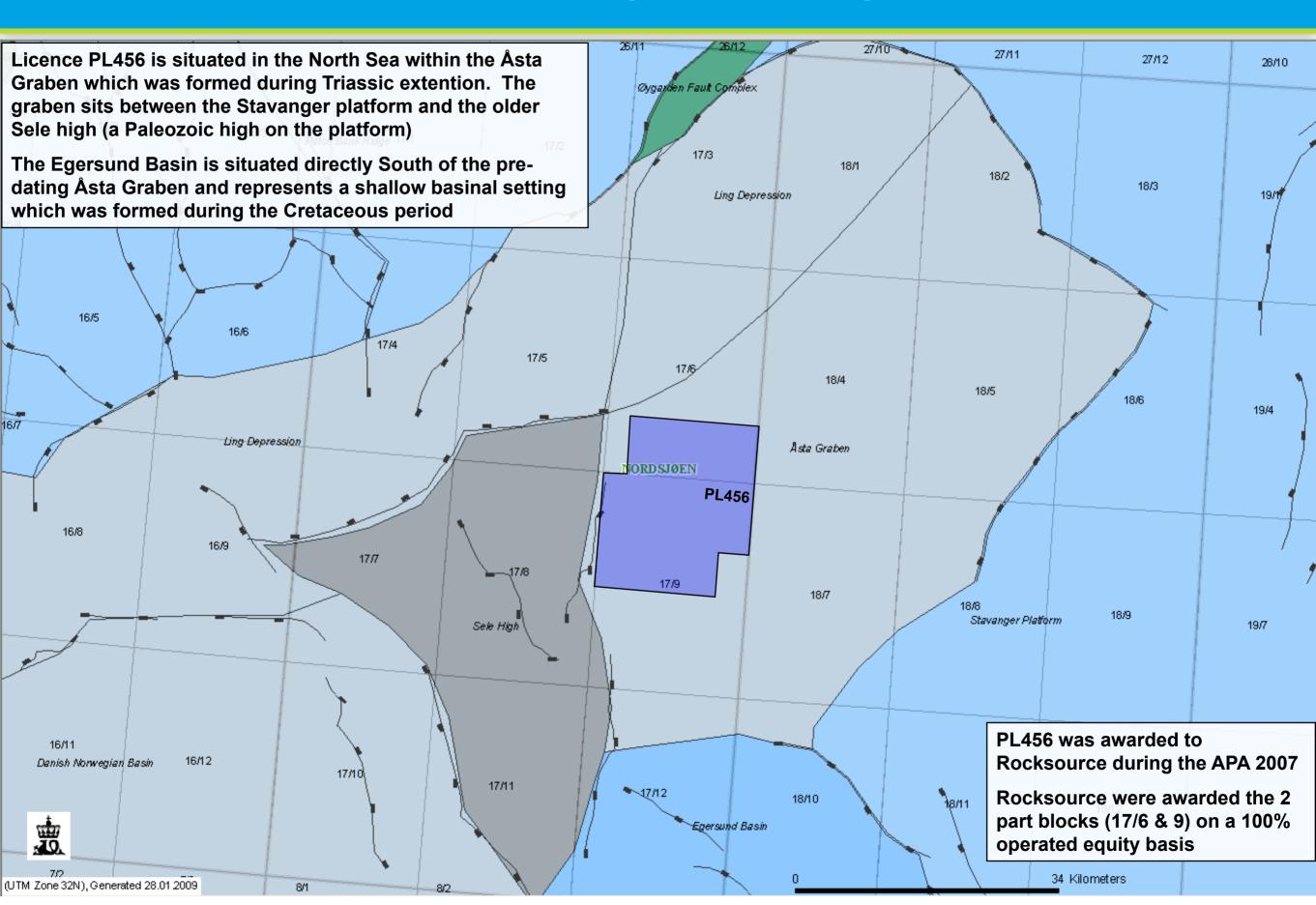
- Introduction to licence and area
- Work program and Budgetary review
- 1st year Work programme status
  - Year 1: CSEM work and current seismic intergration, specifically:
    - · CSEM Data acquisition and processing
    - CSEM data Invesion and interpretation
    - · Seismic re-interpretation
    - Rock physics modelling study
    - Basin modelling
- Geological and Geophysical overview The Cyclops prospect
- Upcoming work programme commitments in 2009: the key decision points
  - 1st March 2009: Decision to acquire and interpret 3D seismic data (minimum 300km²) must be made

Future work – Rocksource exploration strategy



# Introduction to licence – regional setting





# Work program and budget (2008 & 2009)



Work commitment: (1+2+2+1)

1. year: G&G studies

2-3 years: Minimum 300km 3D seismic.

4-5 years: Drill well.

6. year: Submit PDO or relinquish.

Extension period: 20 years.

#### Significant milestones in the licence:

License	2008	2009	2010	2011	2012	2013
PL 456	G&G EM	Seismic Acq + process	Seismic interpret D/D	Drill well	Commercial assessment	PDO

Budget Item	Firm (1000 NOK)
1. Exploration General	9395
1.1 Geology and Geophysics	288
1.2 Seismic (NSR data and AVO modelling)	365
1.3 Special studies (source and migration)	160
1.4 EM acquisition	7,327
1.5 EM Processing	1255
9 General and Administration	226
9.1 Administration ( timekost)	24
9.6 General Management ( 0,65% av tot budsjett)	60
9.7 OLF ( medlemsavgift OLF)	142
Total	9621

2009 Budget Item (estimated)	Firm (1000 NOK)	Optional (1000 NOK)		
Exploration General	1,400	73,000		
1.1 Geology and Geophysics	200	1,000		
1.2 Seismic		70,500		
1.3 Special studies ( migration study)	200	1,000		
1.4 EM acquisition				
1.5 EM Processing	1,000	500		
General and Administration	150	2919		
9.1 Administration	100	1,000		
9.5 R&D (2,5%)		1,850		
9.6 General Overhead (0,65%)	10	19		
9.7 OLF	50	50		
9.8 Financial costs				
Total	1,560	75,919		

#### PL456 – 2008 (Year 1) work program status



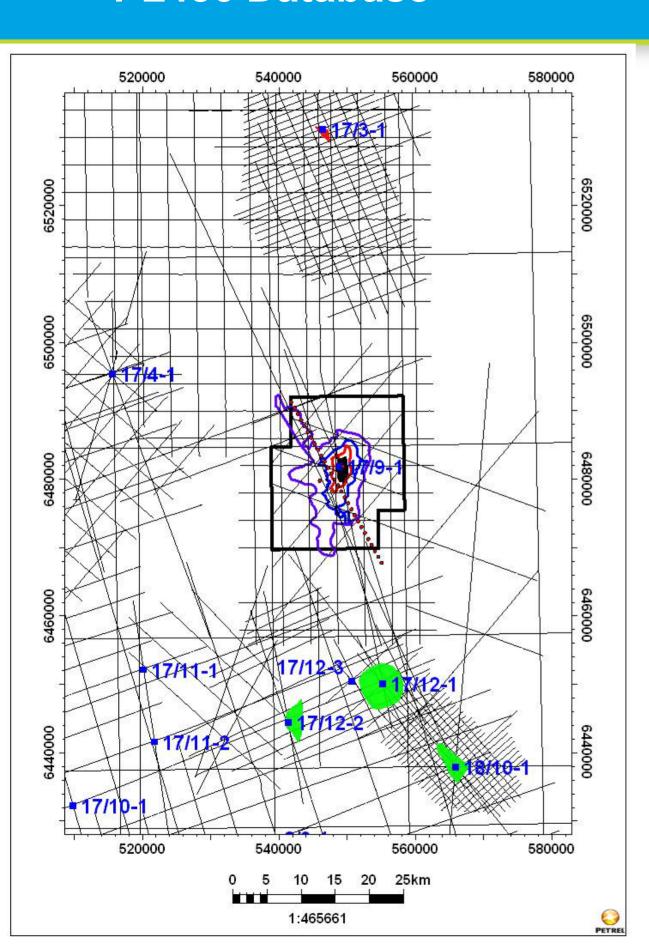
- Acquired additional 2D seismic data.
  - NSR long offset lines from TGS and older vintage data from Western Geco were purchased
- Review of seismic interpretation and geological model.
  - The additional seismic has confirmed the original interpretation and geological model. The prospect size has increased after reinterpretation resulting in a revision of resources.
- AVO feasibility study.
  - Petrophysics and initial rock physics modelling performed on five wells, but no shear wave data available. The modelling results would have been used as input for fluid substitution and AVO inversion had the license proceeded.
- Geophysical review of partial stack offset data.
  - Some signs of amplitude related AVO effects have been identified however these are small in comparison to the overall prospect volumes and do not conform structurally to the trap.
- Source and migration study by Migris.
  - A plausible migration route from the kitchen area to the North has been identified. This reduces the migration risk.
  - Report was delivered by Migris AS in January.
- EM acquisition was decided based on the encouraging migration study.
  - Two EM lines where acquired in September. Due to varying topography over the prospect two lines were acquired, one with constant water depth, and one with constant elevation above seabed. The onboard processing did not reveal any clear anomaly. Detailed processing has been completed and no significant EM anomaly has been detected over the prospect.
- 3D seismic tendering process was initiated in December 2008.
  - Tenders were received from 6 seismic companies throughout January and these were assessed internally.



# Geological and Geophysical Evaluation

#### **PL456 Database**

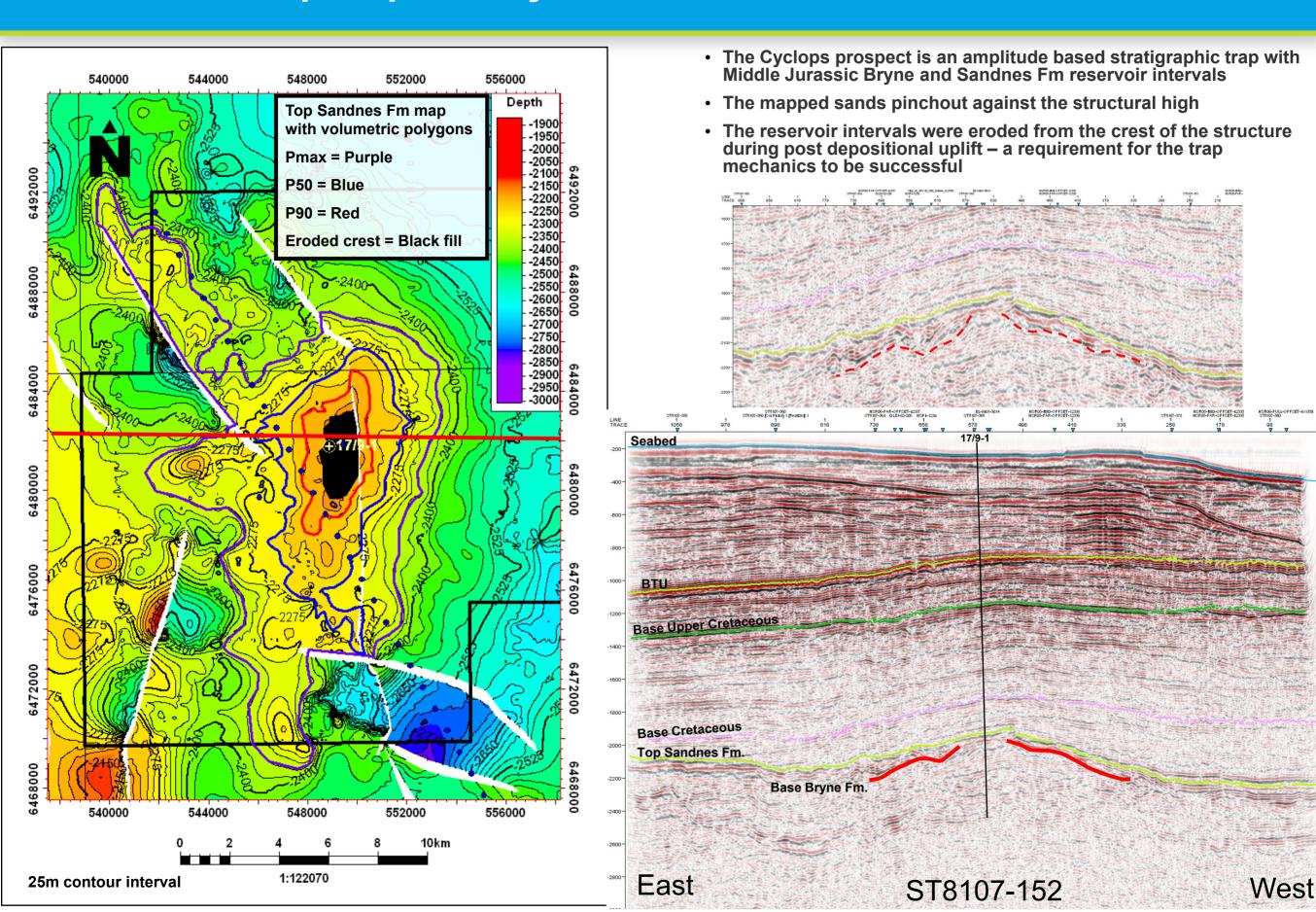




- All of the publically released wells were used in the regional evaluation however 5 key wells were selected for petrophysical analysis.
- Each of these wells contained the expected Middle Jurassic reservoir intervals oultined as prospective within the PL456 licence area and 4 held hydrocarbons within these intervals:
  - 17/3-1 (Gas discovery North of Licence)
  - 17/12-1 R (Bream oil discovery)
  - 17/12-2 (Brisling oil discovery)
  - 17/13-3 (Dry well)
  - 18/10-1 (Oil discovery)
- Seismic database key surveys:
- All publically available except NSR, GES89 & GLDI-92 where selected lines have been purchased.
  - EL8183, EL9401
  - GES89, GLDI-92
  - MOB-79-1, MOB-81-3
  - NS Phase 4, NSR (05/06/07 vintages)
  - PSE171278
  - ST8107, ST8302, ST8602
  - UG97, UGI98
- Two EM survey lines were collected along the same tow path (aimed at resolving bathymetric issues). EM Receivers are displayed in red on the basemap

# **Identified prospectivity**





### **Key Stratigraphy**



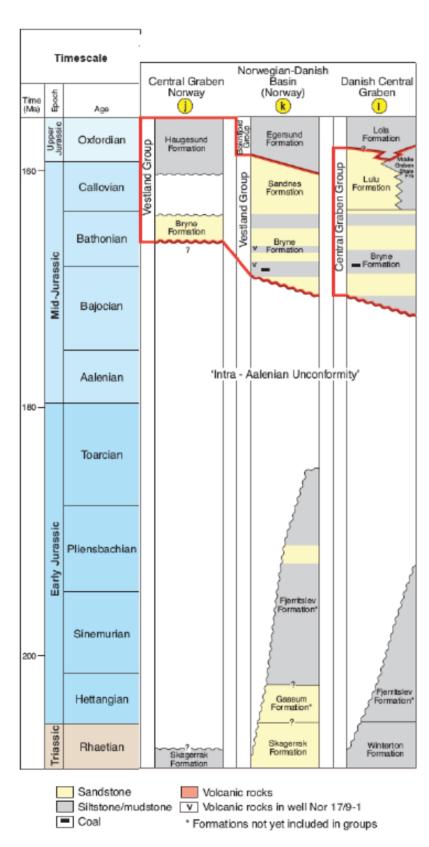


Fig. 1.4 Stratigraphic Column. Lower and Middle Jurassic lithostratigraphic units of the large eastern North Sea province in the Norwegian and Danish sectors. (Millenium Atlas 2003)

- The Cyclops prospect is a middle Jurassic stratigraphic trap with Sandnes and Bryne Fm reservoir intervals
- The sealing lithology is the shale prone Upper Jurassic Egersund Fm
- Both the Bryne and Egersund Fm's can act as local sources but the most likely sourcing unit is the Upper Jurassic Tau Fm which supplies the nearby Bream and Brisling discoveries.

### Risk analysis - pre-award



Block	Prospect n	ame	Disc/Prosp/Lead		d Pros	Prosp ID (or New!) N		NPD	approv	ed?	
17/6 & 9	Cyclops	vclops Prospect						ĺ			
Play (name / new) Struct		Struct. ele	t. element C		Company reported by / Ref. Doc. / Year						
			Egersund	Basin	Basin ROCKSOURCE/2007 APA ROUND/2007						
O/G. case					Res	ources l	INPLACE	5			
OIL			Main ph	ase					Ass. pl	hase	
	Low		Base	2	Hi	gh	Low		Base		High
Oil 10 <sup>6</sup> Sm <sup>3</sup>	14.8		33.1		71.0						
Gas 10 <sup>9</sup> Sm <sup>3</sup>							0.53		1.29		3.14
				F	Resourc	es REC	COVERA	BLE			
			Main ph	ase					Ass. pl	hase	
	Low		Base	2		gh	Low	7	Bas	e	High
Oil 10 <sup>6</sup> Sm <sup>3</sup>	5.4		13.0		30.0						
Gas 10 <sup>9</sup> Sm <sup>3</sup>			J				0.26		0.65		1.56
Prob. discove			il+gas case	≘)					-Prob f	for oil/g	as case
	109	%									100% oil
WI					fractiles are used as Low & High?						
Type of trap Waterdepth (				n) Reservoir Chrono (from - to)			) ]	Reservoir Litho (from - to)			
Combination	Strat/Strue	14	0-230m	Callovian-Bajocian				Sandnes & Bryne Formations			
SourceRock, Chrono SourceRock, Lit			-				Seal, Litho				
Bajocian-Ryaza			-						onkefjor	d & He	egre Groups
					, average line spacing = 4km						
Prob -Reserv	oir (P1)		Charge (P3)	)	- Trap (P2)					etention	ı (P4)
50%		40	1%			70%			70%		
Parametres:				Low		Base			High		
Depth to top		( <b>m</b> )		2225m		2225m			2225m		
Area of closus				18.0	18.0			26.0		37.0	
Gross rock vo				-			ļ			-	
HC column in		n)		20.0			40.0			60.0	
Reservoir thic	kness (m)			25.0			45.0			80.0	
Net / Gross				0.3			0.5			0.75	
	Porosity (fraction)			0.17		0.20			0.23		
Water Saturation			0.35		0.25			0.15			
Bg. NB !(fraction)			-		-		-				
1/Bo. NB !(fraction)			0.71		0.75			0.80			
Recovery factor, main phase			0.25			0.40			0.55		
	Recovery factor, ass. phase			0.40			0.50		0.60		
GOR, free gas (Sm³/Sm³)						1					
		)		10.0			20.0			00.0	
GOR, oil (Sm			(1.6	13.0		1	30.0	D	e, top re	80.0	250

- The key prospect risk was identified as being hydrocarbon charge (40%) – a dry well on the crest of the Cyclops structure had encountered no hydrocarbons and the nearest source kitchens offered only complex migration routes
- HC column predicted to be between 20 60m with oil the most likely phase
- Reservoir thicknesses between 25 80m were expected at the Middle Jurassic target level (combined thickness of Bryne and Sandnes Fms)
- Thick Upper Jurassic and Cretaceous shales provide the sealing lithologies
- The base case area of closure was 26km<sup>2</sup> Area reduction factors of 67% and 37% were applied to the Max and base case figures respectively to account for underfilling of the trap
- Base case recoverable resources were defined as 13 x 10<sup>6</sup> Sm<sup>3</sup> of oil
- These risks and resources were re-evaluated during the first year of the work program and measures were taken to try and reduce the key risks associated with the prospective area
  - i.e. Basin modelling to identify possible migration routes and volumes



# Post award risking and volumetric assessment

### Seismic re-interpretation of key horizons

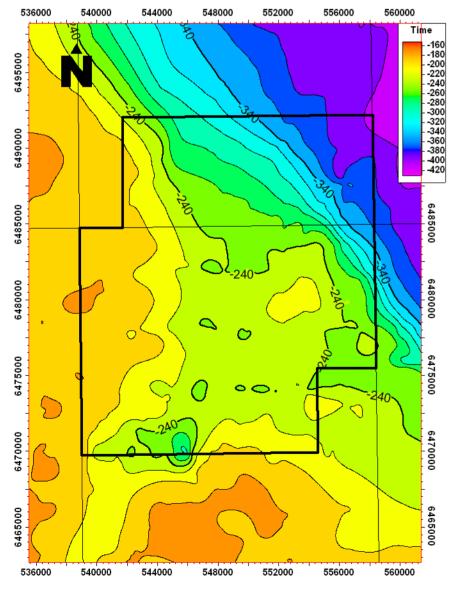


- The following key horizons were re-interpreted over the licence area for use in prospect definition, volumetric assessment, velocity model building, source and migration analysis & EM modelling/Inversion inputs:
  - Seabed
  - Base Tertiary
  - Base Upper Cretaceous
  - Base Cretaceous
  - Top Sandnes Fm (approx Base Upper Jurassic)
  - Base Bryne Fm

- Regional mapping from the North Sea Data Atlas (PGS multi-client product) has also been used in the evaluation:
  - Base Eocene
  - Top Chalk
  - Near Top Triassic

- Base Lower Triassic

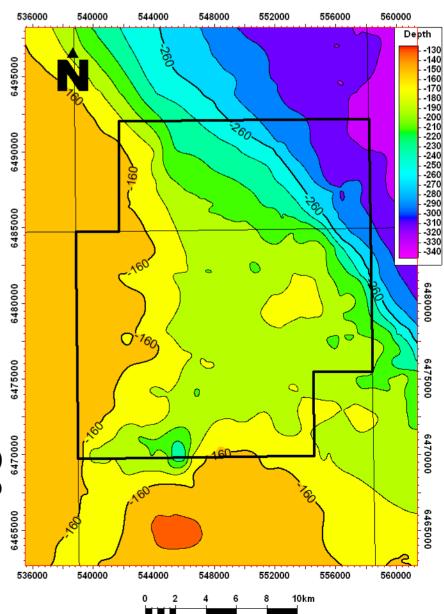
- Base Lower Permian



1:152588

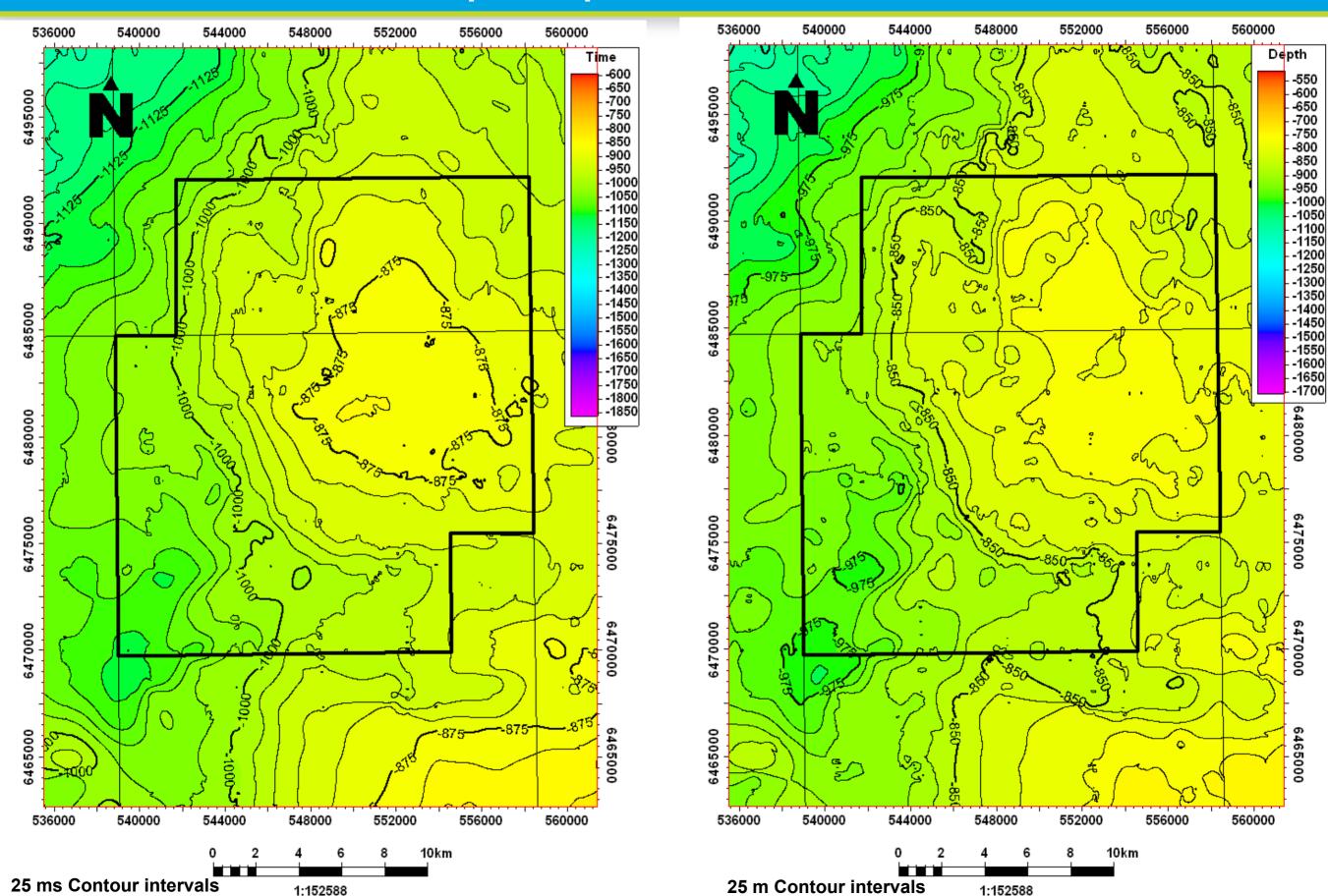
Seabed interpolated TWT (ms) structural map

Seabed interpolated depth (m) § structural map



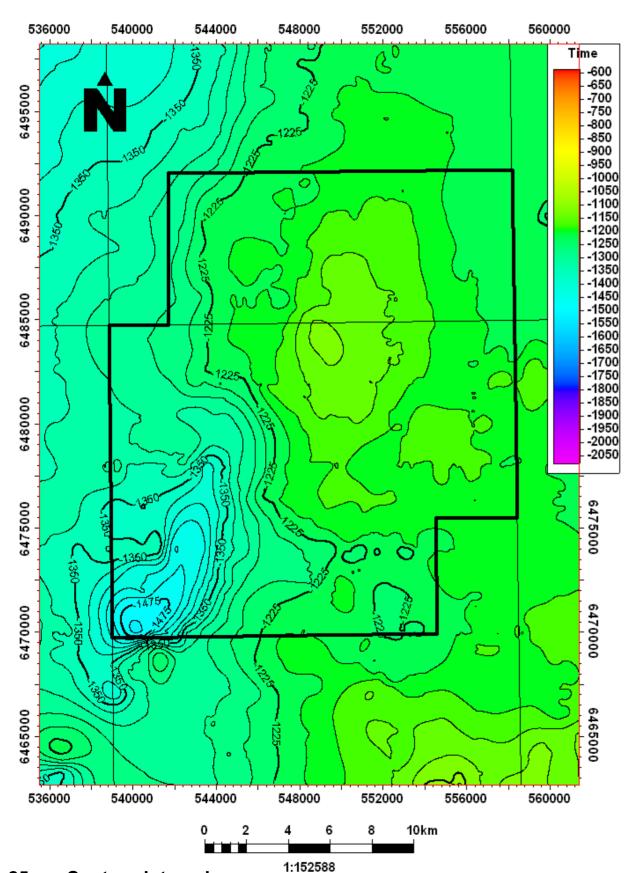
#### **Base Tertiary structural time and depth maps**

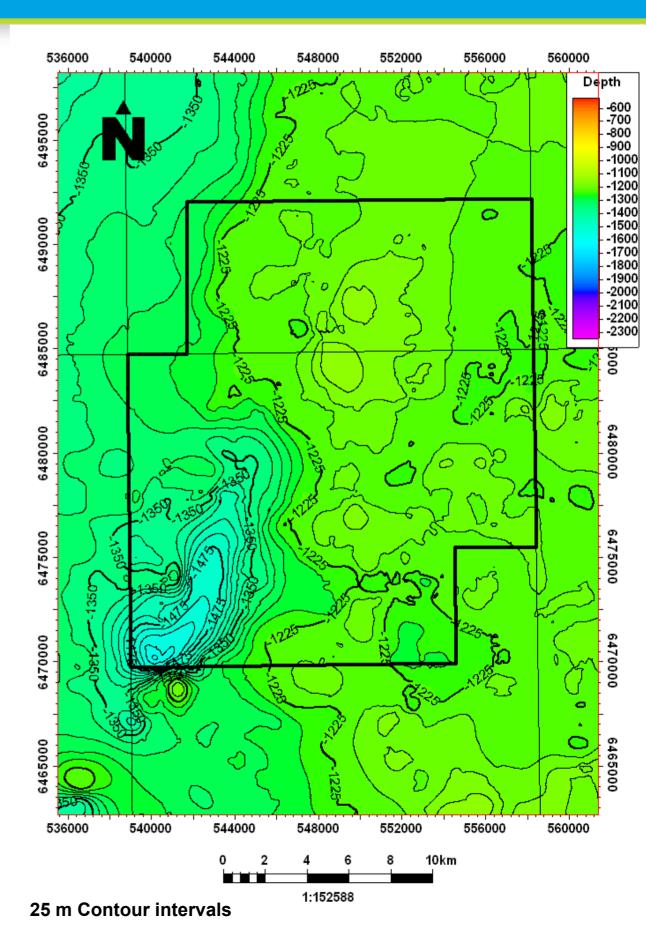




# **Base Upper Cretaceous structural time and depth maps**

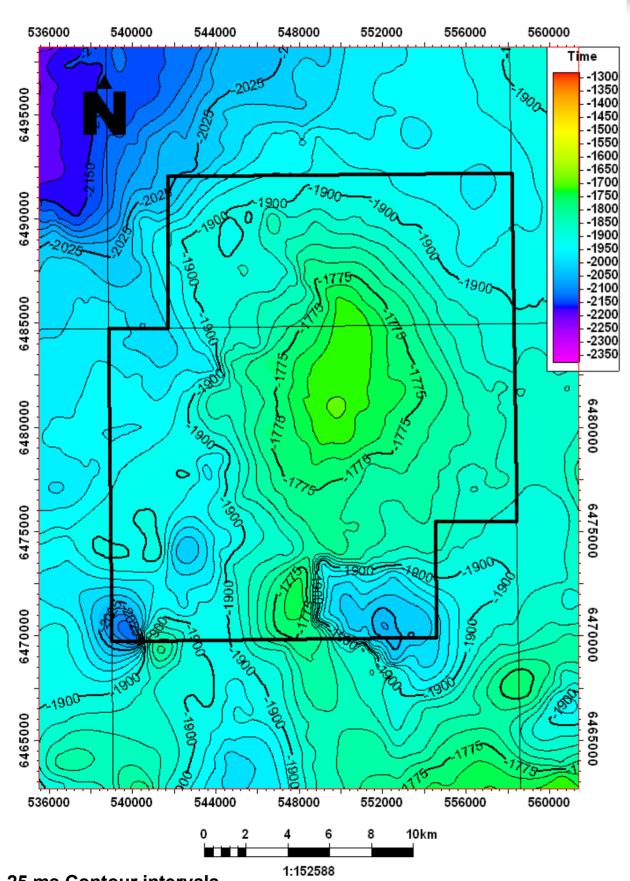


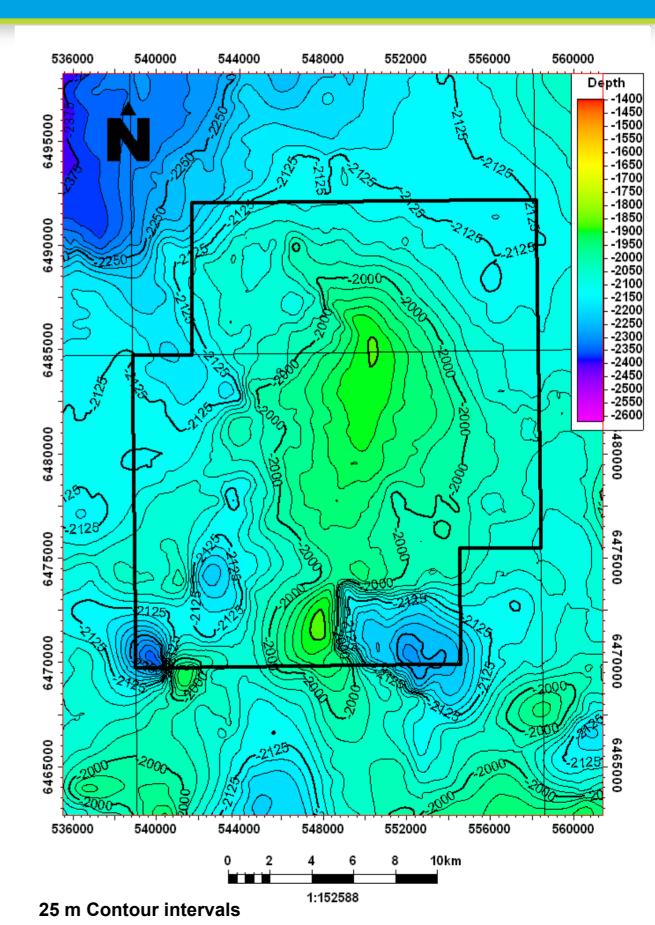




#### **Base Cretaceous** structural time and depth maps



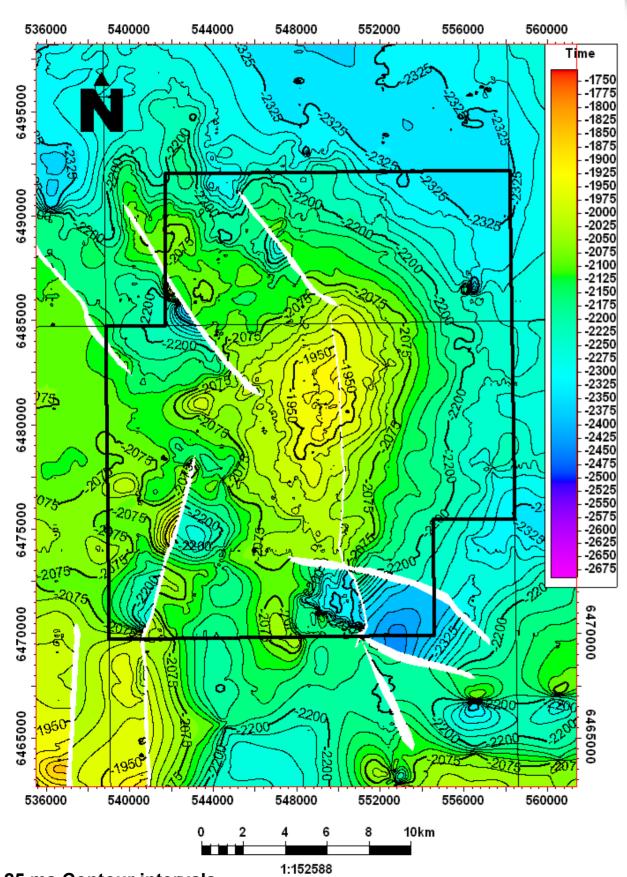


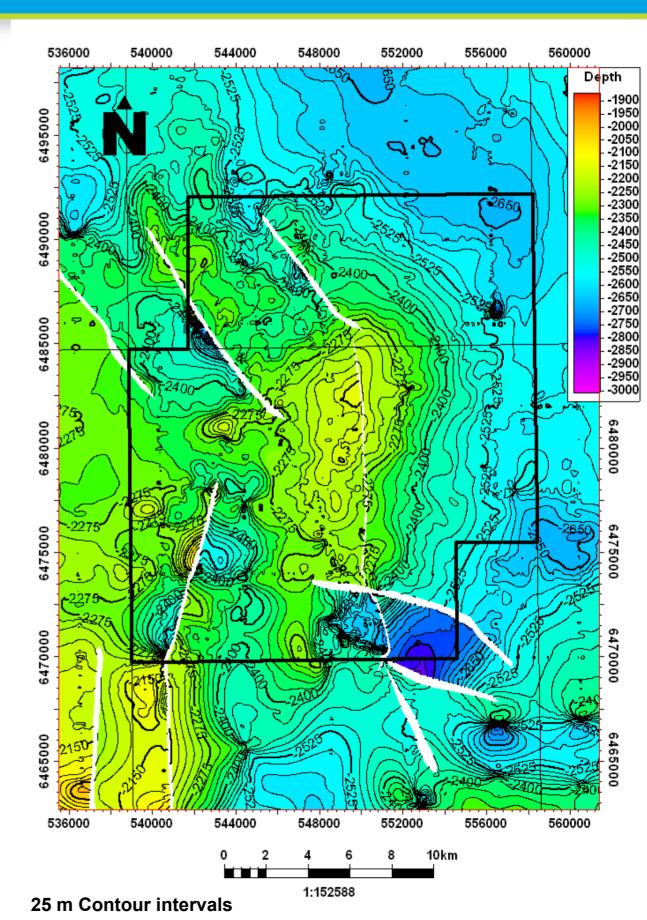


25 ms Contour intervals

# Top Sandnes Fm structural time and depth maps

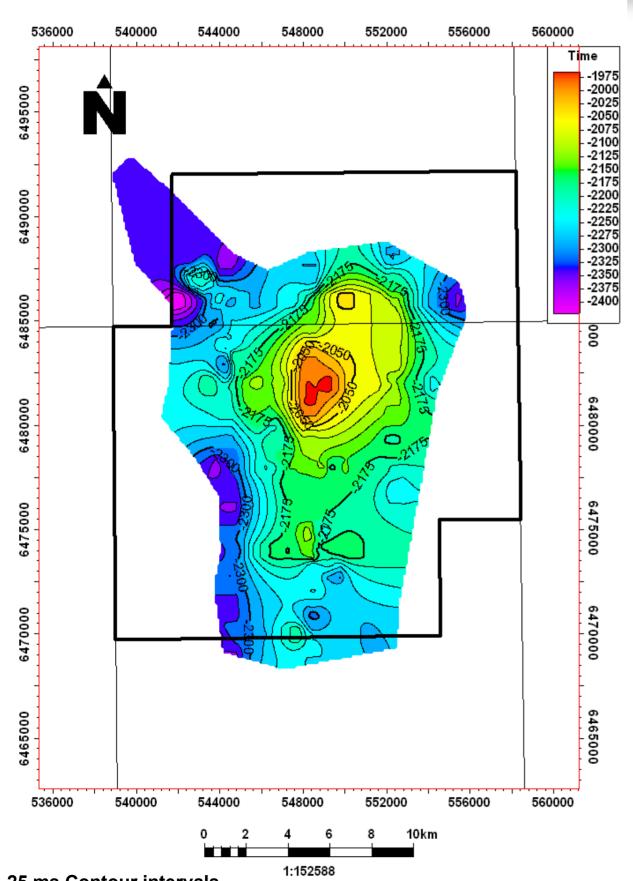


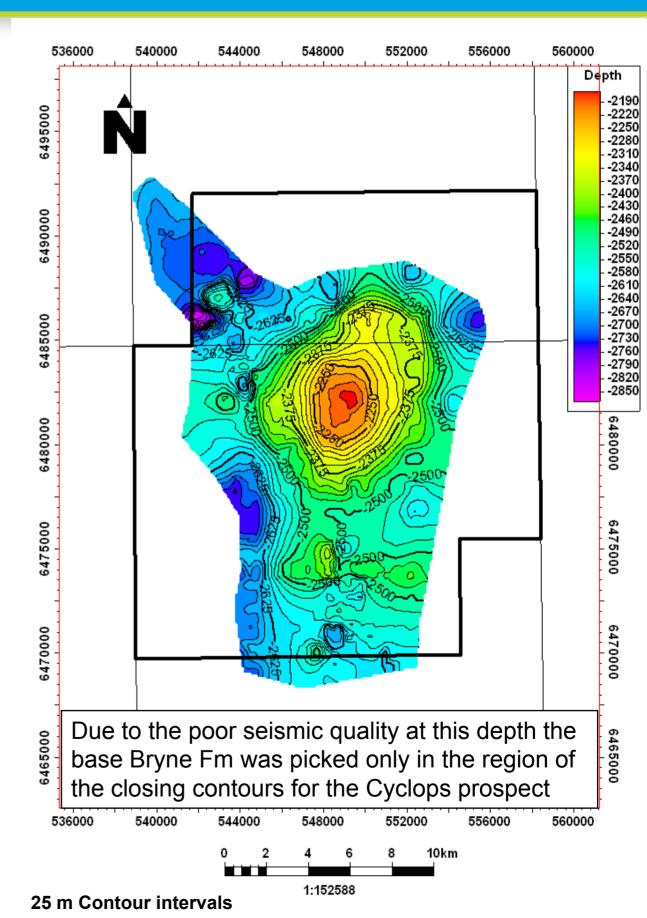




#### Base Bryne Fm (Base of Cyclops trap) structural time and depth maps

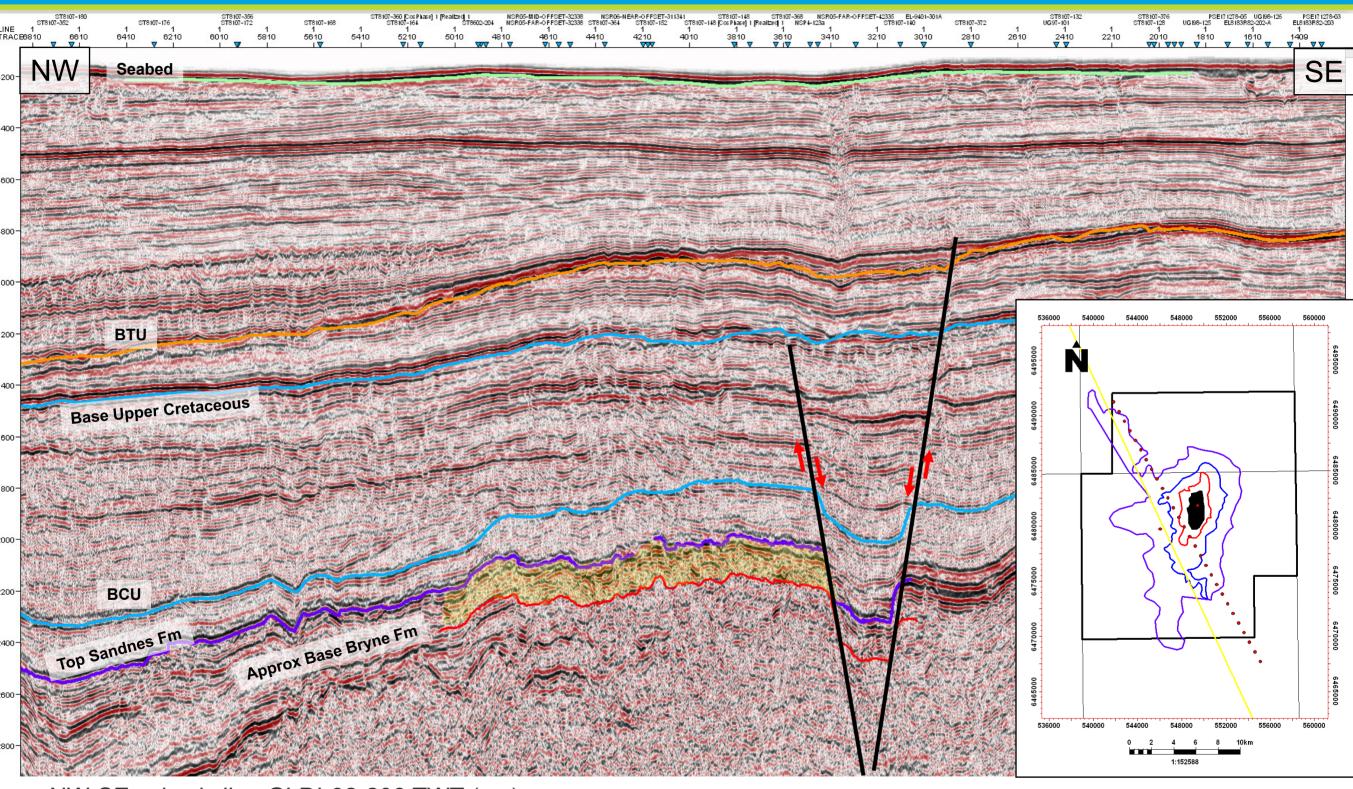






### Structure – the Cyclops prospect

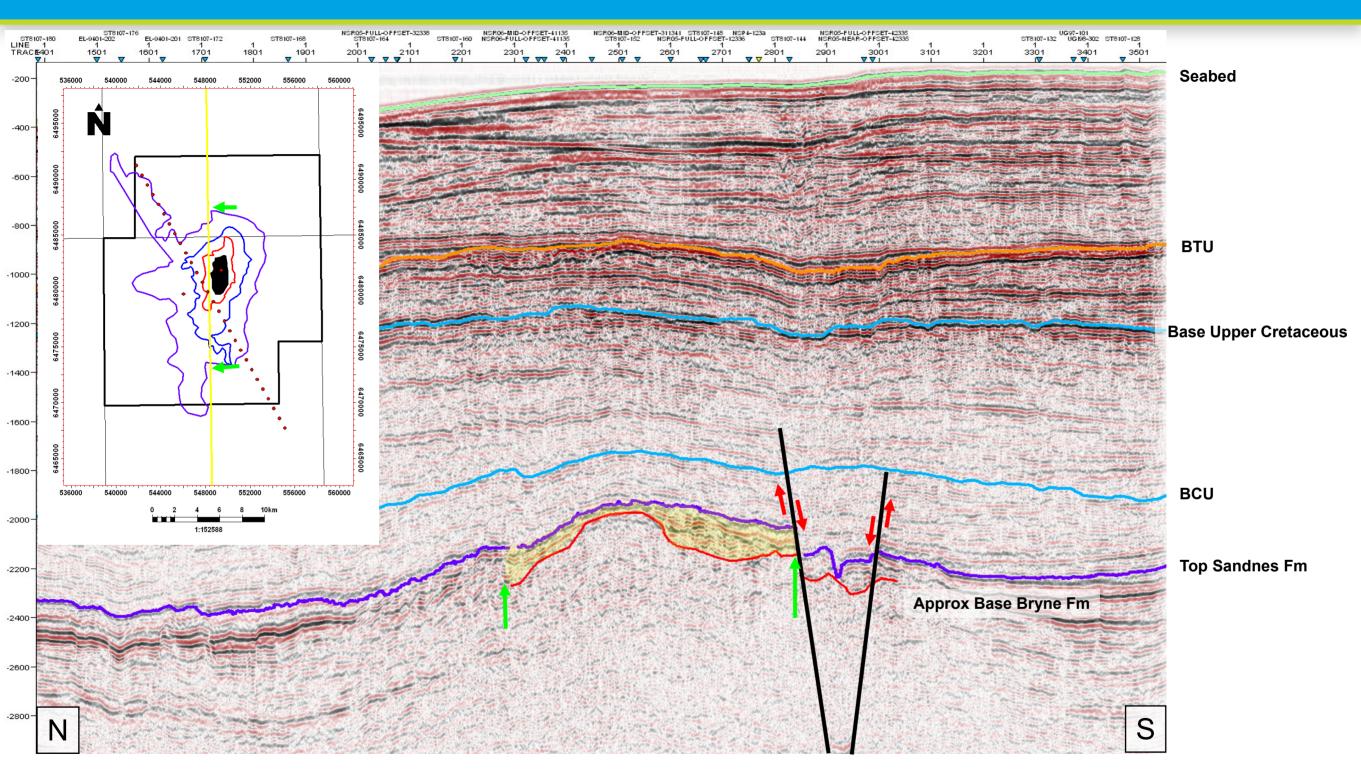




- NW-SE seismic line GLDI-92-206 TWT (ms)
- Moving down dip from the pinchout onto the Western side of the structure the bright and semi-chaotic amplitudes
  associated with the Sandnes and Bryne Fm reservoir intervals can be observed

# Structure - N-S section (TWT - ms)

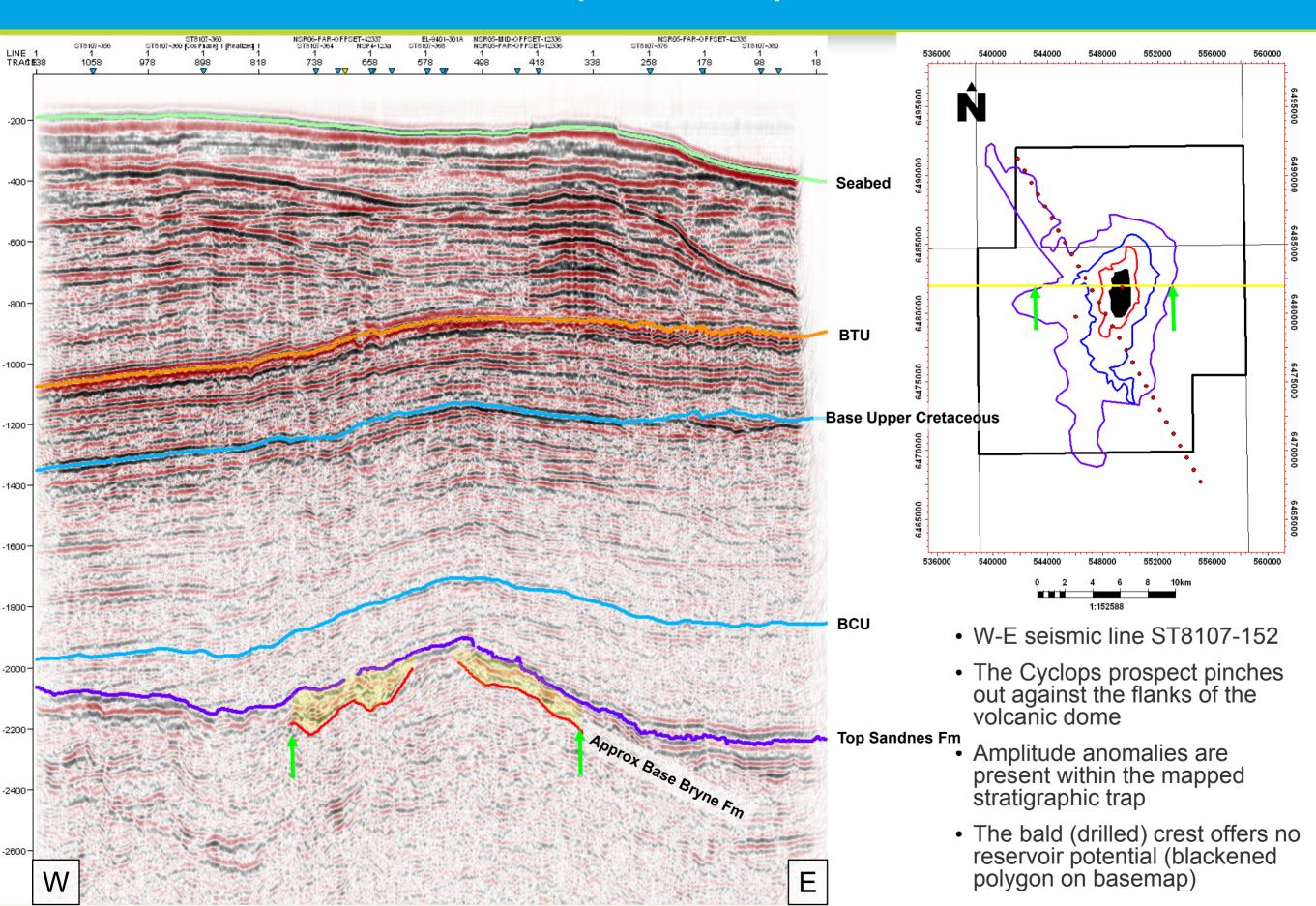




- N-S seismic line ST8107-368 which passes parallel to the western side of the pinch-out.
- Extend of max area trap is depicted by green arrows
- The prospect is almost at the point of pinchout here.

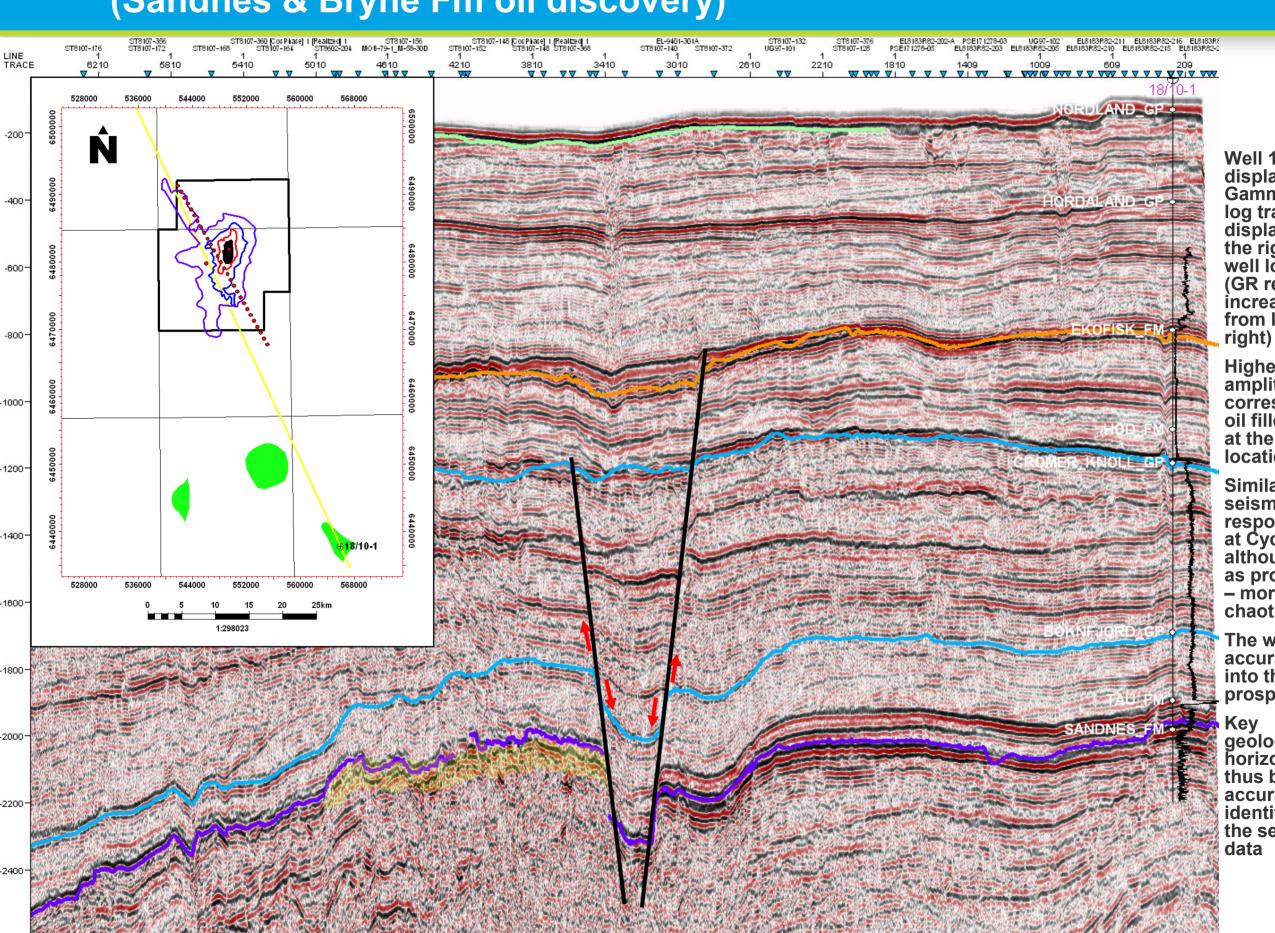
# Structure - W-E section (TWT - ms)





# Well-seismic tie: 18/10-1 (Sandnes & Bryne Fm oil discovery)





Well 18/10-1 displayed and Gamma ray log track displayed to the right of the well location (GR response increases from left to

Higher amplitudes correspond to oil filled sands at the well location.

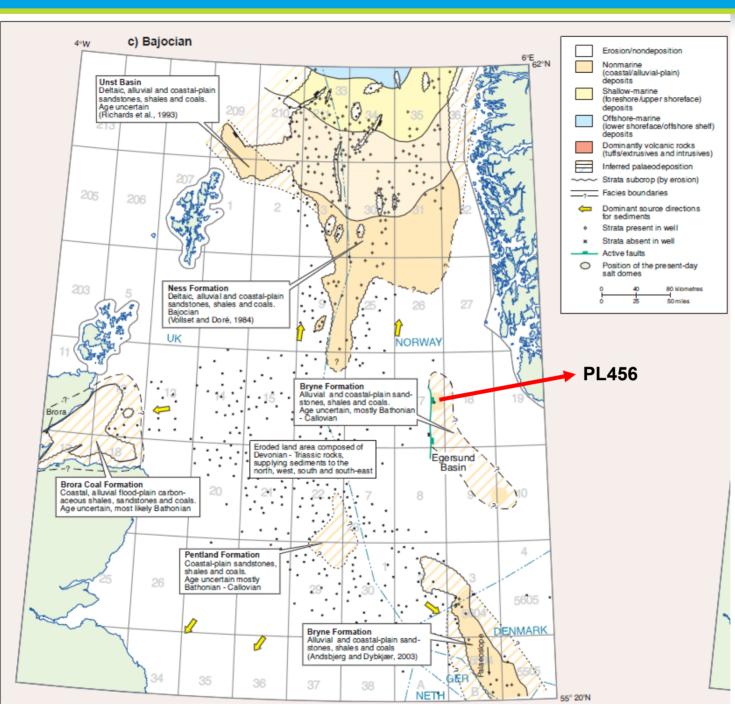
Similar seismic response seen at Cyclops although not as prominant – more chaotic

The well ties accurately into the prospect area

geological horizons can thus be accurately identified on the seismic data

#### Reservoir development - Middle Jurassic stratigraphy 🗬 ROCKSOURCE

Figure 10.13 continued. **During Mid-Jurassic times** (Diagrams c and d), widespread regression occurred as a result of doming centred on the Central Province area, and the depositional environment within the Atlas area changed from offshore marine to predominantly nonmarine and shallow marine. Erosion removed much of the existing Lower Jurassic strata and also underlying Triassic and older strata from the area south of 59° N. Clastic sediments sourced from the dome were deposited in surrounding basins extending beyond the Atlas area. In the **Dutch and German Central** Graben, Middle Jurassic strata consist of marine and fluvial sandstones and claystones up to 800 m thick (Van Adrichem Boogaert and Kouwe, 1993) and in north Denmark the strata consist of marine sandstones and shales. To the south-west of the Atlas area, on the Yorkshire coast, Middle Jurassic alluvial, deltaic and coastal-plain sandstones, shales and coals are 200 m thick (Rawson and Wright, 1995).



- The Middle Jurassic Bryne Fm is the first significant sandy facies to be deposited in the licenced area following the mass deposition of Triassic sediment that occurred in the proximal Åsta Graben and Egersund Basins where salt wall growth had only a limited influence on facies distribution.
- These Triassic Alluvial fan-stream and debris-flow deposits had advanced westwards from the Stavanger platform margins into the Åsta Graben and Egersund Basin margins (Skagerrak Fm).
- During the Aalenian period the Åsta
   Graben was at the center of the North Sea
   dome where uplift and erosion was
   thought to have eliminated most of the
   Lower Jurassic shales which were
   prominent in the area during this time.
   Siginificant erosion of the Triassic
   deposits may also have occurred
- Well 17/9-1, situated on the crest of the Cyclops structure, does contain some Lower Jurassic stratigraphy suggesting that the licenced area was not badly effected by the Aalenian unconformity.

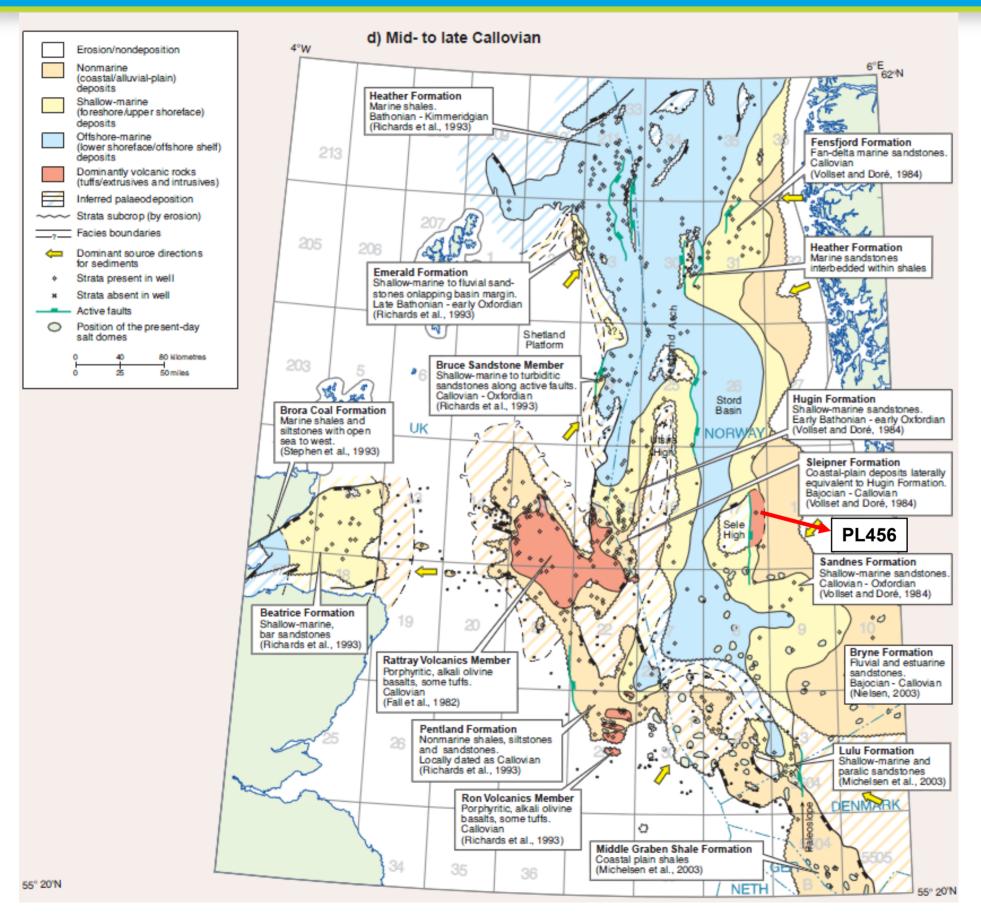
#### Bryne Fm (Bajocian age):

The Non marine Bryne Fm comprises interbedded sandstones, shales and coals deposited on an extensive alluvial/coastal plane. The unit is found to be as thick as 225m in the licence area as was deposited post-subsidence of the North Sea Dome.

The Bryne Fm is the main reservoir interval in discovery well 18/10-1 approximately 35km South of the Cyclops prospect.

Significant sandy intervals have also been identified in wells regionally – the petrophysical well logs have been analysed to give reservoir parameters in the following slides.

#### Reservoir development – Middle Jurassic stratigraphy 😎 ROCKSOURCE



The Sandnes Fm consists of coastal and shallow marine, white, glaucontitic sandstones and shales up to 100m thick.

The relative timing of deposition has been debated but it is said to have been deposited from the Mid-Late Callovian all the way through to the Early Oxfordian.

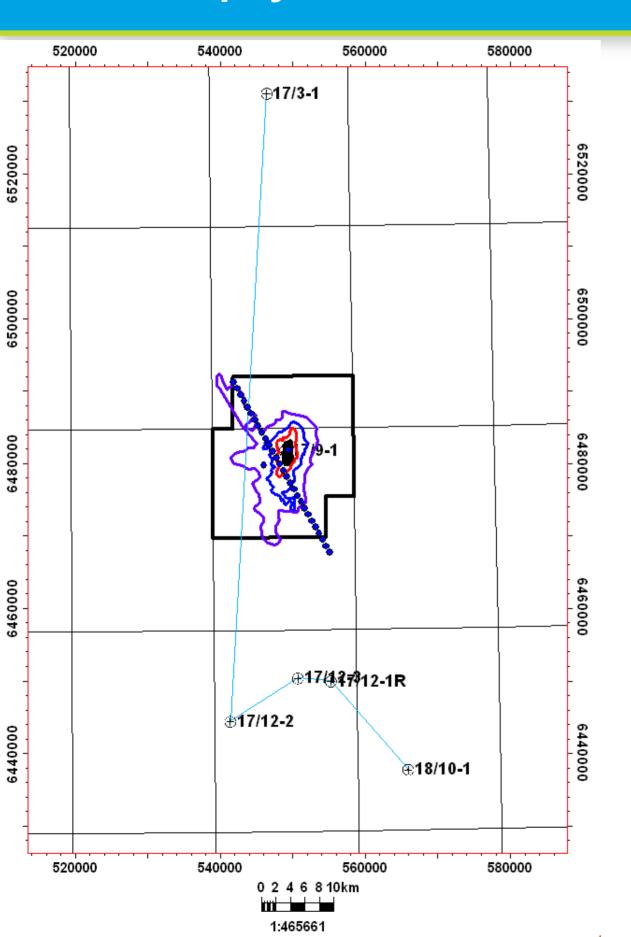
17/9-1 Volcanics (Lower and Middle Jurassic period – in sync with reservoir deposition)

As described by Furnes et al. 1982: The Asta Graben is thought to have been subjected to extrusive Igneous activity during the latter stages of the Mid Jurassic. Extrusive volcanic rocks in well 17/9-1 (drilled on the crest of the Cyclops structure) have been studied in two 9m long cores taken from near the top of the 400m thick Middle Jurassic succession. Petrographically, they are quite distinct from the alkali basalts of the Rattery and Ron provinces: they have clino-pyroxene phenocrysts, are strongly altered, highly alkaline, and have planar, horizontal vesicles suggesting they are subaerial lavas.

These lava's may have effected some of the reservoir potential and could also be responsible for some of the higher amplitude events associated with the Sandnes Formation in the Cyclops prospect.

#### Petrophysical well database





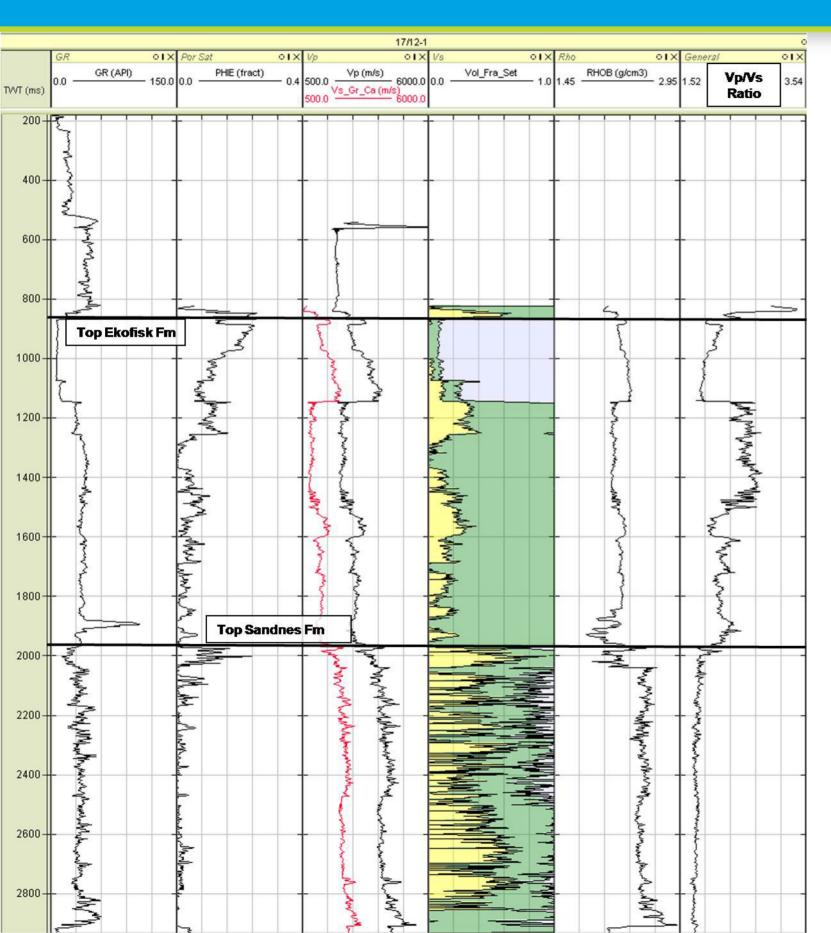
- 5 wells were selcted based on their proximity to the prospect and variations in hydrocarbon fluid fill at the proposed target intervals
- Well 17/3-1 is a small, non-commercial gas discovery to the North of Cyclops. A 2m gas column was discovered within the Sandnes Fm
- 17/12-1R (Bream), 17/12-2 (Brisling) & 18/10-1 are all oil discoveries with 30m, 13m and 30m oil columns respectively within the Sandnes and underlying Bryne Fm's.
- 17/12-2 is a dry well with Sandnes Fm reservoir present.
- Petrophysical modelling was carried out by IKON science on behalf of Rocksource and the reservoir parameters generated were used as a basis for the volumetric analysis in GEOX





#### Analysis of key wells and target intervals



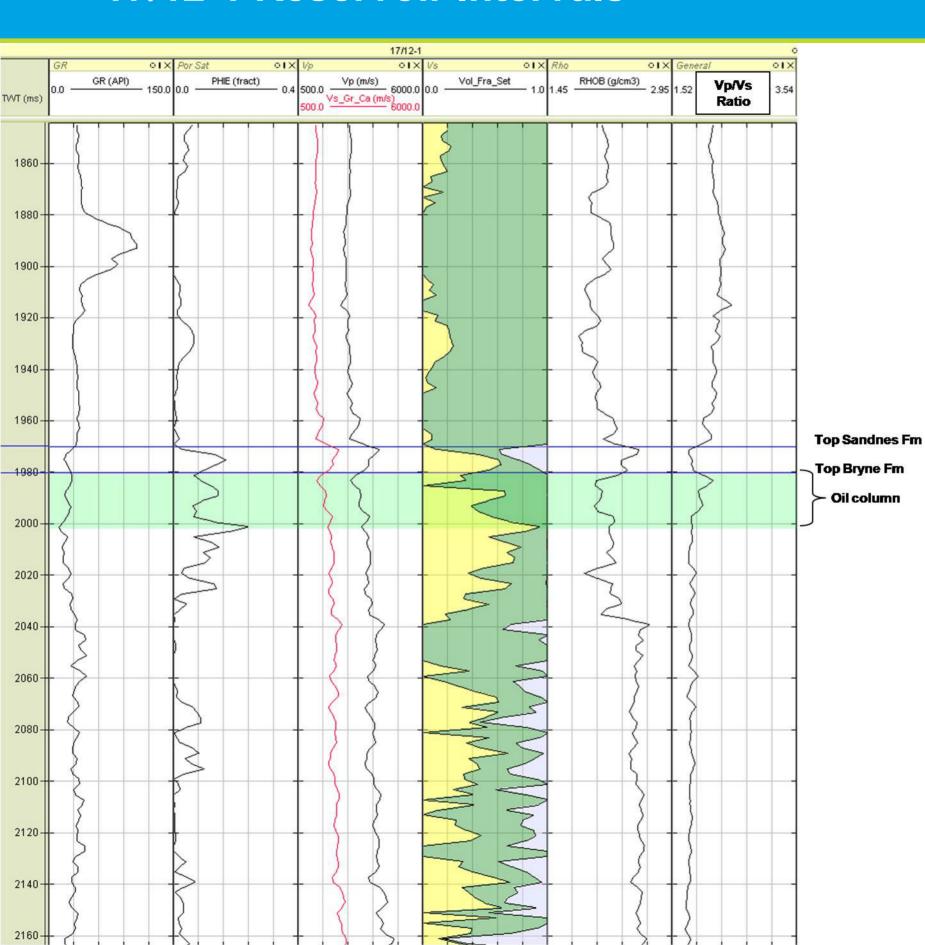


- Petrophysical analysis of 5 wells were carried out as part of the AVO workflow.
- Volume fraction sets and Vp/Vs curves were generated from the petrophysical well log suite.
- Well 17/12-1 (Bream discovery) is displayed opposite
- Porosities within the Ekofisk chalk Fm vary between 6 - 25% whilst at the key Bryne and Sandnes Fm reservoir intervals porosities range from 15 - 22%
- The volume fraction sets show the quartz/clay/calcite content and how it varies between the lithologies
- The Bryne and Sandnes Fm are between 50-75% quartz grain dominated making them the sandiest intervals within the well

- = Calcite/carbonate fraction
- = Quartz fraction
  - = Clay/Shale fraction

#### 17/12-1 Reservoir Intervals

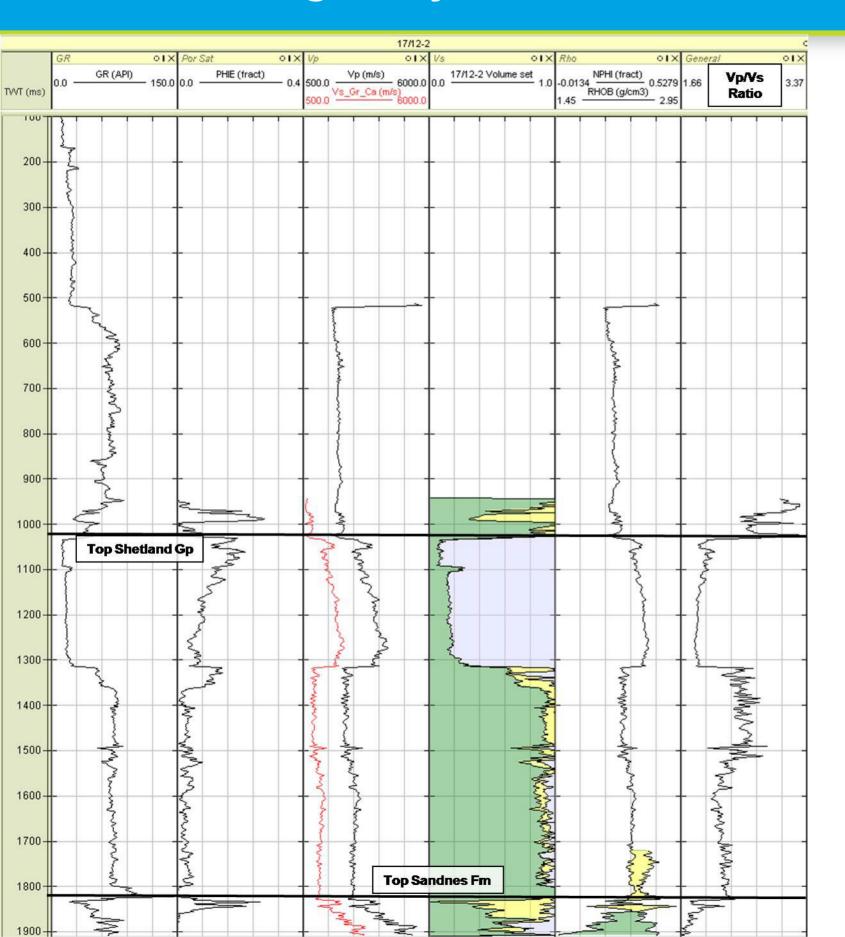




- The Bream discovery appears to be underfilled in the sandstone prone section however strongly defined compartmentalisation is observed in other wells in this area suggesting that there may have been a shale/clay barrier preventing further fill.
- The Sandnes Fm is 16m thick whilst the Bryne Fm is 104m.
- The oil column is approxmately 30m
- Water saturations for the gross rock intervals are 93% and 79% for the Bryne and Sandnes Fm's respectively however the hydrocarbon filled compartment within the bryne Fm has an average Sw of 31.5%.
- N/G ratio for the Sandnes Fm is 60% whilst the Bryne Fm is 33%
- Porosities for the net sand intervals are 19% whilst the net pay sands within the Bryne Fm have an average porosity of 22.8%

#### 17/12-2 Log Analysis

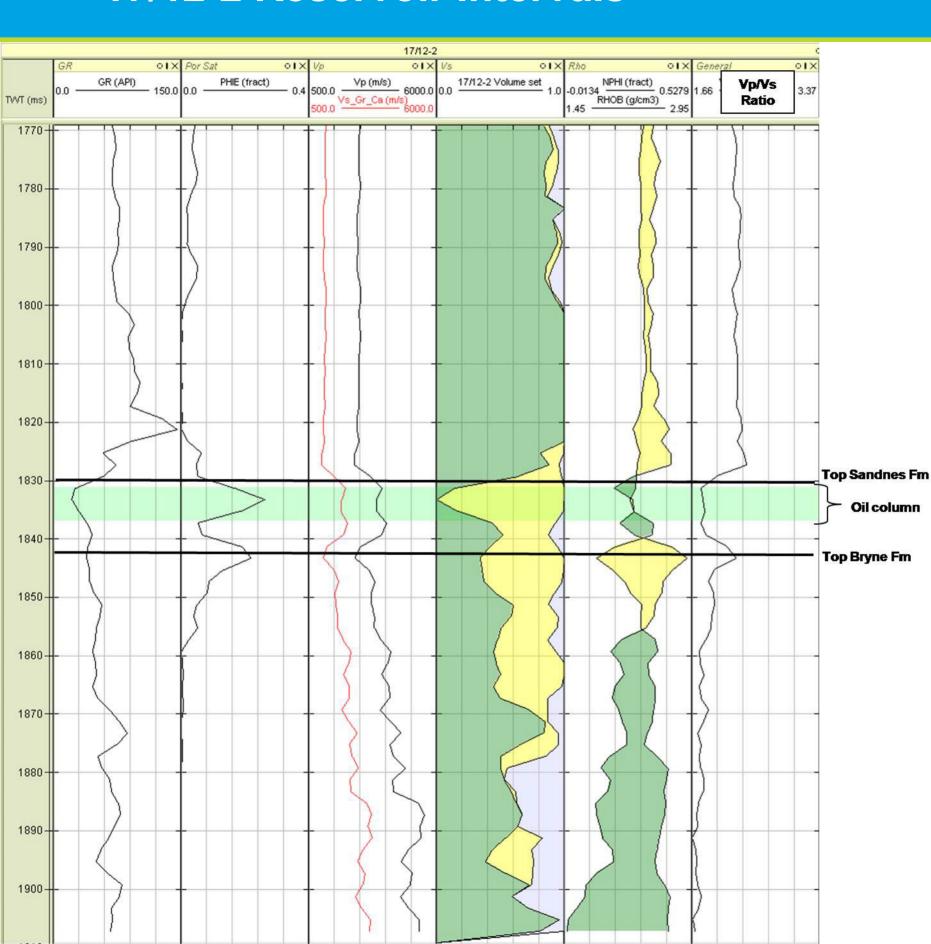




- Well 17/12-2 (Brisling discovery) AVO log suite
- The volume fraction sets show the chalk beneath the Top Shetland Gp which are identifiable by their high carbonate content, low gamma and high density/velocity trend
- The Tor and Hod Fm's are included in this 300m chalk sequence
- Porosities for the chalk interval are lower in this well (9-13%) than observed in 17/12-1. These variations become important during the EM modelling as highly porous water filled chalks with have significantly lower resistivities.
- The Top Sandnes Fm within the Middle Jurassic stratigraphy is the main reservoir interval along with the Bryne Fm
- The Sandnes and Bryne Fm's show average porosities for the gross rock intervals of 11.5 – 17.6%

#### 17/12-2 Reservoir Intervals

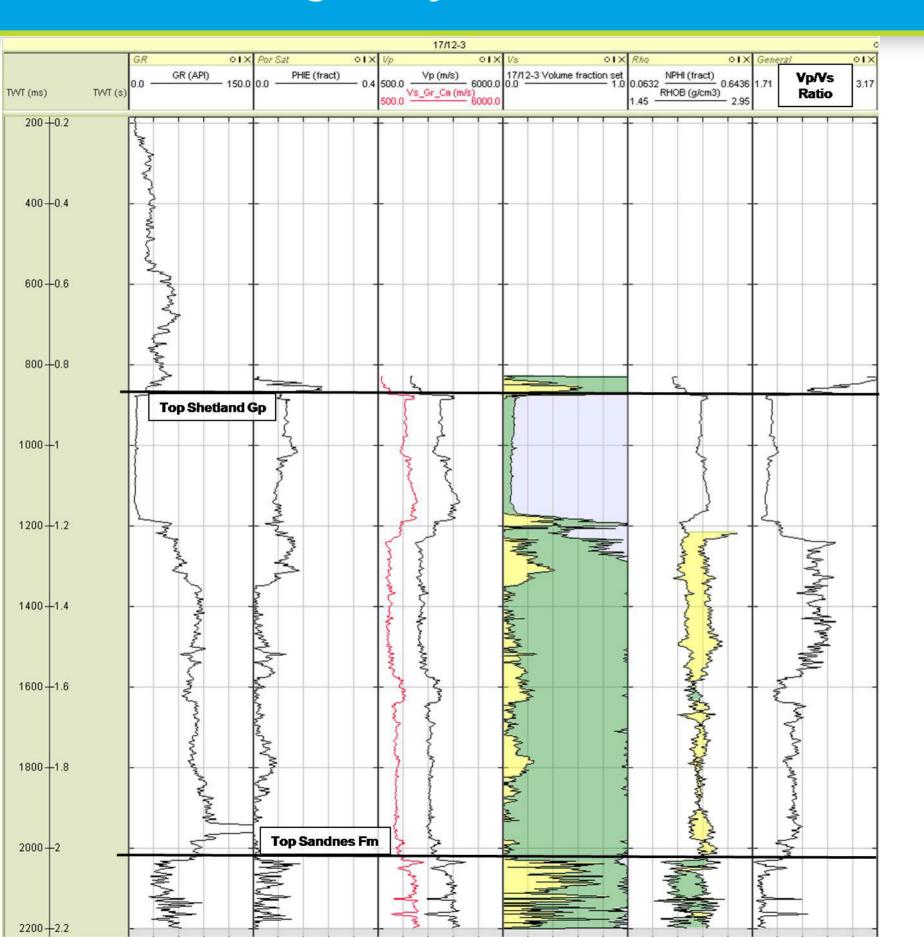




- There is a clear neutron/density cross over at the oil filled reservoir interval
- The reservoir corresponds to the interval with highest quartz content (more sandy) and has the highest porosity (25%)
- The Vp/Vs ratio dips in this scenario where oil filled sands are present
- The variations between wells in Vp/Vs where HC's are present can be attributed to the fact that no fluid based assumptions have been included in the modelling of Vs at this stage (dominated thus by Vp and lithology trends)
- The Sandnes and Bryne Fm's have gross rock thicknesses of 22m and 64m respecitively.
  - N/G ratios for these intervals are 70% (Sandnes) & 12% (Bryne)
  - Average porosities for the net sand intervals are calculated to be 19.5 (Sandnes) and 20% (Bryne) whilst the water saturations are 71% for both
  - The hydrocarbon filled net sand intervals had higher average porosities – 21% (Sandnes) and 25% (Bryne) as well as lower respective water saturations 38% & 46.5%

#### 17/12-3 Log Analysis

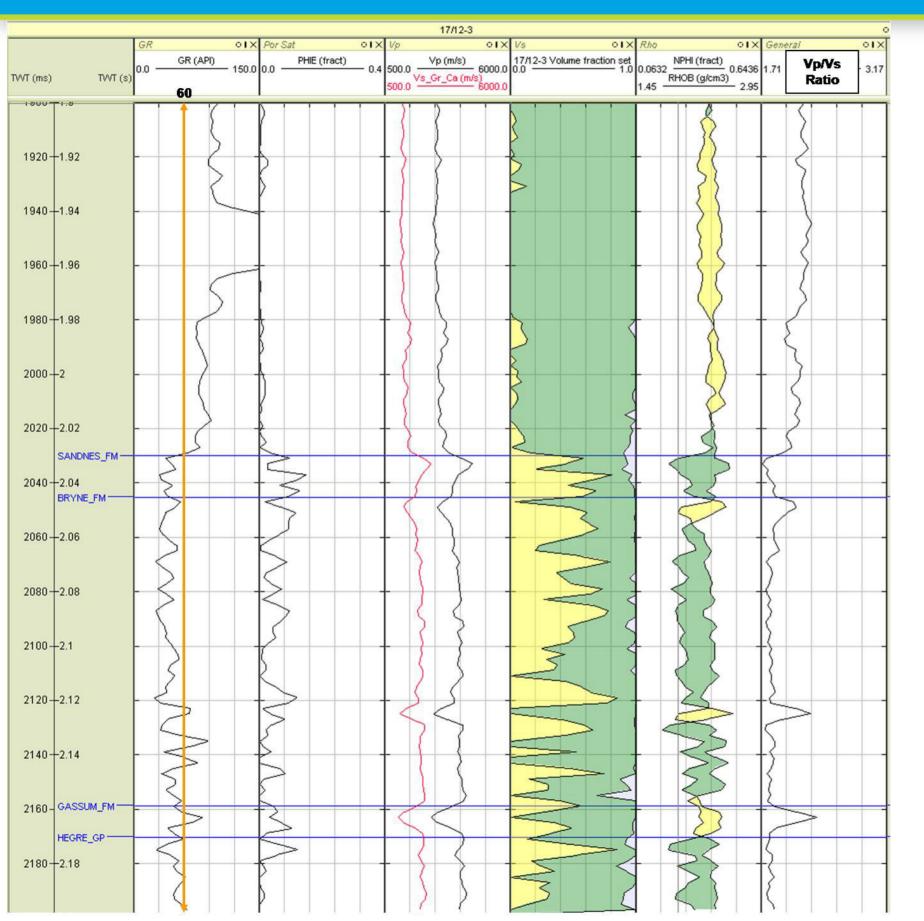




- 17/12-3 (Dry well) AVO log suite
- Below the Top Shetland Gp lies the Tor and Hod Fm chalks although they are not as porous here as they are in 17/12-1: 7 – 10% average porosities observed.
- The Bryne and Sandnes Fm's are the main reservoir intervals but they were not found to contain significant hydrocarbons
- The Sandnes Fm is 26m thick whilst the Bryne Fm is 221m
- Net to gross ratios are 53% (Sandnes) and 30% (Bryne)
- Average gross rock interval porosities for the Sandnes and Bryne Fm's are 16.5 & 10.5% respectively
- Vs curve has been estimated using the Greenberg Castagna relationship

#### 17/12-3 Reservoir Intervals

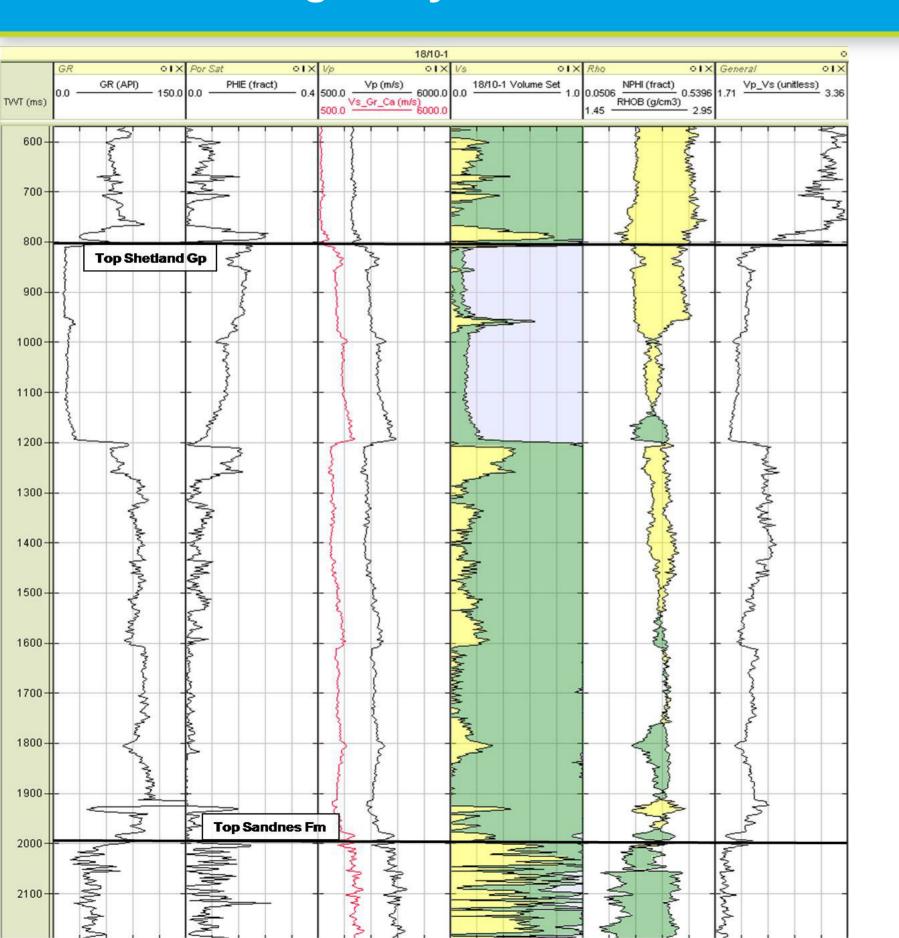




- The Gamma ray curve from the Sandnes Fm to well TD is indicative of sandies facies however the variability suggests multiple interbedded sand/shale interval lie within the section
- The Vp and Vs logs are not sensitive to these rapid and subtle changes due to the checkshot sampling interval
- The orange line on the Gamma log delineates the sand cut off point (60 API)
- The variable nature is clearly observed in the volume fraction curve and average porosities for the net sand intervals within the Sandnes and Bryne Fm's are 17 & 13% which are well below that observed in neighbouring wells
- The water saturation is, as expected, high in this dry well (95% for both formations)

#### 18/10-1 Log Analysis

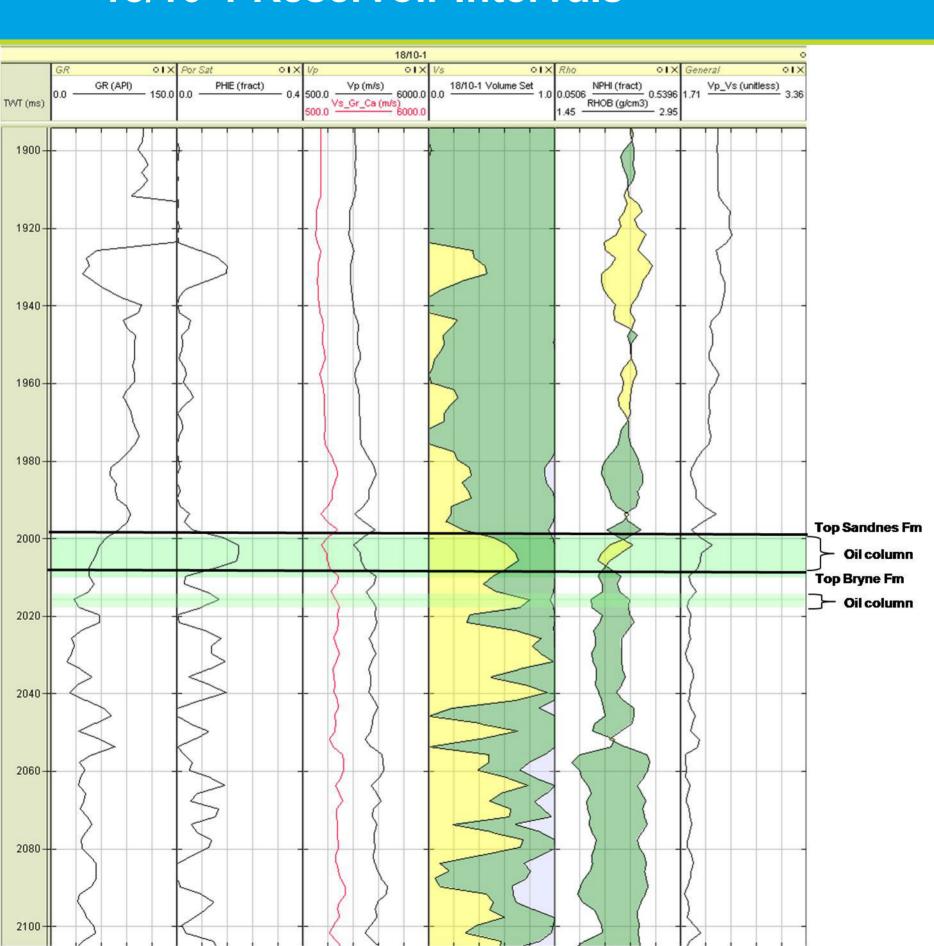




- 18/10-1 (Oil well) AVO log suite
- Below the Top Shetland Gp lies the Tor and Hod Fm chalks – these intervals have moderately good average porosities ranging from 8% in the Hod Fm to 15% in the Ekofisk Fm.
- The Bryne and Sandnes Fm's are the main reservoir intervals and were both found to contain oil in this well (compartmentalised reservoir intervals)
- The Sandnes Fm is 16m thick whilst the Bryne Fm is 85m whilst net to gross ratios are 42% & 46% respectively
- Gross rock interval water saturations were calculated as 27% within the Sandnes Fm and 93.8% within the Bryne Fm
- Vs curve has been estimated using the Greenberg Castagna relationship

#### 18/10-1 Reservoir Intervals

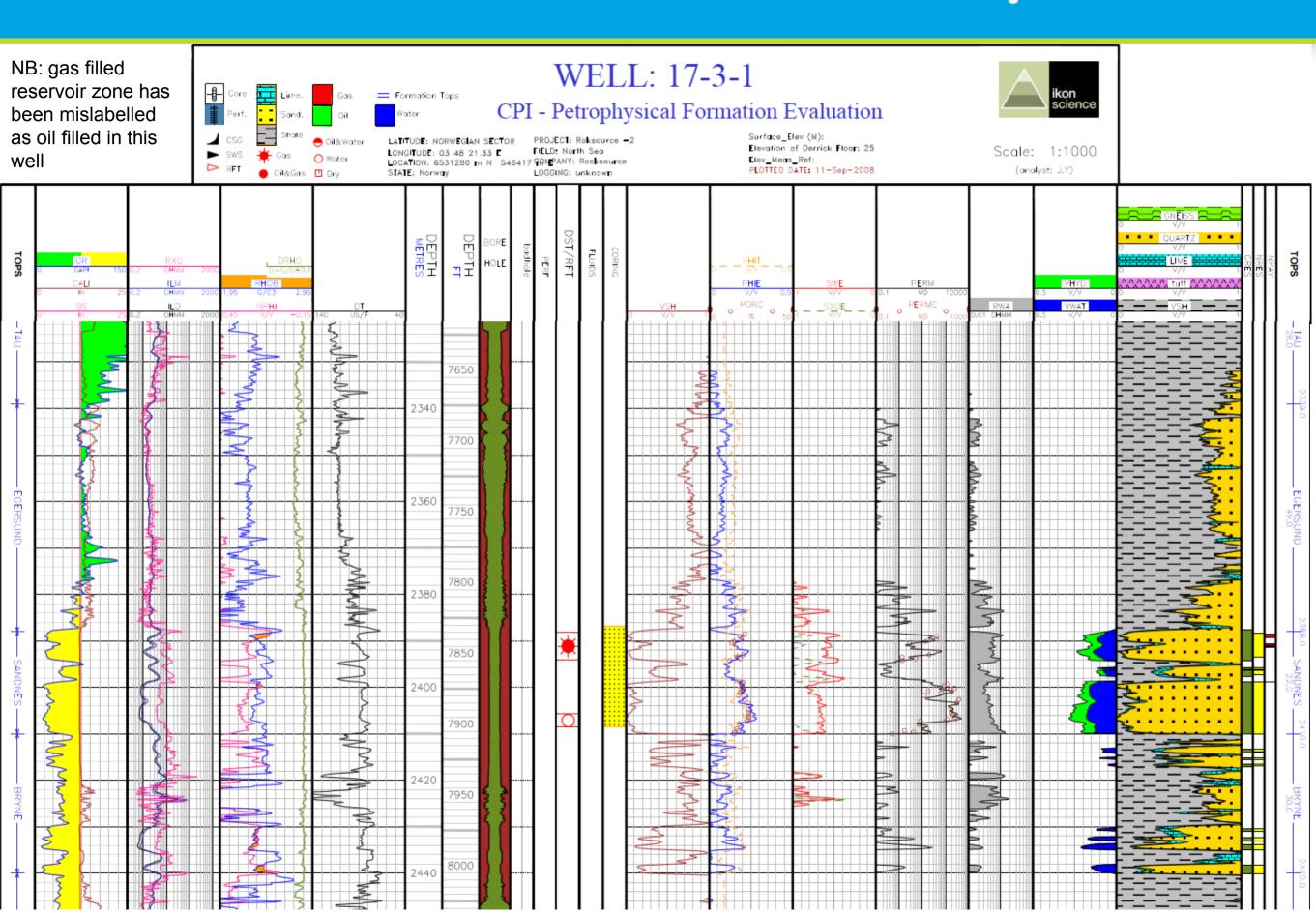




- Well 18/10-1 had two oil filled zones seperated by a more shale prone interbed
- The two oil filled sections are 22m and 5m thick respectively and only a 6m shale prone interval seperates them
- Porosities are 24.7% on average in the net Sandnes Fm sand interval but drop down to 22.3% on average in the net sand interval of the Bryne Fm
- Water saturations for these net sand sections were 27% for the Sandnes and 93.6% for the Bryne Fm
- Within the HC filled net sand sections the average porosities were 27.6% and 22.4% whilst the Sw was 21.9% and 33% for the Sandnes and Bryne Fm's respectively
- There is no notable neutron density cross over in the upper oil filled section however there is directly above and below this interval
- The Vp/Vs ratio shows no distinctive pattern in either of the reservoir intervals

#### 17/3-1 Reservoir Intervals





#### 17/3-1 reservoir interval evaluation



- The Sandnes Fm has a gross reservoir thickness of 22m in this well whilst the Bryne Fm is 30m
- A think 2m gas column was discovered withinthe Sandnes Fm however the gas was found to be biogenic in origin.
- N/G ratios for the reservoir units were 88% & 20% for the Sandnes and Bryne respectively whilst average porosities for the net sand intervals were 20% & 12.5%.
- Average porosity within the net pay section was 16.8% whilst the water saturation was 49%
- Water saturations for the gross rock intervals were 64% and 100% for the Sandnes and Bryne Fm's respectively.
- No time/depth relationship was available for this well making it difficult to accurately tie the well to seismic

### Reservoir parameter summary table



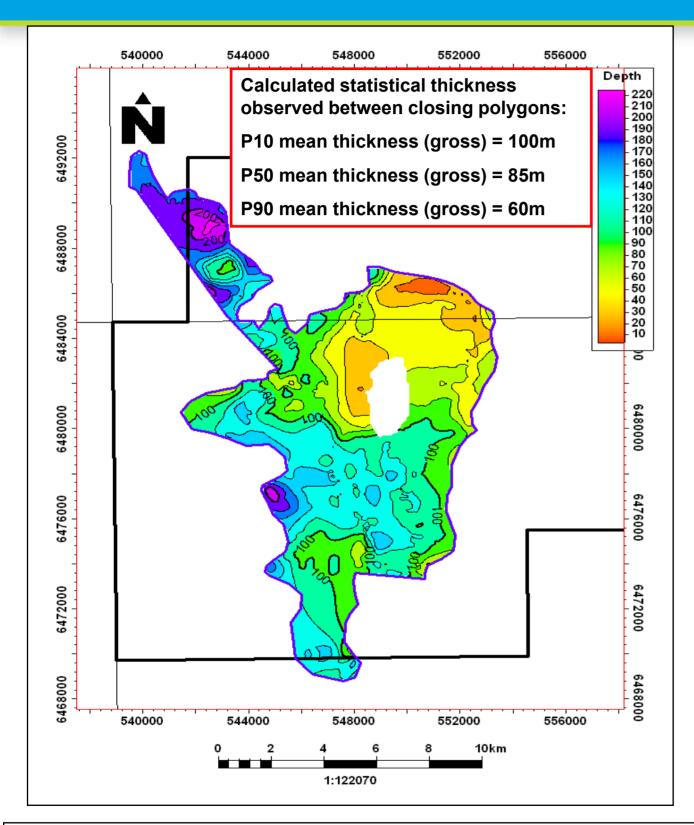
Well & Formation	Gross reservoir interval (m)	N/G ratio	Gross interval Porosity (%)		. ,	Gross interval Sw (%)	Net interval Sw (%)	Net pay Sw (%)
17/12-1 R	intervar (iii)		rolosity (70)	porosity (70)	porosity (70)	SW (70)	3W (70)	3W (70)
Sandnes Fm	16	60	15.2	19		94	93	
Bryne Fm	104	33	18.4	19.1	22.7	80	79	31.5
17/12-2								
Sandnes Fm	22	70	17.6	19.4	21.2	70.8	70.4	38.1
Bryne Fm	64	12	11.6	20.1		71	67.1	
17/12-3								
Sandnes Fm	26	53	16.4	17		100	100	
Bryne Fm	221	30	10.5	13	22.1	98.4	98.1	45.3
18/10-1								
Sandnes Fm	16	42	24.7	24.7	27.6	27.6	27.6	22
Bryne Fm	85	46	13.4	14.1	22.4	93.8	93.6	33
17/3-1								
Sandnes Fm	22	88	19.4	20.1	16.8	65	65	49
Bryne Fm	30	20	12.2	12.4		100	100	

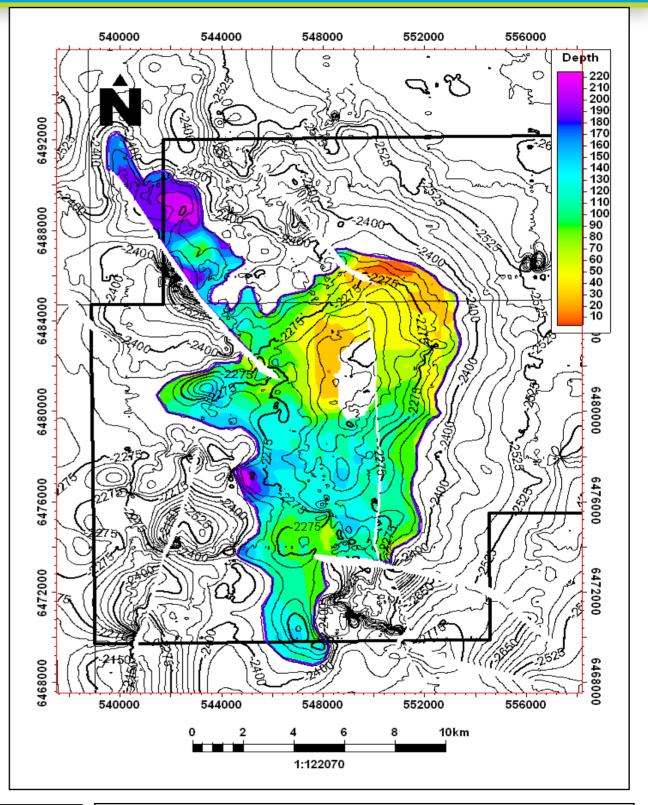
- Above: summary of the 5 wells submitted for petrophysical evaluation with regards to the key reservoir parameters around the PL456 licence. The range of values highlights the heterogeneity witnessed within these alternating sand/shale prone interbedded units.
- Below: averaged (mean) reservoir parameters for the Bryne and Sandnes Fm's which can be used as baselines in the volumetric evaluation for the Cyclops prospect

Average Gross reservoir representation for interval (m)		N/G ratio	Gross interval Porosity (%)	Net interval porosity (%)	Net pay porosity (%)	Gross interval Sw (%)	Net interval Sw (%)	Net pay Sw (%)
all wells								
Sandnes Fm	20.4	62.6	18.66	20.04	21.8	71.48	71.2	36.3
Bryne Fm	100.8	28.2	13.22	15.74	22.4	88.64	87.56	36.6

# Reservoir thickness map - Cyclops







- Thickness map between Top Sandnes Fm and Base Bryne Fm (approx horizon)
- The thickness range is from 0 (at the pinchout point) to 220m deep in the outer reaches of the prospect closure (only this thick for the max case fill polygon).
- Thickness map between Top Sandnes Fm and Base Bryne Fm (approx horizon) sat within the Top Sandnes Fm depth map closing contours

#### Reservoir character from seismic



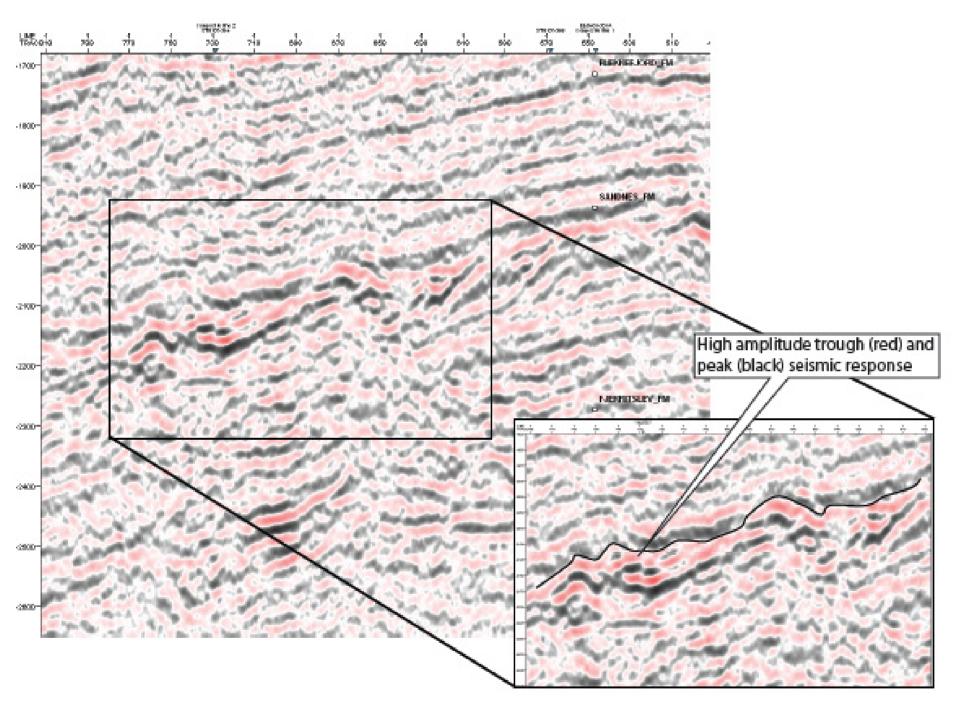


Fig. 2.11 Reservoir seismic character. Seismic response of the mapped Cyclops reservoir interval (Sandnes Fm) on seismic line ST8107-152. The amplitudes show a trough-peak response which corresponds with the synthetic seismogram generated over the Sandnes interval at well 17/12-2. This further suggests that the amplitudes observed are unlikely to be related to Bryne Formation coals as a peak - trough transition would be expected for these. The seismic line is displayed in TWT (ms).

The Middle Jurassic sands in the Cyclops area are seismically fast and can be represented by a Trough-Peak seismic response

This signature reduces the risk associated with coal presence in the reservoir intervals however a relative softening is commonly expected when HC's fill the pore space of such high velocity strata.

This could be an indication that the extrusive Middle Jurassic volcanics as seen in well 17/9-1 have mixed with the reservoir sands as an erosional product from the structural high.

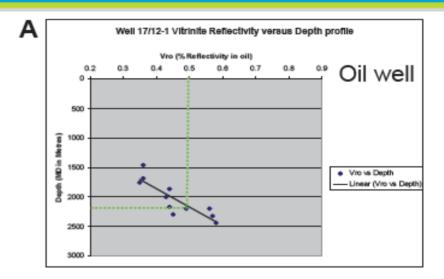
Such a diagenetic mix would give a seismic fast response meaning AVO inversion would be recommended in order to determine whether HC fluids could be present

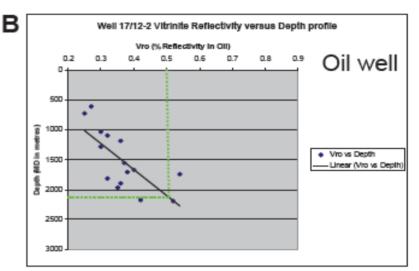
Any further AVO work is dependant on a positive EM response at the main prospect level (Middle Jurassic target)

### Source and migration

ROCKSOURCE

- The BCU is not buried deeply enough in the prospect area to sufficiently heat the Tau Fm. Vro readings of this interval in well 17/9-1 are 0.55% suggesting that this unit is immature for oil genration at the present day (see opposite)
- Alternative source kitchens had to be investigated if the Cyclops pinchout trap was to be filled.
- An isolated hydrocarbon system occurs in the Norwegian-Danish basin in Norwegian Quad 9, where the Upper Jurassic Tau Fm is buried deeply enough to reach a marginally mature level in a small hydrocarbon source area that has supplied oil to reservoirs in the Sandnes Formation at the Bream, Brisling and Yme fields.
- It is highly unlikely that the same source kitchen could transport hydrocarbons to the Cyclops prospect sitting 50km North although this source model does explain the underfilled reservoirs i each of these discoveries
- Furthermore the Bream and Yme fields are thought to be directly related to salt tectonics thus structurally small closures in comparison to the tilted fault blocks to the North.
- Migris AS were contracted to carry out a full investigation of the potential sourcing mechanisms for the Cyclops prospect using their proprietory source and migration modelling software (Migri).
- Rocksource worked in close collaboration with Migris in order to provide the neccissary geological input for the area allowing a strong model to be built which could de-risk the HC sourcing issue for this area.





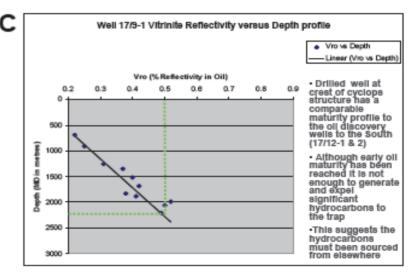


Fig. 2.15 Vitrinite reflectance versus depth. A. Well 17/12-1, Bream oil discovery. The early oil window entry depth (0.5% Vro) is marked on in green. B. Well 17/12-2, Brisling oil discovery. The early oil window entry depth (0.5% Vro) is marked on in green. C. Well 17/9-1. This is representative of the maturity profile at the Cyclops prospect. The early oil window entry depth (0.5% Vro) is marked on in green.

### **Basin modelling input**



The main proven source rock in the area is the Upper Jurassic Tau Fm., but this unit is only expected to be marginally mature within the kitchen area for the PL456 structures.

Alternative source rocks include the Egersund Fm. shales and Bryne Fm. coals and mudstones. There may also be potential for Paleozoic source rocks in the area, but the richness and extent of these intervals are not known.

The database made available for constructing the basin model consisted of:

- Regional (1000m resolution) depth and time maps for 6 mapped horizons
  - Fault polygons at carrier levels.
  - A set of regional 2D seismic lines
  - Well logs
- Vitrinite reflectance, temperature and pressure data from released wells

Basin reconstruction was carried out using the proprietory 'Semi' software and the Late Cenozoic erosion and uplift estimates described by Dore and Jensen (1995) were used as the driving input in the construction of the erosional model.



Oil stained Bryne Fm reservoir intervals from well 18/10-1

#### Source rocks and carrier beds



Table 4.1 Source rock properties - Tau Fm.

Parameter	Minimum (P90)	Most likely (P50)	Maximum (P10)
TOC (wt%)	3.0	5.0	7.0
HI (mg HC/g TOC)	305	500	695
Organofacies model	Type B (II/III kerogen)	Type A (II-S kerogen)	Type A (II-S kerogen)
Oil gen. potential (%)	0.67	0.80	0.93
Thickness (m)	11% of isopach μ=36m	30% of isopach, μ=99m	49% of isop., μ=165m

Table 4.2 Source rock properties - Egersund Fm.

Parameter	Minimum (P90)	Most likely (P50)	Maximum (P10)
TOC (wt%)	2.1	3.5	5.5
HI (mg HC/g TOC)	270	400	530
Organofacies model	Type B (II/III kerogen)	Type B (II/III kerogen)	Type B (II/III kerogen)
Oil gen. potential (%)	0.67	0.80	0.93
Thickness (m)	10% of isopach μ=30m	20% of isopach μ=60m	30% of isopach μ=90m

Table 4.3 Source rock properties - Bryne Fm.

Parameter	Minimum (P90)	Most likely (P50)	Maximum (P10)
TOC (wt%)	2.0	3.5	5.0
HI (mg HC/g TOC)	200	300	450
Organofacies model	Type DE (III kerogen)	Type DE (III kerogen)	Type DE (III kerogen)
Oil gen. potential (%)	0.57	0.70	0.83
Thickness (m)	70m	100m	130m

Table 4.4 Reservoir properties for Sandnes Fm.

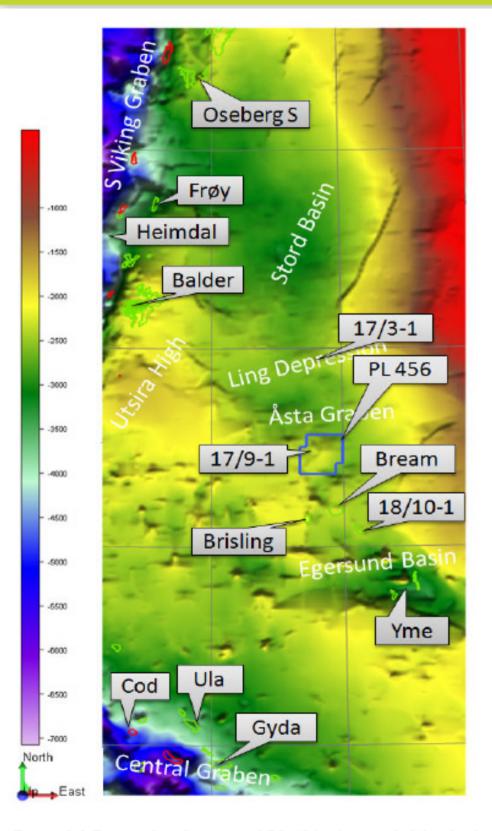
Parameter	Minimum (P90)	Most likely (P50)	Maximum (P10)
Thickness	35	100	165
Net/gross	14%	40%	66%

NB: Optimistic source thickness for Bryne Fm used – this is to show that even in a best case scenario the unit does not offer sufficient HC's charge to the Cyclops prospect

- Three different Jurassic source rocks are included in the migration model: Tau Fm., Egersund Fm. And Bryne Fm. The souce rock properties that were assigned to these intervals during the modelling are listed in tables 4.1 – 4.3.
- The kinetic models used in the generation modelling were taken from Pepper and Corvi (1995).
- Migration modelling was performed along the Sandnes/Bryne Fm. Carrier beds. These shallow marine/fluvial-deltaic intervals constitute the main reservoir in the Egersund Basin discoveries (Yme, Bream, Brisling and 18/10-1). The reservoir parameters used in the migration modelling of this unit are listed in table 4.4.
- Thermal modelling and heat flow estimations were made on a regional scale based on the numerous wells within the vicinity of the licenced area. Further details on these inputs can be found in the full modelling report, "Hydrocarbon Migration Screening Study PL456 "Cyclops""

# **Modelling results**





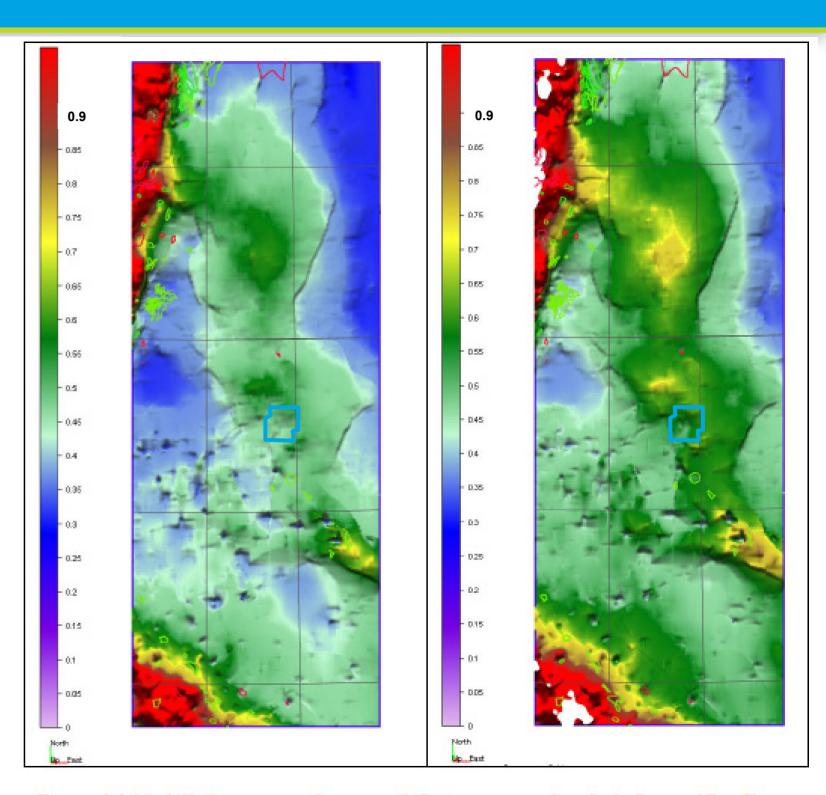


Figure 5.1 Modelled vitrinite reflectance (%Ro) at present day. Left: Base of Tau Fm. Right: Top of Bryne Fm.

Figure 2.1 Extent of study area and PL 456 colour-coded for depth (m) to Top Sandnes Fm. Main structural elements and discoveries references in the report are annotated.

#### **Transformation ratios – Tau Fm**



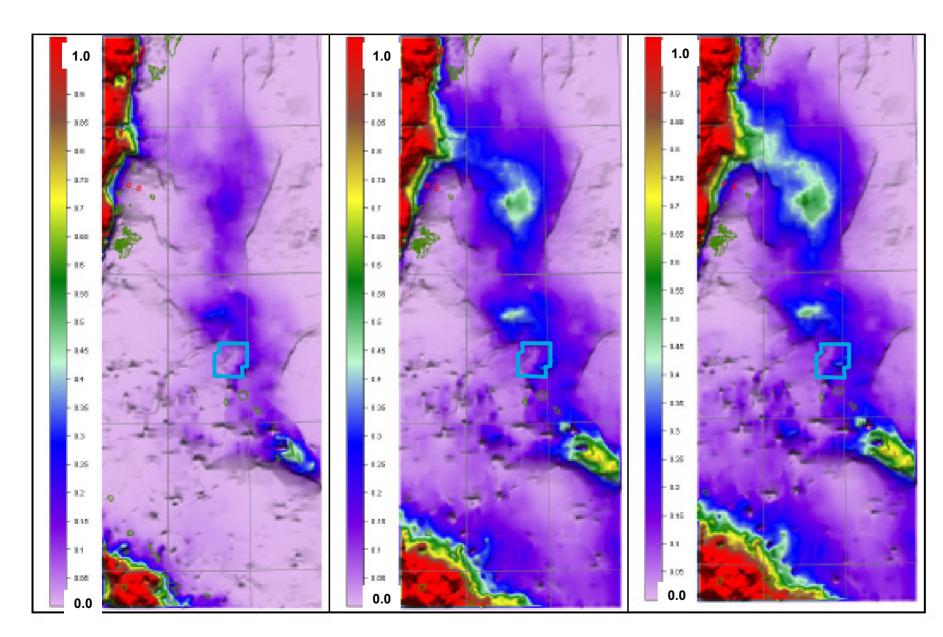
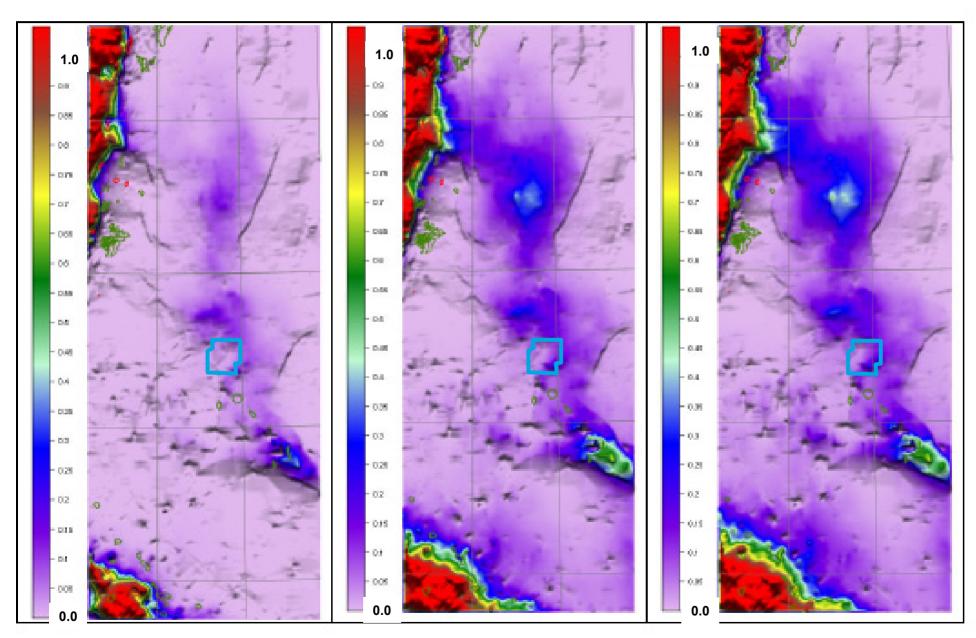


Figure 5.4 Modelled oil transformation ratio for Base Tau Fm. at 24 Ma (left), 2 Ma (middle) and present day (right).

- Modelled oil TR maps for the base of the Tau Fm. Through time are shown opposite.
- At 24Ma, the deepest parts of the South Viking Graben and Central Graben have already passed through the oil window, while the Egersund Basin is about to enter the oil window.
- By 2Ma, most of the Egersund
   Basin has reached peak oil
   generation, while the Stord
   Basin and Åsta Graben
   kitchens are just entering the oil
   window.
- At present day, maximum TR ratios in the Egersund Basin are ca. 80%. In the deepest parts of the Stord Basin and Åsta Graben they reach ca. 50%.

# **Transformation ratios – Egersund Fm**



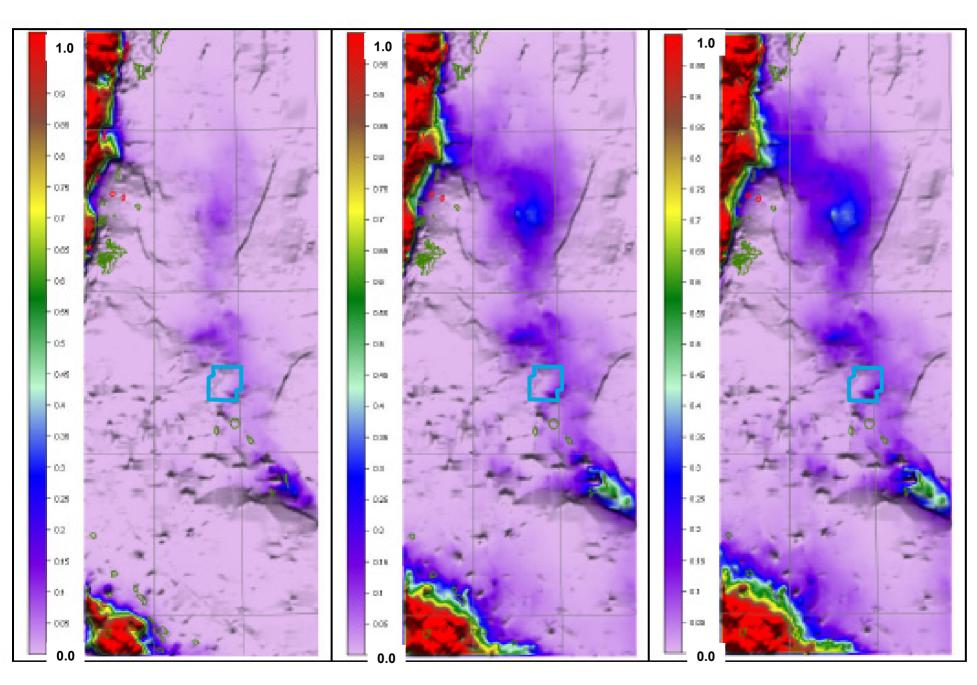


- The modelled maturation history for the Egersund Fm. Is quite similar to the Tau Fm., but with lower maturity levels due to the less reactive kinetic scheme.
- Modelled present-day transformation ratios reach 60 -70% in the Egersund Basin and only 40% at maximum in the Stord basin

Figure 5.5 Modelled oil transformation ratio for Top Egersund Fm. at 24 Ma (left), 2 Ma (middle) and present day (right).

### **Transformation ratios – Bryne Fm**



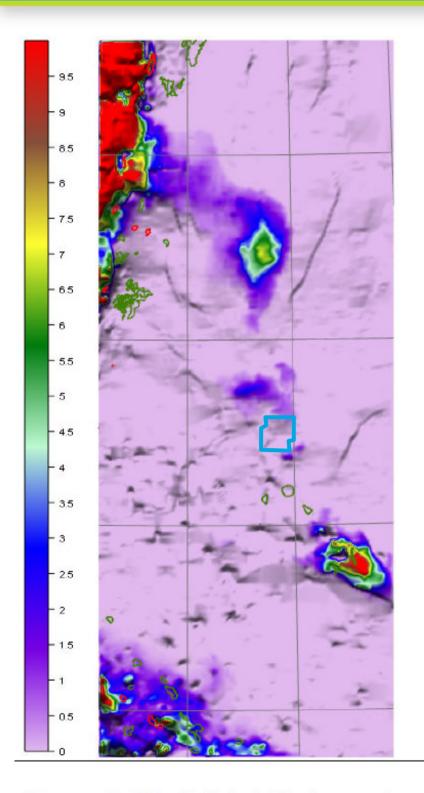


- The modelled TR maps for the Bryne Fm are displayed opposite.
- Even though it is more deeply buried than the Upper Jurassic intervals, the modelled maturation is lower than for both the Egersund Fm. And the Tau Fm. Sources.
- Given that the chosen kinetic model (Type DE) is representative of the Bryne Fm. In the Egersund Basin, it is unlikely to contribute with significant quantities of hydrocarbons

Figure 5.6 Modelled oil transformation ratios for top of Bryne Fm. at 24 Ma (left), 2 Ma (middle) and present day (right).

### **Expulsion maps – Tau Fm**





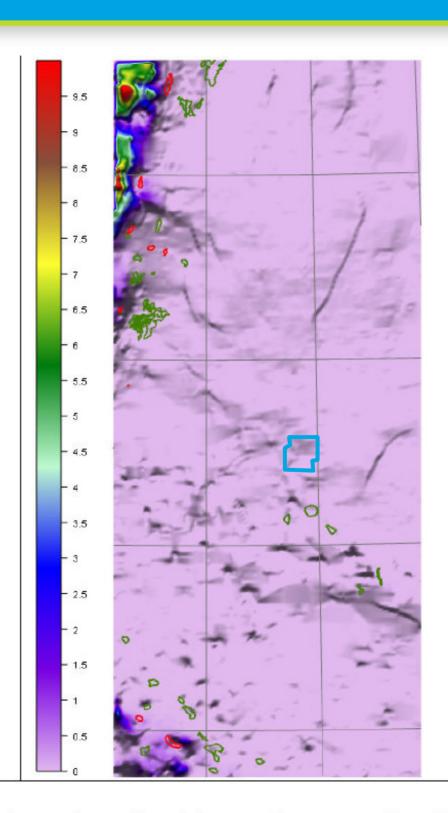


Figure 5.7 Left: Modelled cumulative expulsion from Tau Fm. until present day. Left: Oil expulsion (10<sup>6</sup> Sm³/km²) Right: Gas expulsion (10<sup>9</sup> Sm³/km²).

- Modelled cumulative oil and gas expulsion from the Tau Fm. Source rock is shown in figure 5.7.
- The highest oil expulsion rates per area are modelled in the South Viking Graben, but significant volumes are also expelled in the Central Graben and Egersund Basin.
- Only low to moderate oil volumes are expelled in the Cyclops kitchen area.
- Gas expulsion is modelled to only take place in the deeper parts of the South Viking and Central Grabens. No gas expulsion is predicted in either the Egersund or Stord Basins
- The Tau Fm was deemed the only significant HC expelling source interval in the viable source kitchen areas around Cyclops

# Modelled migration flow – Sandnes Fm carrier bed



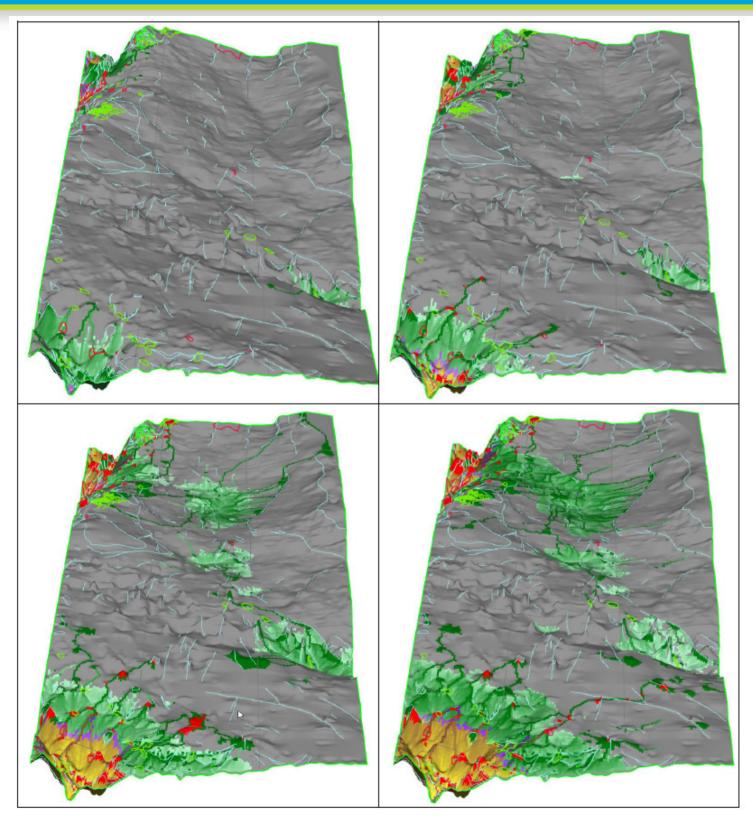


Figure 6.2 Modelled migration flow rates for Sandnes Fm. carrier bed. Model is seen towards north. Upper left: 55Ma, upper right: 24Ma, lower left: 2Ma, lower right: 0Ma. For map legend, see Chapter 6.1.

- Modelled hydrocarbon flow-rates through time for the Sandnes Fm. at the regional scale can be seen in Figure 6.2.
- By Early Eocene (55 Ma), active oil migration is taking place in both the South Viking Graben and Central Graben kitchen areas. Oil migration has also started in the deeper parts of the Egersund Basin.
- By 24 Ma, the central parts of the South Viking Graben and Central Graben are moving into the gas window, and the oil migration front is moving further up the basin margin.
- The main fields (see Figure 2.1 for location map) along the margin (e.g. Frøy and Heimdal in the northwest and Cod, Ula and Gyda in the south) are now being charged with hydrocarbons. In the Egersund Basin, the Yme field is now oil-filled, but the migration front has not yet reached the structures along the northern basin margin.
- The Cyclops kitchen area (Åsta Graben and Ling Depression) has entered the oil window by 2 Ma, and is actively charging both the Cyclops structure and 17/3-1 structure with hydrocarbons.
- The spill routes from the Egersund Basin are now charging the Bream field, while the 18/10-1 structure is filled by local drainage.
- The South Viking Graben kitchen is now fully dominated by gas flow and the oil migration zone has moved onto the Heimdal Terrace. The Balder and Grane fields are being filled via major spill routes from the north.
- The central parts of the Stord Basin are also dominated by oil flow. Most of the expelled volumes, however, migrate out of the basin towards the Øygarden Fault Zone, where flow paths are refocused in a northwards direction.

### **Modelled migration flow**

### - Sandnes Fm carrier bed - focussed on PL456



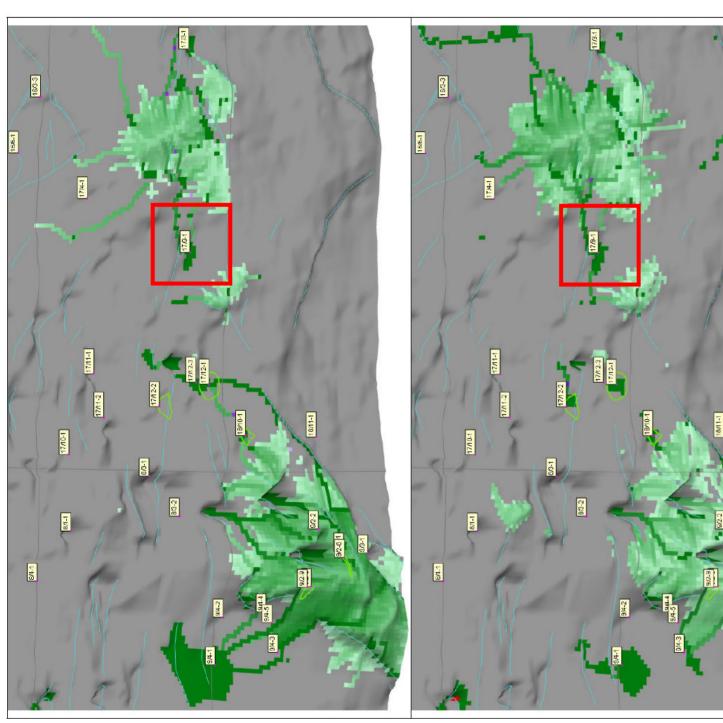
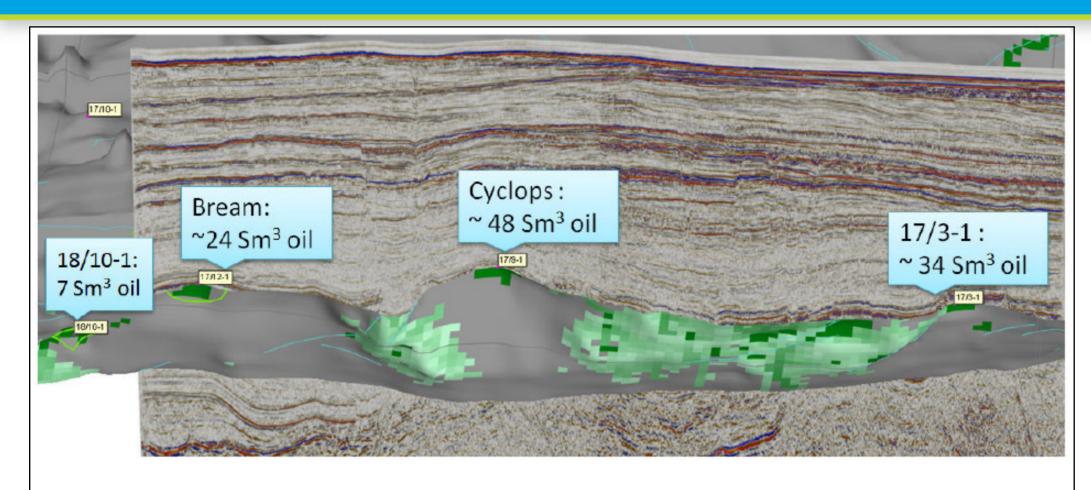


Figure 6.3 Modelled hydrocarbon flowrates in Egersund Basin and Cyclops area at 2 Ma (upper) and at present day (lower).

- The Bream structure receives oil charge from two spill routes, one passing through the 18/10-1 structure and one coming from the north-eastern part of the basin.
- The Bream structure is spilling oil towards the east at 2 Ma. This spilled oil is not modelled to reach the Brisling structure until the 1 Ma time step when the topography is gently tilted as a result of the Quaternary erosion. This results in remigration into the Brisling structure.
- Unless any Paleozoic oil sources are present in the area, it seems unlikely that the Brisling field could be charged in any way other than long-distance spill from the Egersund Basin.
- The Cyclops structure is modelled to be filled via two spill paths emerging from the kitchen to the north.
   Some oil is also generated in the small sub-basin to the south, but this is volumetrically insignificant compared to the northern sub-basin.
- Long distance migration from deeper kitchens (Egersund Basin or Stord Basin) appears unlikely.
- The catchment area for oil drainage and spill into the Cyclops area covers about 760 km2.
- Present-day depths within the catchment area are in the range of 2200-3000 meter.
- Predicted trapped in-place volumes for the Cyclops prospect are ca. 48·106 Sm3 oil, while the Bream structure is modelled to contain ca. 24·106 Sm3 oil in-place, which is in good agreement with the NPD estimates of 9.5·106 Sm3 oil recoverable reserves.
- Figure 6.5 shows modelled migration pathways along the N-S trending seismic line EL9401-301 which crosses both the Cyclops prospect and Bream structure.
- Predicted trapped volumes for the major accumulations along the transect are shown in the figure.

### Fill levels – seismic example EL9401-301





Most likely HC column height for the Cyclops prospect given a discovery:

Between 25 - 65m

Predicted trapped in-place volumes for the Cyclops prospect are ca.
48 Sm3 oil

Figure 6.5 Modelled hydrocarbon flow and trapped oil volumes along N-S trending seismic line EL9401-301. For flow map legend, see Chapter 6.1.

- Monte Carlo simulation of the migration results showed that the modelled probability of hydrocarbon charge to the Cyclops prospect is about 50%. This is slightly lower than for the Bream and 18/10-1 structures, but higher than for the Brisling structure (ca 40%).
- The Yme field segments are very robust with respect to hydrocarbon charge, and are always modelled to contain a significant column. The remaining dry wells in the area are all modelled to have low probability of charge (< 30 %), with the exception of wells 9/3-2 (> 90%) and 9/3-1 (>40%).
- Remaining undrilled prospects with high probabilities of discovery include a fault-related trap in Block 18/11 just north of Yme Beta, two four-way closures in Block 17/3 and 17/1 and a large, but shallow, fault-bounded trap in block 18/2.
- Given a discovery, the most likely hydrocarbon column heights for the Cyclops structure are 25-40 meter.
- Corresponding column heights for the Bream structure are 20-30 meter, while the Brisling structure is modelled with ca. 10 meter.
- For the Yme field, modelled hydrocarbon columns reach 70-80 meters.

### **Sealing capacity**



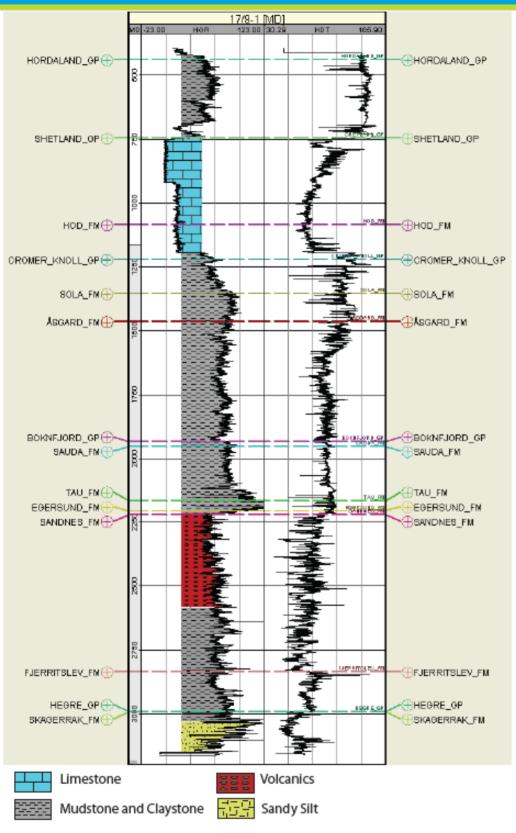


Fig. 2.4 Log Response. Gamma ray and sonic log (slowness) response for well 17/9-1 plotted against measured depth (meters). The interpreted downwell lithologies have been added to the gamma ray trace. Shale sequences dominate the well along with a thick limestone section between 750 - 1194m and the fore-mentioned volcanic sediments between 2215 - 2580m. A silty sandtone package was recorded in the Hegre Group between 3030 m and TD.

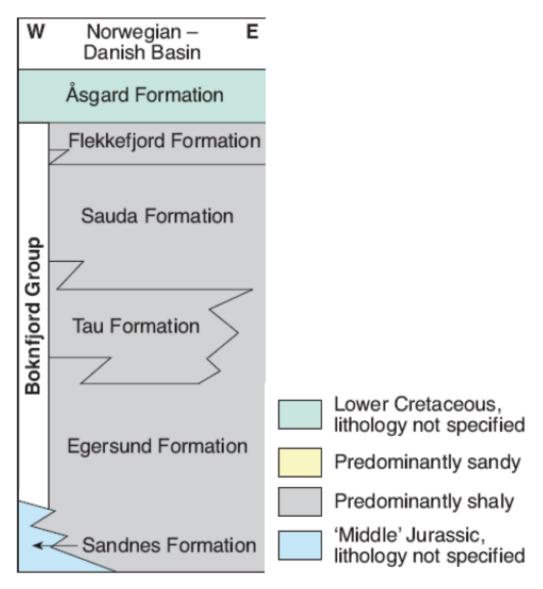
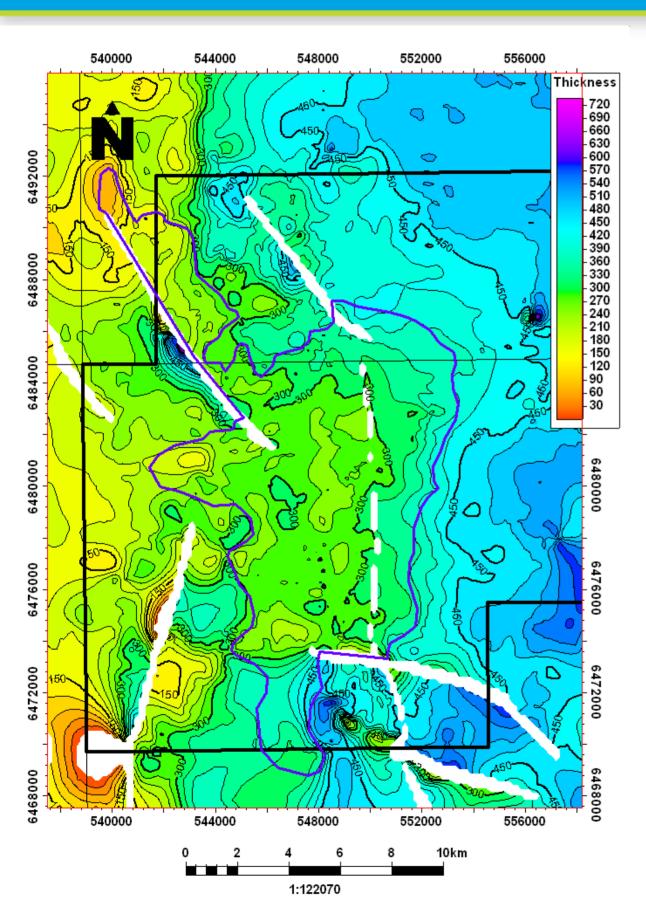


Fig. 2.6 Top Seal Stratigraphy. Bonkfjord Group stratigraphy from the Millennium atlas (2000). The Group is regionally renowned for being composed entirely of shale providing an excellent Top seal for the Cyclops prospect. The presence of these sealing units in the vicinity of Cyclops are confirmed by well 17/9-1.

- The risk associated with a valid seal over the Cyclops prospect has not changed post application
- Thick shale layers are observed at well 17/9-1 which sits directly adjacent to the Cyclops prospect and these intervals are observed to act as excellent sealing unit regionally

# **Base Upper Cretaceous – Top Sandnes Fm Isopach**





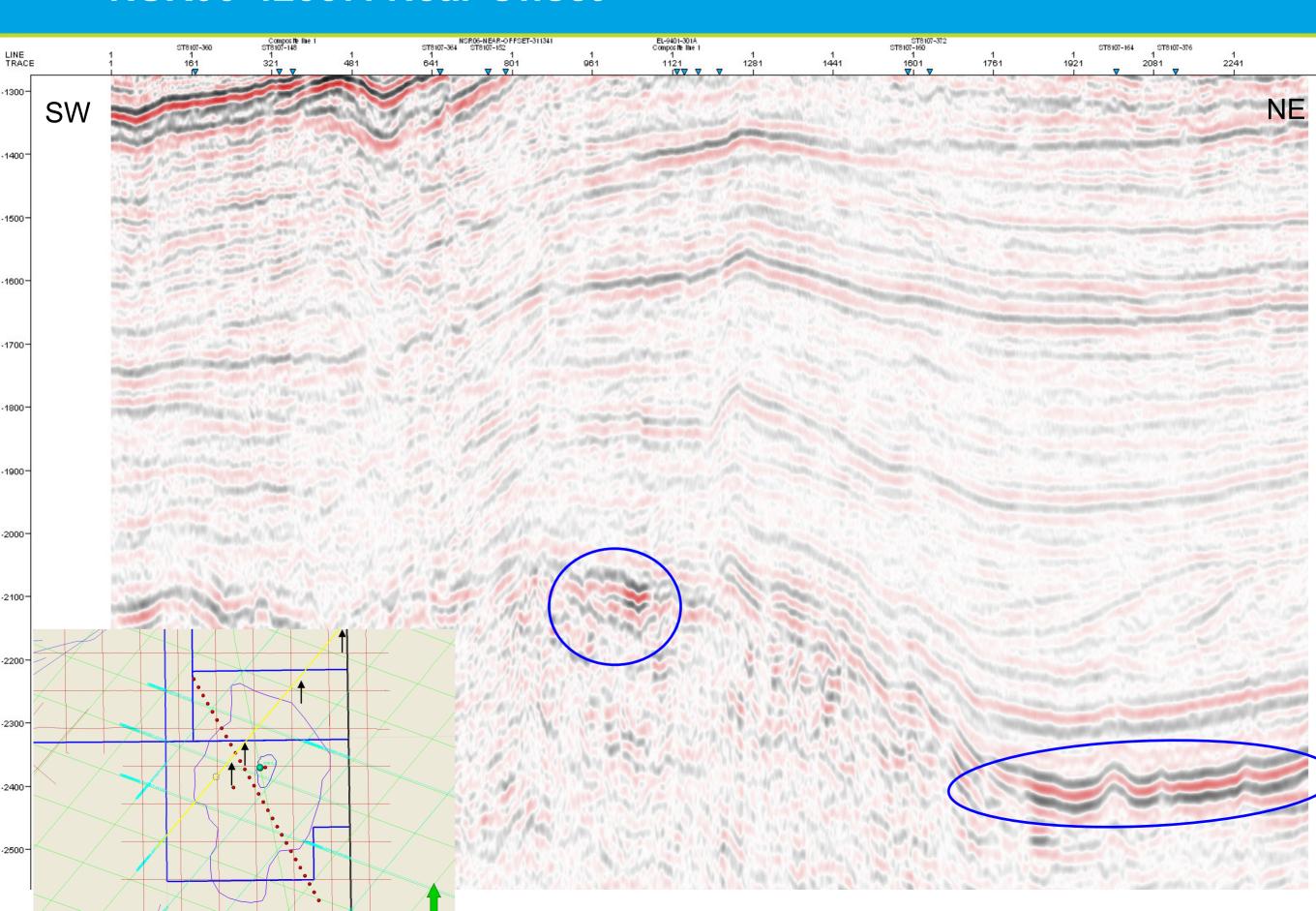
- The shale prone section over the prospect area is approximately 200-300m thick and should act as an excellent sealing unit
- There are very few faults cutting all the way through this package indicating that fluid loses via fault leakage should be minimal.





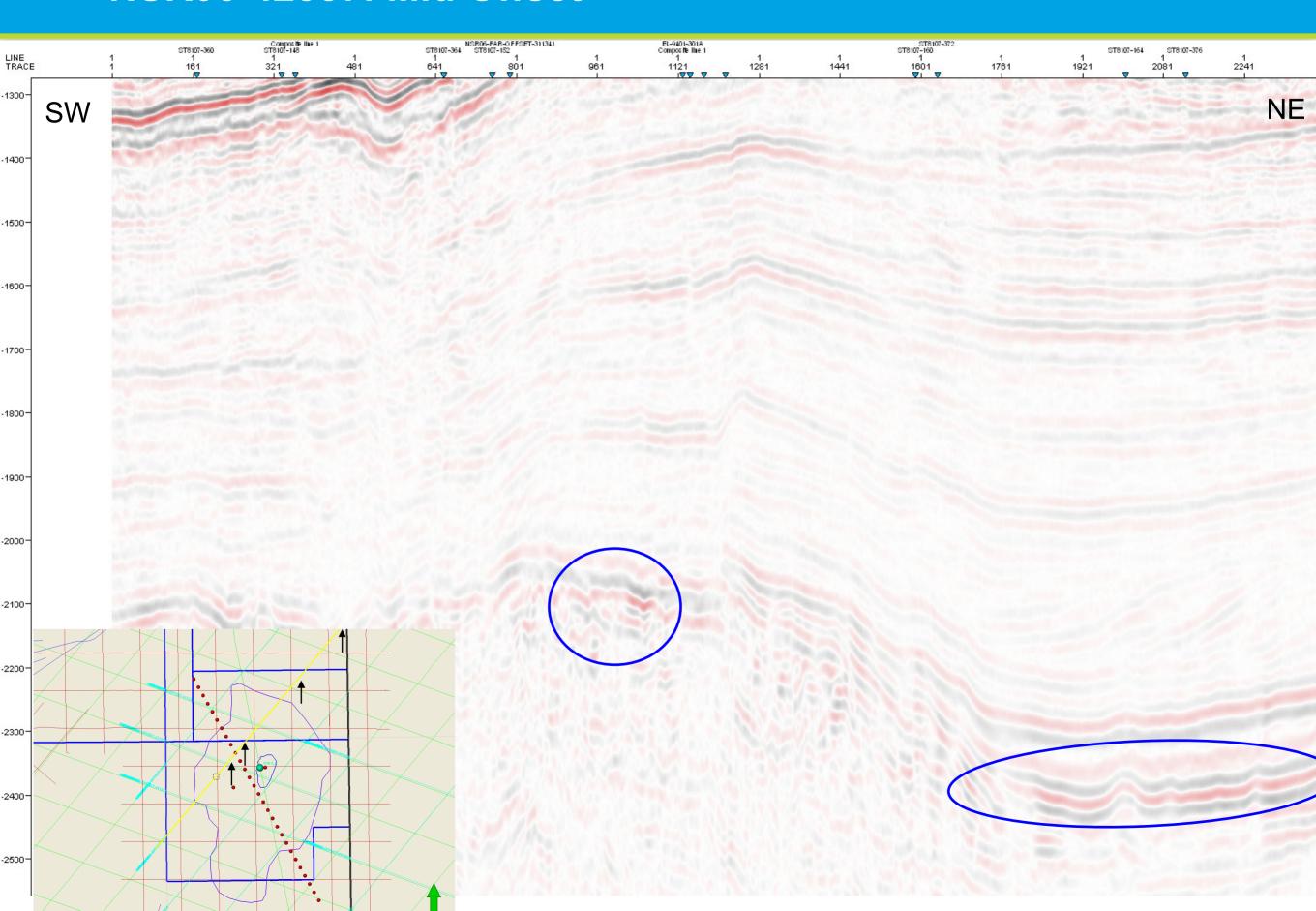
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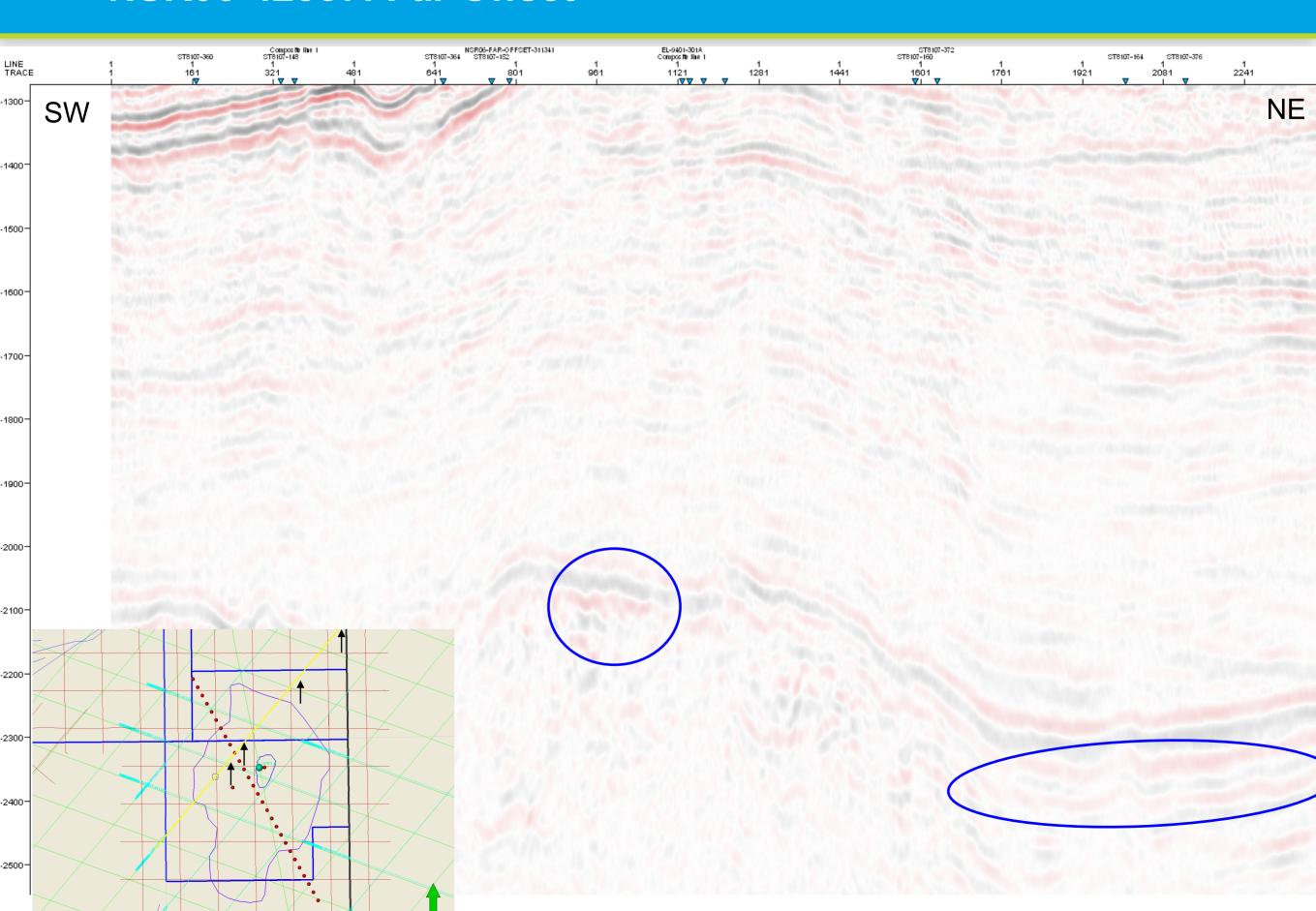
# NSR06-42337: Mid Offset





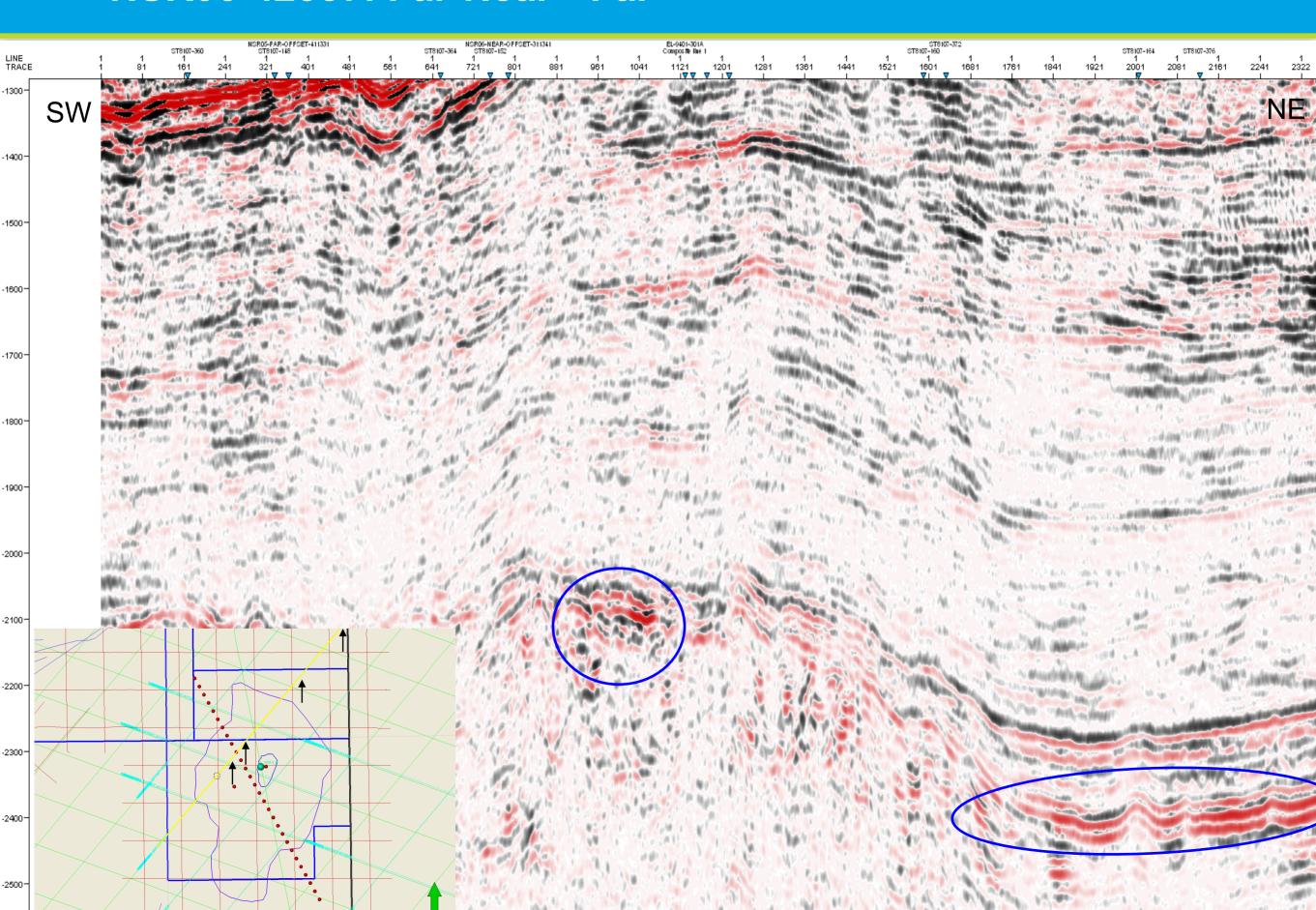
# NSR06-42337: Far Offset





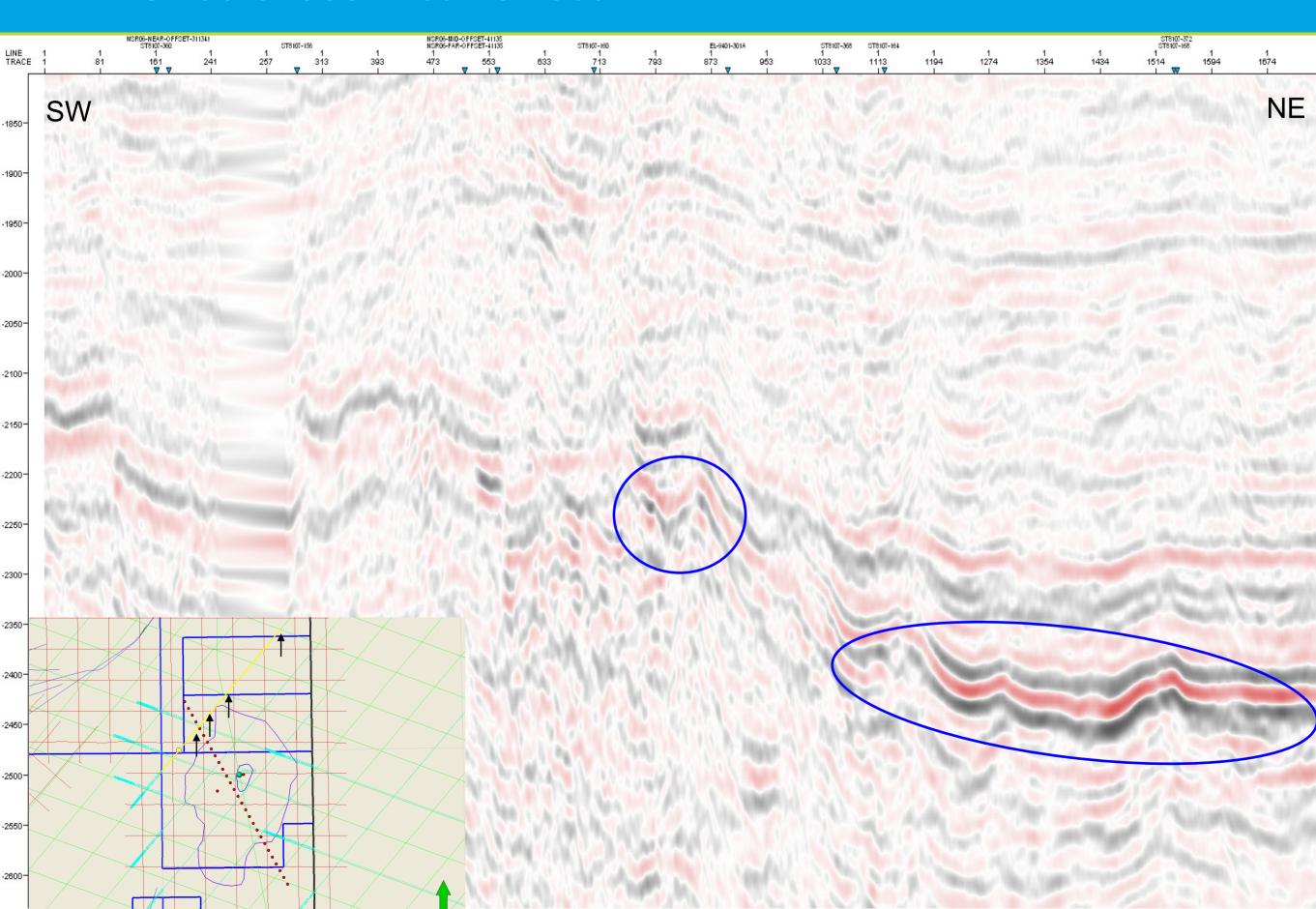
# NSR06-42337: Far-Near \* Far





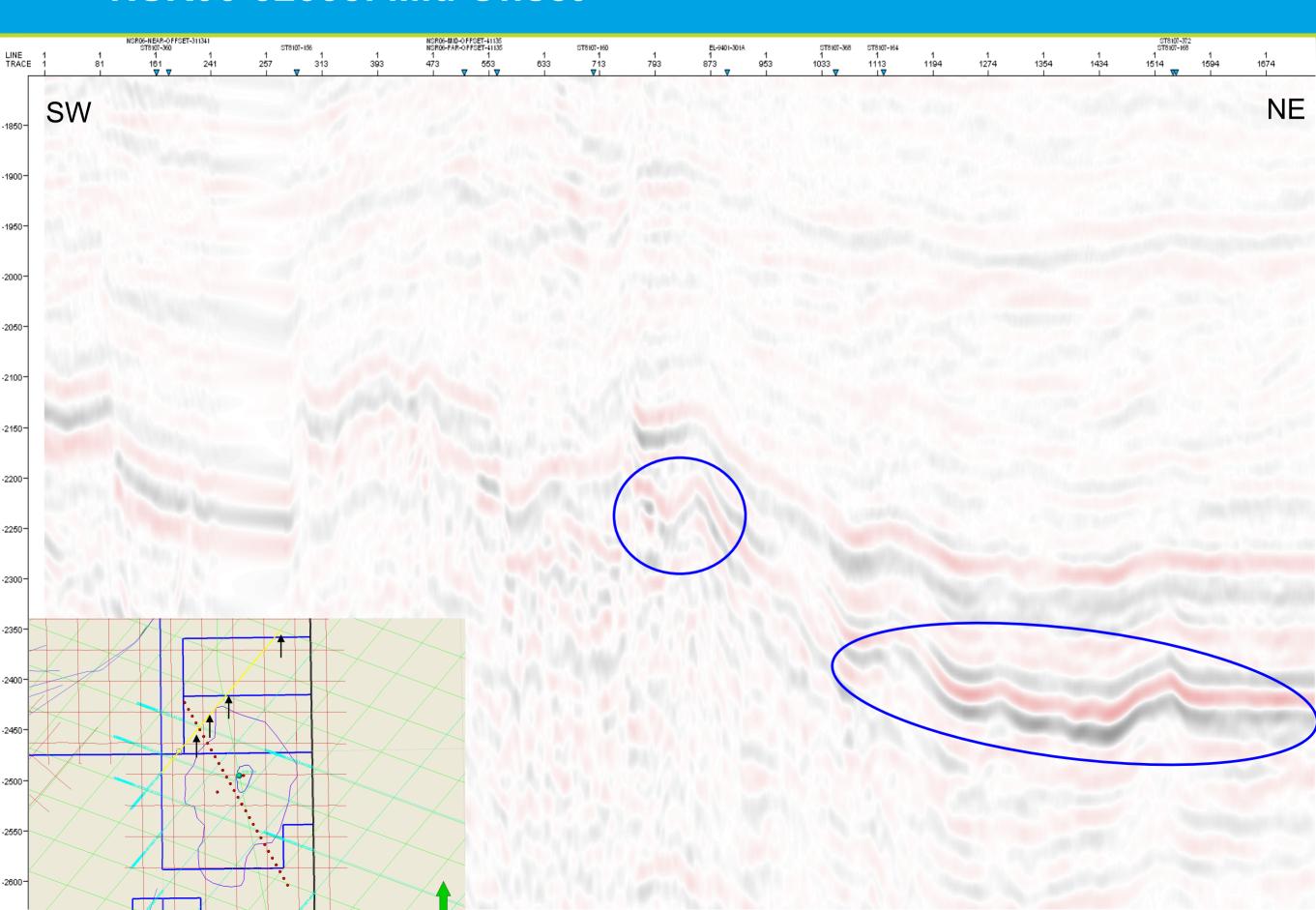
# NSR06-32338: Near Offset





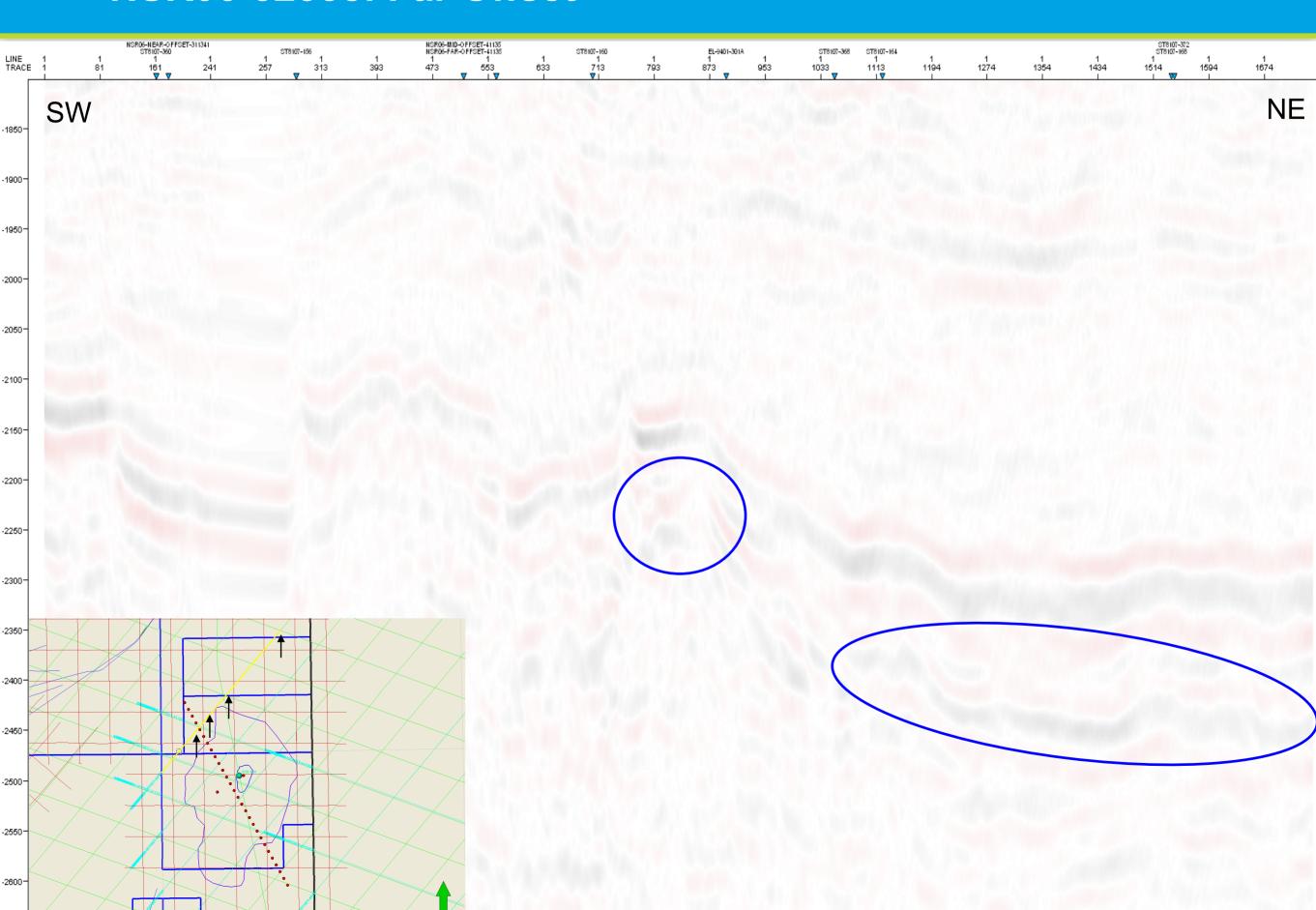
# NSR06-32338: Mid Offset





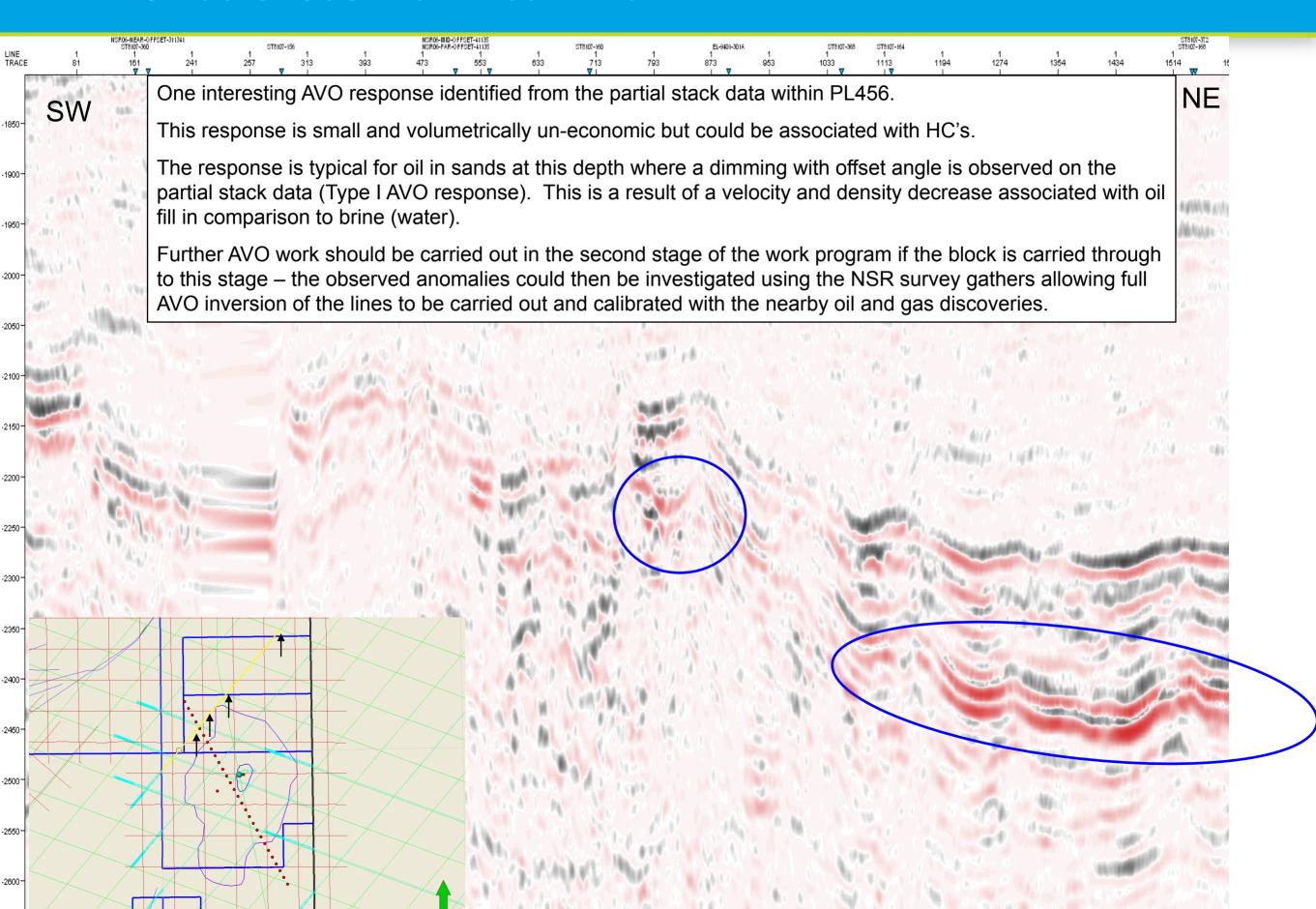
# NSR06-32338: Far Offset



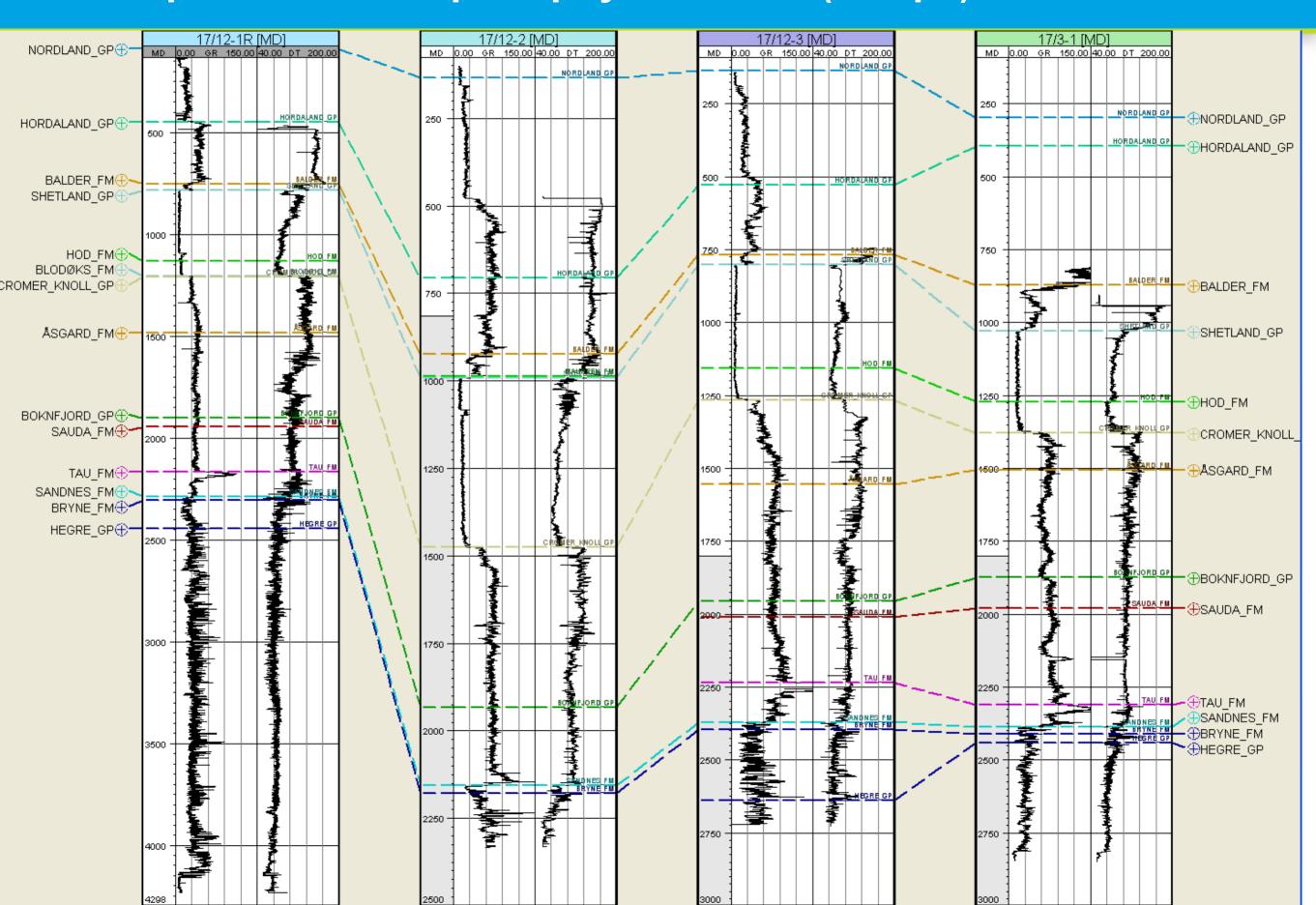


### NSR06-32338: Far-Near \* Far



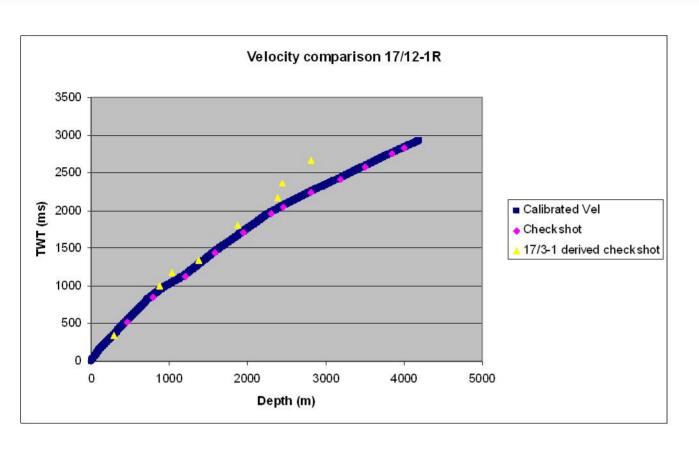


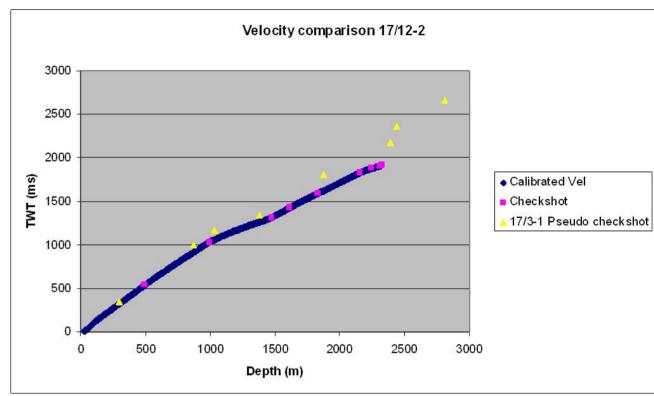
# Well panel review – petrophysics wells (w/tops) 🗭 ROCKSOURCE

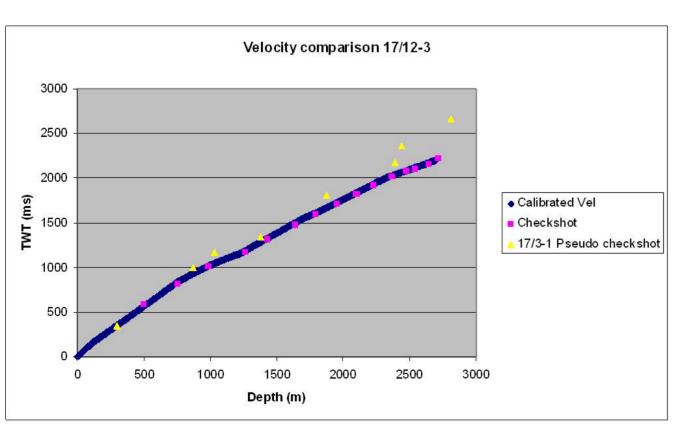


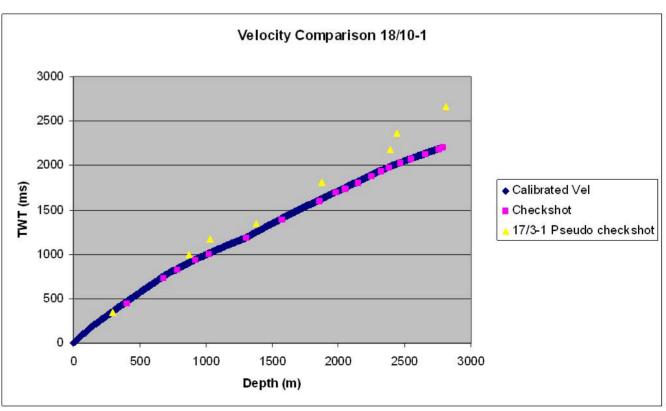
# Checkshot versus calibrated velocity log QC





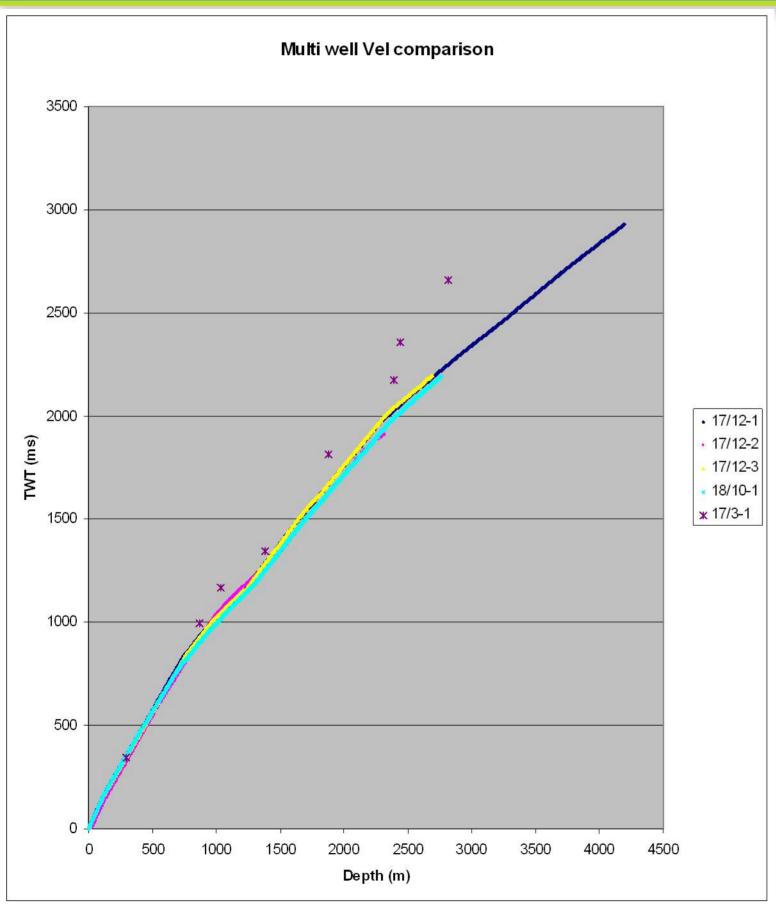






### Calibrated velocity log QC – all wells





Regionally there is very little variation in velocity with depth

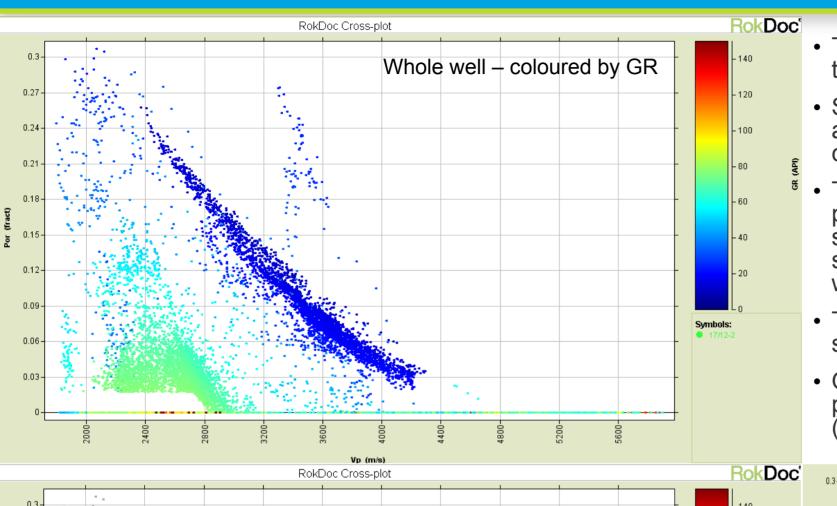
The data appear to follow the same general trends and kinks in the crossplot can be used to define the major velocity boundaries within the Cyclops region.

Significant geological boundaries are found to be the Balder Fm, Base Tertiary, Base Upper Cretaceous (Top Cromer Knoll GP), Top Tau Fm (regional gas source rock and significant for observed amplitude and EM anomalies over the prospect)

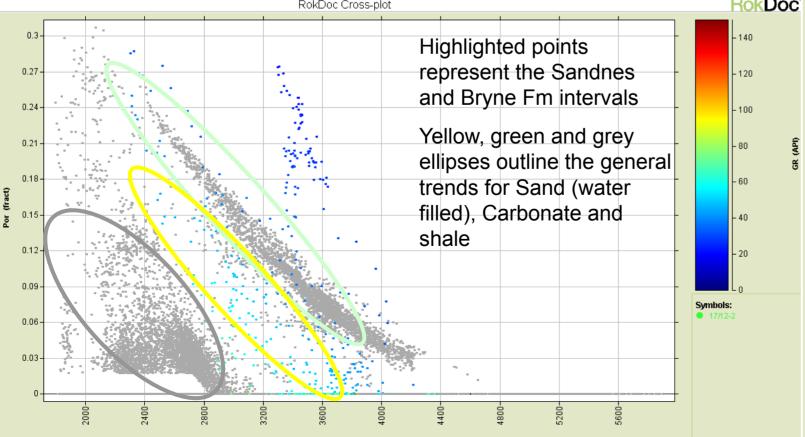
These boundaries correlate with the EM background model boundaries (resistivity variations witnessed in the Tau, Balder, Tor & Hod Fm's.

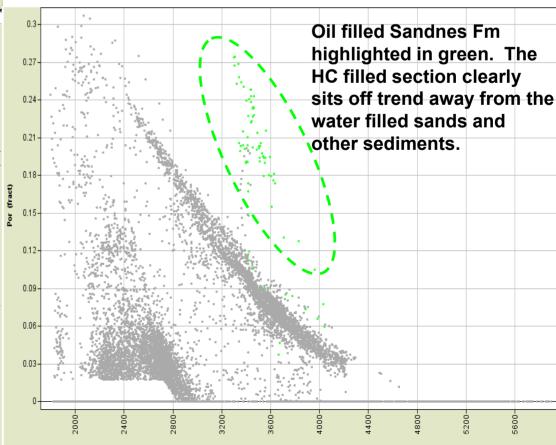
### **AVO crossplots – Vp versus Porosity 17/12-2**





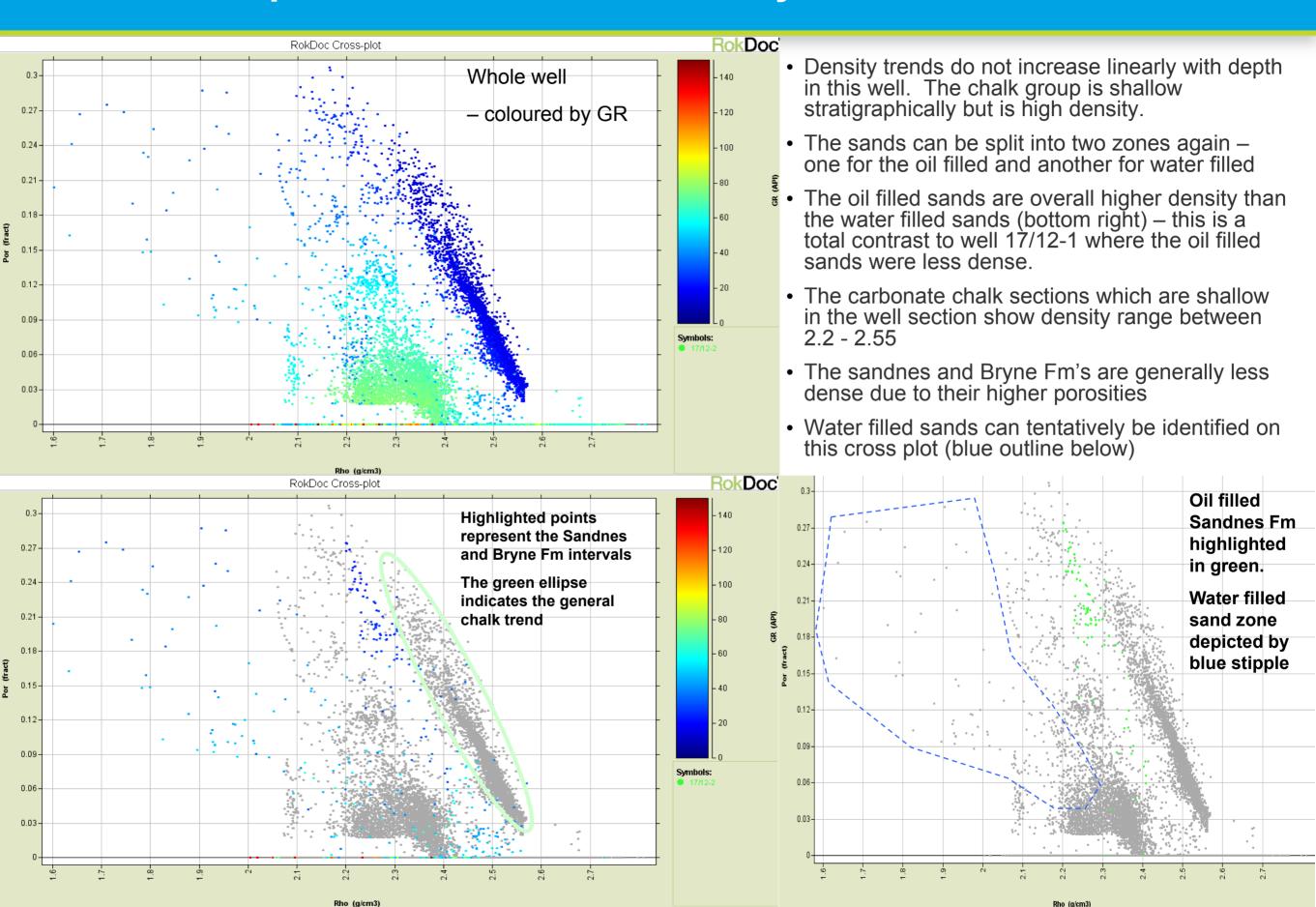
- The crossplot shows the chalk and sand units to be clearly seperated by Gamma response
- Sediments with GR values greater than 60 API are observed to have low porosities and largely correspond to shales
- The sandy Sandnes and Bryne Fm's are more porous than the shale formations but have significant overlap with the chalks. Overall the sands appear to be less heterogeneous than in well 17/12-1.
- The velocity variation observed throughout the sandy sediments is large: 2400 - 4000m/s
- Oil filled sands can be clearly identified on this plot due to their narrow velocity distribution (approx average 3400m/s) and high porosities.





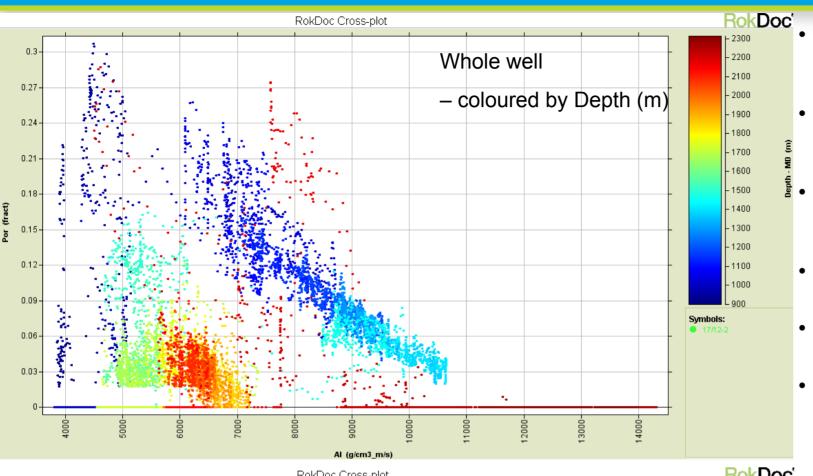
### AVO crossplots – Rho versus Porosity 17/12-2 PROCKSOURCE



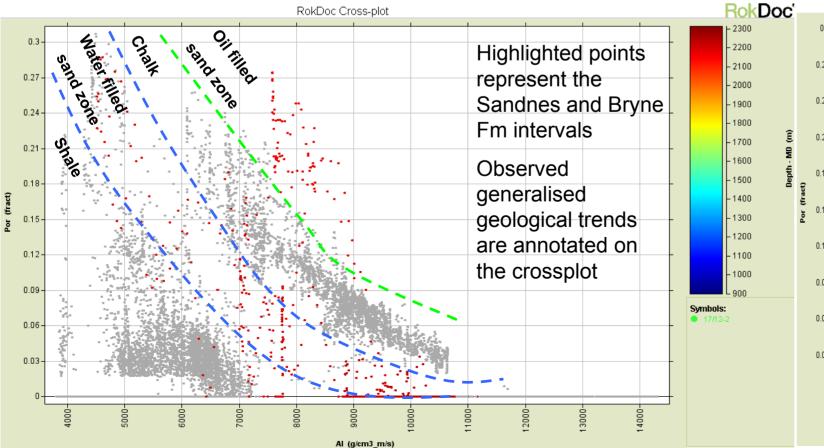


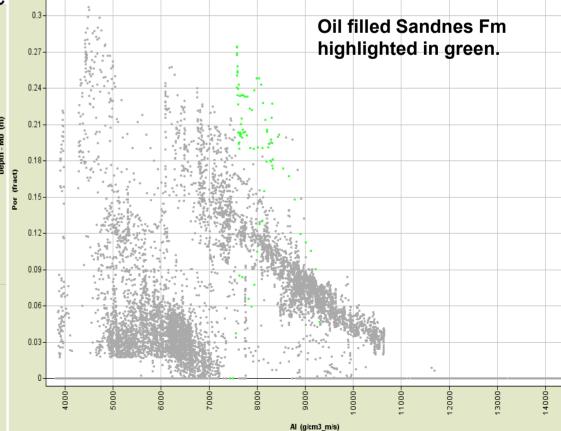
# **AVO crossplots – Al versus Porosity 17/12-2**





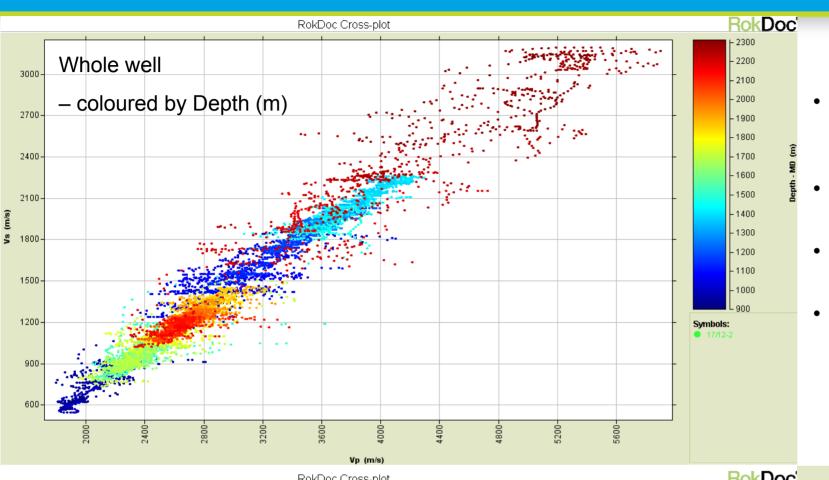
- The Acoustic impedance trend generally increases with depth although the thick chalk section within this well is the exception to this rule
- The Chalks have higher Al values than expected for sediments at this depth, due to its higher density
- The acoustic impedance trend for oil filled sands shows a clear increase in AI as we replace water with oil in the pore space
- There is a small overlap between the chalk characteristics and the oil filled sands
- Reasonably well defined trends can be established using AI versus porosity down this well
- The oil filled sands are clearly defined with high porosity and a narrow range of Al values (correlating with the velocity limits observed previously)



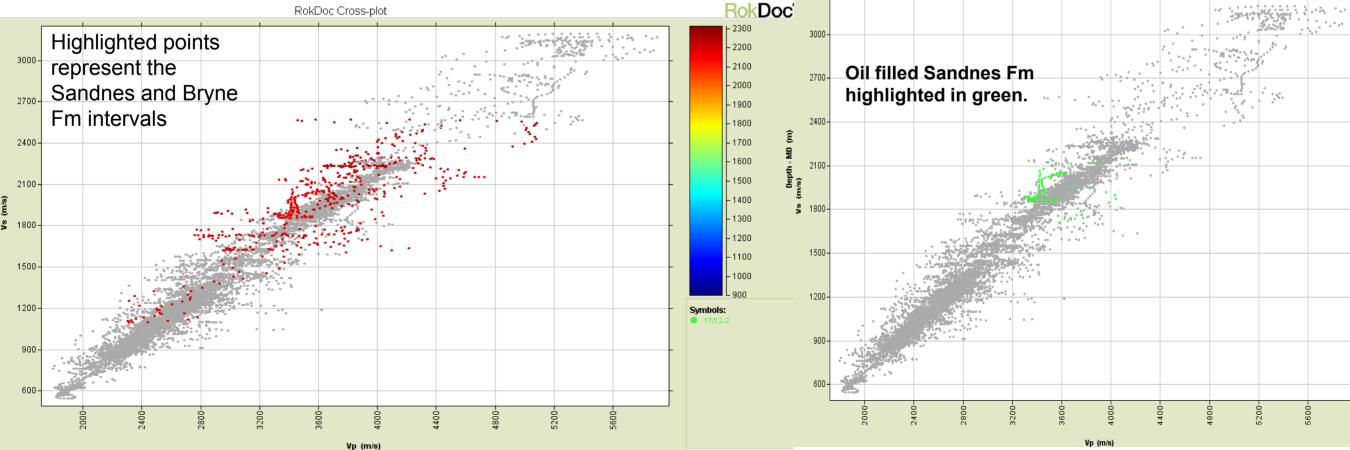


# AVO crossplots – Vp versus Vs 17/12-2



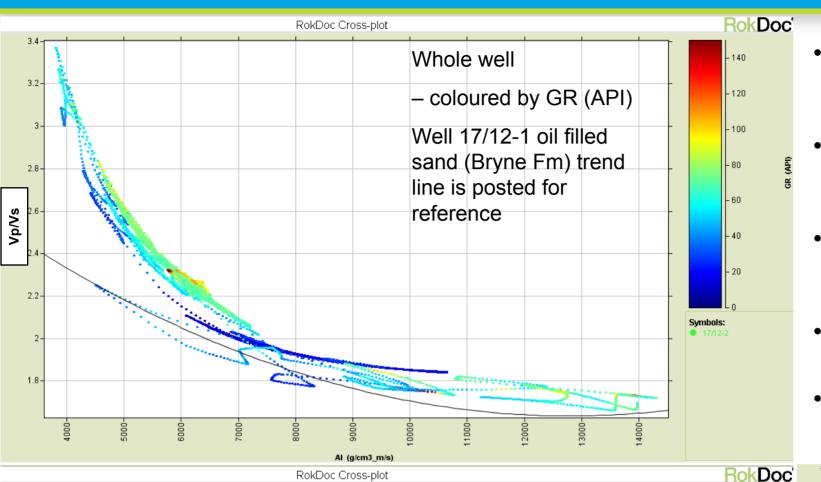


- Vp and Vs generally increase with increasing depth although the chalk has abnormally high velocities for sediments at shallow depth
- There is significant overlap between the sandy lithologiesa and the chalks on this crossplot
- The oil filled sands are hard to distinguish from the water wet sands
- Once the fluid velocity/density/porosity trends have been derived for the HC filled sands they will be built into the Vs model and fluid variations will stand out more clearly on these velocity plots

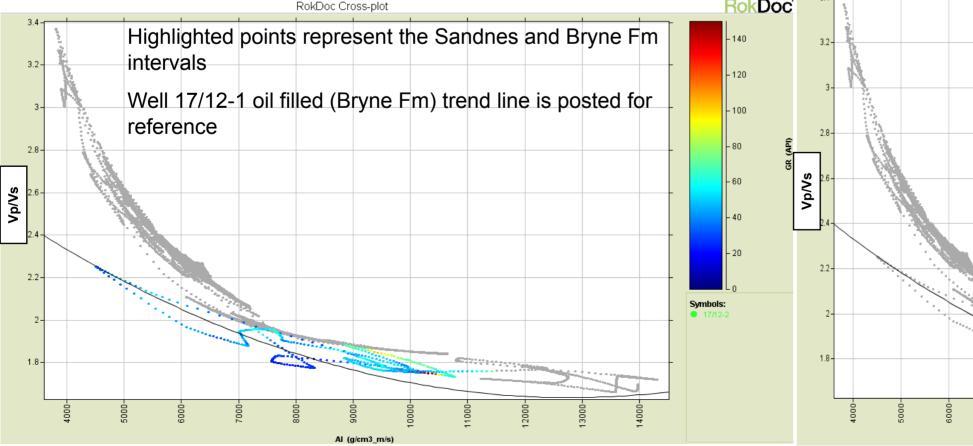


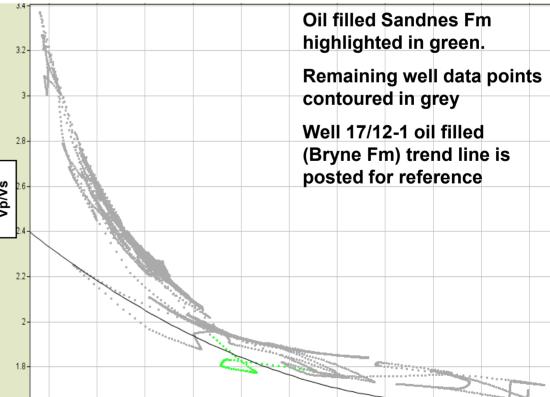
# AVO crossplots – Al versus Vp/Vs 17/12-2





- The Bryne and Sandnes Fm sands display lower Vp/Vs ratio's than both water filled shales and chalk
- The trend line created for the oil sands in well 17/12-1 correlates with the oil sands in well 17/12-2
- These plots are not ideal for assesing the fluid variations though as this has not been built into the Vs log estimation
- Shales generally have the highest Vp/Vs ratios in this well and varying AI values
- The AI range is controlled by variations in burial depth





### **AVO** work summary slide



- Rock physics modelling is in the preliminary stages for the Cyclops prospect however some positive indications are given from both the partial stack and crossplot data that AVO fluid substitution modelling and consequent inversion could be effective in delineating hydrocarbon accumulations in this area
- Oil filled reservoir rocks behave as expected with regards to density, velocity and Al
  variations which makes it easier to create coloured inversions
- Future work (dependant on a positive CSEM result) would include completion of 2D modelling including fluid substitution. This work would have allowed a decision to be made regarding the application of full AVO inversion during the second phase of the work program (if the licenced had progressed).
- AVO could be of further use in delineating the effects of the extrusive volcanics observed in the 17/9-1 well and ultimately reduce the reservoir risk at the prospect location
- Rocksource require any geological work to be de-risked by CSEM technology before more costly exploration practises (3D seismic acquisition) are justified.
- It should also be noted that the dimming responses on the partial stack data DO NOT conform to the Cyclops prospect trap and are likely to be economically unviable as stand alone prospectivity.



# **Risking and Volumetrics**

# Rocksource Risk Standards

Fluids	HYDROCARBON CHARGE: (Source, Migration, Timing & Quality)		
	What is the probability or confidence that hydrocarbons of the correct phase and quality are present, having been generated from an adequate volume and richness of source rocks, such that the trap has had access to them in reasonable quantity to provide producible hydrocarbons at the drill site?	P <sub>10</sub> Filled Area P <sub>01</sub> Reserves	
	RESERVOIR: (Porosity, Permeability, Thickness & Continuity)		
Rate	What is the probability or confidence that reservoir rock is present and of adequate permeability to produce at commercial rates at the proposed drill site and has sufficient porosity, thickness and lateral continuity to attempt a development completion?		
	STRUCTURAL INTEGRITY: (Quantity, Quality & Control)		
Shape	What is the probability or confidence that the geometry of the trap at the closing contour and the geologic age of the horizon are essentially as represented on maps and cross sections; such that any subtle variation would not jeopardize the accumulation of hydrocarbons at the proposed well?	Closing	
Barriers	SEAL: (Continuity, Proximity, Impermeable & Preservation)		
	What is the probability or confidence that all top and lateral seals at the median filled area exist with adequate differential permeability and proximity to the reservoir to retain a column of hydrocarbons of sufficient height to be tested by the proposed well?	Median Filled Area	

Seal Risk	Strong Evidence For	Encouraging Data	Some Support Data	Discouraging Data	Strong Evidence Against
Top Seal	80 - 100% confidence	60-80% confidence	40-60% confidence	20-40% confidence	0-20% confidence
Lithology and Ductility	Known excellent porperms known excellent (>1000psia) merc inj profiles (cap-pres. curve) sampled and tested in wells	Lithology described but not tested in nearby wells	Lithology predicted from depositional models and seismic. No well data	predicted improvement in adjacent well data	Known topseal failures
T1:1 1 1:1	Salt or anhydrite	shales	tight carbonates	le : L	
Thickness and continuity	Proven seal at similar thickness Clear seismic continuity over trap; simple geometry	Seals in other wells but on specific seismic character tie. Minor thinning expected	Thickness and continuity predicted from seismic dim zones only	Evidence of scouring or severe thinning on seismic	no evidence of separation of reservoir sections except unconformable boundary
Curvature over trap (stress/strain regimes)	Nominal curvature no indication of crestal faulting	Complex or significant curvature No evidence of crestal faulting	minor crestal faulting stops in seal or overlying section	Complex folds or crestal faulting to surface	Crestal faults with amplitudes against faults above seal
pressure	Known pressure boundary significant spread between frac and hydro gradients	no pressure increased in nearby wells significant spread; frac and hydro gradients	no information on pressure	strong overpressure	overpressure and frac and hydro gradients known to be close
Fault seal	80 - 100% confidence	60-80% confidence	40-60% confidence	20-40% confidence	0-20% confidence
fault type, number and timing	Several faulted analogs one normal fault contemp. With deposition faulting known to predate top of seal	one extensional fault stopping above seal	Multiple extensional faults through seal	Lateral faults or 3 or more faults required to seal	normal changing to scissor radical variation in throw en echelon faulting
amount of throw and juxtaposed lithology	throw very large upthrown objective predicted sand against shale	very large throws in a predominantly shaley section	moderate throw, (1 to 3 reservoir thicknesses) downthrown objective	second or deeper sand in faulted reservoir section	massive sands predicted across fault or mapping stops at fault
seal gouge	fault seals on trend	very low SGR or high % shale amplitude support for sealing character	unknown shale gouge	Throw less than one reservoir thickness along fault at p50 SGR>2 or %shale <60	minor throw offset less than 1/4 reservoir thickness
Dip of beds across fault	Downdip a t same or increased dip	downdip but less steep	unclear angle of dip across fault due to poor data	flat or updip	updip at same angle of dip
pressure across fault	known moderate pressure increase across fault	known severe pressure increase across fault	unknown pressures	known moderate pressure decrease across fault	known severe pressure decrease across fault
Stratigraphic seal	80 - 100% confidence	60-80% confidence	40-60% confidence	20-40% confidence	0-20% confidence
	known rapid lithology changes with analog production in area	known rapid changes but no analogs	model for lithology variation	slow change requiring distal pinchout	lateral change due to diagenisis
Unconformities		associated with transgressive systems tract unconformity		associated with regressive systems tract	
"bottom" seal		two directions of dip reversal bottom seal only required in tow along strike	critical to updip pinchout		
Other Issues	80 - 100% confidence	60-80% confidence	40-60% confidence	20-40% confidence	0-20% confidence
Diagenisis					
Fracturing				apparent from data	
Surface Seeps Amplitudes and AVO	all AVO and amplitudes below seal	amps occur both above and below seal		Amps occur above seal	amps occur in seal

Geometry Risk Strong Evidence For Structural Integrity 80 - 100% confidence		Some Support Data	Discouraging Data	Strong Evidence Against	
80 - 100% confidence	60-80% confidence	40-60% confidence	20-40% confidence	0-20% confidence	
3D data and/or tight 2D grid tied to nearby well control. All spillpoints clearly imaged.	At least one 2D line defines each key spillpoint.	grid spacing.	Infill seismic needed to accurately define geometry.		
Excellent 3D or 2D time or depth data. Late vintage seismic data. High resolution. Final migration Prestack processing.	High resolution seismic. "Fast Track" of "Quick Cube" preliminary processing.	Fair S/N dataset(s). Data quality degrades over prospect/structure. Multiples obscure primary reflectors. Reprocessing suggested.	Poor S/N dataset(s). Low resolution, early vintage seismic grid in need of reprocessing. Horizons phantomed.	NU seismic data.	
No seismic misties/bulk shifts. No statics/shallow effects noted. Fault throws consistent with structural style and consistent along faults.	Over/undermigration of seismic data suspected.	Misties < 1/2 of closure/trap height. Drop in fold noted above trap/structure. Fault throw problems and improper integration with overall structural style.	Throw inconsistent along faults. Wrong faulting pattern for structural style.	Mistie creates structure. Severe statics problems above structure, impossible to work out correct geometry.	
Lateral and vertical velocity variations proven not to exist via calibration of seismic to offset well control.	Minor lateral and/or vertical velocity problems known, not enough to distort trap/structure.  Trap not sensitive to velocity variations.	edge/overhang. Large fault offsets of high-low or low-	occur in subsurface. Offset drills unsuccessful due to velocity sags/pull-ups.	Extreme velocity corrections needed to create structure/trap. Unrealistic velocities unsupported by well control used to make depth maps.	
3D multicomponent anisotropic prestack depth migration or 2D prestack migration over robust structures exists.	3D Poststack depth migration exists. 2D prestack depth migration exists. Rigorous velocity model created to depth correct structure.	Time data used to stretch to depth. Isopach summation depth corrections used to construct depth maps. Strong water bottom depth variation exists over prospect.	Time maps used to depict depth structure in areas of known time/depth variations.  Deep structure may not be reachable due to wrong velocity estimates.	Structure created purely by depthing mechanism where well control suggests no structure.	
80 - 100% confidence	60-80% confidence	40-60% confidence	20-40% confidence	0-20% confidence	
Large simple structure mappable on all available datasets. Pronounced thinning seen over prospect defining structural growth. Structural style of prospect consistent with regional structural style.	thinning and observation of		Closure/trap under highly variable thickness of salt. Critical structural closure unresolved.	Monoclinal dip, edges of structure unresolved or outside of seismic dataset coverage.	
Numerous well control in and around prospect support presence of structure/trap.  Nearby well control directly tied to prospect.	presence of trap/structure. Strat trap documented by well control with reservoir/top seal couplet	Jump correlations over great distances		Numerous well control points condemns presence of structure/trap.	
Adjacent successful structure with same geometry as undrilled prospect.	similar geometries as undrilled	New or old play in new basin.	New play type unsupported by all available well control.	Play type tested and known not to have worked or shown to have fundamental flaw.	
Simple 4 way closure easily seen on all available datasets.  Modern structural technologies and concepts applied to prospect.	area.	Complexly faulted low relief structure. Obscured geometry due to high velocity overburden or poor signal to noise ratio.	well control and seismic datasets. Subsalt prospect with poor reflection resolution.	Well control conflicts with current interpretation(s).	
Interpretation agrees with structural restoration and reconstruction work. No other interpretation possible or alternate interpretations all suggest trap/structure.	Interpretation honors all boundary conditions. Cross sections balance.	Interpretation validated or agrees with regional gravity and magnetics signatures.	Interpretation conflicts with regional datasets and well control.	Structure doesn't balance to offset well control. No structural techniques applied in complex structural area.	
		Amplitude anomalies suggest some type of closure or geometry conducive to containing hydrocarbons.	Spotty amplitudes with little to no conformance with structure.  Non hydrocarbon bearing amplitudes tied to well control.	No amplitudes or regional amplitudes indicative of sequence boundaries tied to numerous wells.	
	3D data and/or tight 2D grid tied to nearby well control. All spillpoints clearly imaged.  Excellent 3D or 2D time or depth data. Late vintage seismic data. High resolution. Final migration Prestack processing.  No seismic misties/bulk shifts. No statics/shallow effects noted. Fault throws consistent with structural style and consistent along faults.  Lateral and vertical velocity variations proven not to exist via calibration of seismic to offset well control.  3D multicomponent anisotropic prestack depth migration or 2D prestack migration over robust structures exists.  80 - 100% confidence  Large simple structure mappable on all available datasets. Pronounced thinning seen over prospect defining structural growth. Structural style of prospect consistent with regional structural style.  Numerous well control in and around prospect support presence of structure/trap. Nearby well control directly tied to prospect.  Adjacent successful structure with same geometry as undrilled prospect.  Simple 4 way closure easily seen on all available datasets. Modern structural technologies and concepts applied to prospect.  Simple 4 way closure easily seen on all available datasets. Modern structural technologies and concepts applied to prospect.  Simple 4 way closure easily seen on all available datasets. Modern structural technologies and concepts applied to prospect.  Excellent amplitude anomalies (DHI's) with flat spots. Amplitude conforms to time and depth	3D data and/or tight 2D grid tied to nearby well control. All spillpoints clearly imaged.  Excellent 3D or 2D time or depth data. Late vintage seismic data. High resolution. Final migration Prestack processing.  No seismic misties/bulk shifts. No statics/shallow effects noted. Fault throws consistent with structural style and consistent along faults.  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Over/undermigration of seismic data suspected.  Minor fault throw problems.  Over/undermigration of seismic data suspected.  Minor fault throw problems.  Minor fault throw problems.  Over/undermigration of seismic data suspected.  Minor fault throw problems.  Minor statics problems noted.  Min	3D data and/or light 2D grid lied to nearby well control. All spillpoints clearly imaged.  Excellent 3D or 2D time or depth data. Late viritage seismic data. High resolution seismic. High resolution. Final migration Prestack processing. No selsmic misties/bulk shifts. No statiscis/shallow effects noted. Fast Track* of "Quick Cube* proliminary processing. All throws consistent with structural style and consistent along faults.  Lateral and vertical velocity variations proven not to exist via calibration of seismic to offset well control.  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Simple 4 way closure easily seen on all available control or prospect.  Simple 4 way closure easily seen on all available control maps servicution work. No other interpretation possible or alternate interpretation possible or alternate interpretation possible or alternate interpretation possi	Signature and/or tight 2D grid feled to nearby well control. All spillipoints clearly imaged. All spillipoints clearly imaged. All spillipoints clearly imaged. All spillipoints clearly imaged. Excellent 3D or 2D time or depth data. Latio virtage seismic data spillipoint. Excellent 3D or 2D time or depth data. Latio virtage seismic data. Highly resolution in Trian dingration. High resolution in Trian dingration. Frestlack processing. High resolution in Trian dingration. Frestlack processing. Frestlack processing. Whill pressible the spillipoint. No selatics shallow effects noted. Fault throws consistent with structural style and consistent with structural style and consistent along faults. 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Dispretakch migration or ver robust structure in a proper processing demonstration of unity of the processing demonstration of the pro	

Reservoir Risk	Strong Evidence For	Encouraging Data	Some Support Data	Discouraging Data	Strong Evidence Against
Presence	80 - 100% confidence	60-80% confidence	40-60% confidence	20-40% confidence	0-20% confidence
WELL CONTROL	Presence of reservoir in a nearby sister well, or A reliable isopach from multiple subregional wells, or	Prolific regional occurrence of reservoir in the target interval, or	Presence of reservoir in limited well control and no negative data, or	Spotty occurrence of reservoir with no seismic data or model to resolve the variation, or	Regional absence of reservoir, or
SEISMIC EVIDENCE		Moderately calibrated amplitude or AVO support, or Good 3D seismic morphology coupled with a depoditional model, or	Seismic data adequate to show thickening or at least minimal thinning, or	Seismic thinning of target zone, or	Good seismic data but sand poor characteristics, or
DEPOSITIONAL MODEL		Favorable depositional model with sand fairway corroborated by well control.	Favorable depositional model but limited or no seismic or well control support, or	Depositional model predicts poor chance of reservoir at prospect, or	Model predicts absence of reservoir at prospect, or
WELL LOCATION			Thick section under closure with multiple reservoir opportunities.	Seismic data inadequate to properly locate well (miss channel, poor structural position, faulted out, etc).	Well likely to be misplaced on avaiable data.
Quality	80 - 100% confidence	60-80% confidence	40-60% confidence	20-40% confidence	0-20% confidence
POROSITY AND PERMEABILITY	Regional analog at similar depth, or Additional burial exonerated by reservoir quality prediction (eg, EXEMPLAR).	Analog more remote than regional.	Favorable depositional model but limited or no well control, or Burial depth greater than well control.	Excessive overburden, or Poor porosity & perm in analog, or Provenace quality problem.	Non reservoir quality rock in regional anlog.
CONTINUITY	Regional analog, or Favorable depositional type, or No negative data.	Geological concern (eg, excesive faults, reflector discontinuity, depostional type) but offset by seismic flat spot.	Geological concern ( eg, excessive faults, reflector discontinuity, depositional type)	Depleting well tests in regional analog.	
FRACTURE POTENTIAL	Regional analog verified by production or well tests.	Regional analog verified only by log or core data.	No regional well control. Evidence based only on indirect data ( structural analysis, seismic attributes)		

#### Hydrocarbon Charge

Control Excellent

Strong Evidence, Data Quality and Encouraging Data, Data Quality and Control Good

Some Support Data, Data Quality and Control Fair

**Discouraging Data, Data Quality Control Poor** 

Strong Evidence Against, Data Quality and Control Excellent

	80 - 100% confidence	60-80% confidence	40-60% confidence	20-40% confidence	0-20% confidence
Source Quality	Source rock found in wells, thickness	Sub regional production established,	Source rock identified regionally by	Dry hole failure attributed to insufficient	Source rock oxidized or non
	and areal extent understood, source	basement tectonics or source rock	outcrop, or inferred through regional		existant, through non deposition or
	rock attributes such as TOC and HI	distribution somewhat understood,	studies, source rock distribution not	control very little data exist, rank basin or	erosion
	known, Depositional environment of	kerogen type, maturity understood	understood	moderaterately drilled with little success	
	source rock and distribution known	through oil analysis,			
Examples:	North Sea Central Graben	Niger Delta	Kwanza	Santos	
Generation	Thermal history well constrained by	Thermal history understood but may	Thermal history complex, multiple	Subregional accumualtions are noted,	Source rock is overmature,
	Ro data, hydrocarbon type and	be complex due to unconformities,	models plausible, source kitchens	however soruce kitchens unidentifed,	generation occurred long before
	modeling well matched, burial	production established however	not identified, depth somewhat	depth unknown, Ittle knoweldge of	trap formation, or source rock
	history, heat flows and kinetics well	source kitchens, and volumes	known, some hydrocarbon noted in	source extent, basin tectonics not	clearly immature
	· · · · · · · · · · · · · · · · · · ·	availble to prospect unclear,	sub-basin, basin tectonics fairly	understood.	
		modeling parameters agree with	understood		
	hydrocarbons for prospect	production, resasonable confidence			
	volumetrically calculated and	in depth of source rock			
	abundant				
Migration	1 '	Carrier beds known, offset fields	Primitive migration vector anlaysis,	Prospect requires fill and spill from other	· ·
	to source rock, backstripping	illustrate similar conduits for	migration pathway directly to the	prospects or is located within a migration	
	indicates focusing toward prospect	prospect,short distance migration	prospect not defined or imaged,		supporting well control
	during migration, trap formed before	laterally or vertically invoked	lateral migration necessary within a	affect migration paths	
	migration, modeling support offset		moderately to highly faulted terrain		
	accumulations				
Preservation	No biodegradation observed within	Some biodegradation noted along	Prospect well within zone of	'	Heavy crude expected clearly
	analogs along trend, gas flushing not	trend, prospect is somewhat unique		and somewhat unquantifiable, gas	noncommercial at the present
	a concern	to analogs, slight concern of	some extent, gas flushing may be	flushing significant concern	time.
		biodegration	some concern		
		_			
			Ī	i	'

# Risk summary – Probability of geological success $(P_{\alpha}) = 18\%$



• Structure: The stratigraphic trap geometry is well defined with a clearly mappable pinchout in every dimension against the inversion structure. Some uncertainty must remain as the interpretation has been carried out on a 2D grid leaving room for more detailed trap compartmentalisation to exist if mapped in 3D.

= 90%

• Reservoir: The Sandnes and Bryne Formations are present throughout the region and act as the main hydrocarbon reservoirs sands in the surrounding wells displaying excellent reservoir parameters and sufficient sand prone thicknesses. There is a large concern however regarding the quality of sands present at the Cyclops prospect due both to the coeval extrusive volcanics observed at well 17/9-1 and the significant erosion that effected the volcanic dome during the Middle Jurassic. The sands and their associated amplitudes could be a crude diagenetic mix of sub-aerial lava flows and sand thus greatly reducing the reservoir potential. The reservoir risk remains unchanged post-award and AVO inversion should be used to reduce the risk associated with the volcanics.

= 50%

• Seal: Seal risk is considered low for the Cyclops prospect but as with all stratigraphic traps there is some small risk associated with sub-seismic thief sands and faults. Regionally the Bonkefjord Gp shales provide an excellent seal for the Sandnes and Bryne Fm's which is proven in a number of nearby wells.

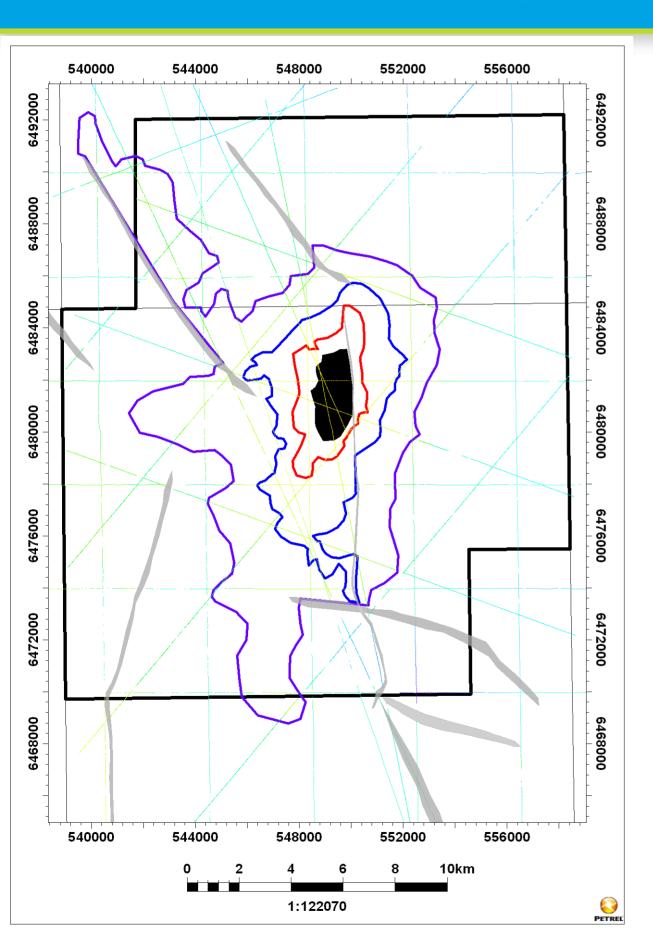
= 70%

• Source and migration: The key risk associated with the Cyclops prospect has now been reduced as a result of the extensive basin and migration modelling carried out over the licenced block and surrounding areas. Probabalistic testing has increased the chance of HC presence at the prospect however there is still sigificant risk associated with the kinetic model used and likely flow paths.

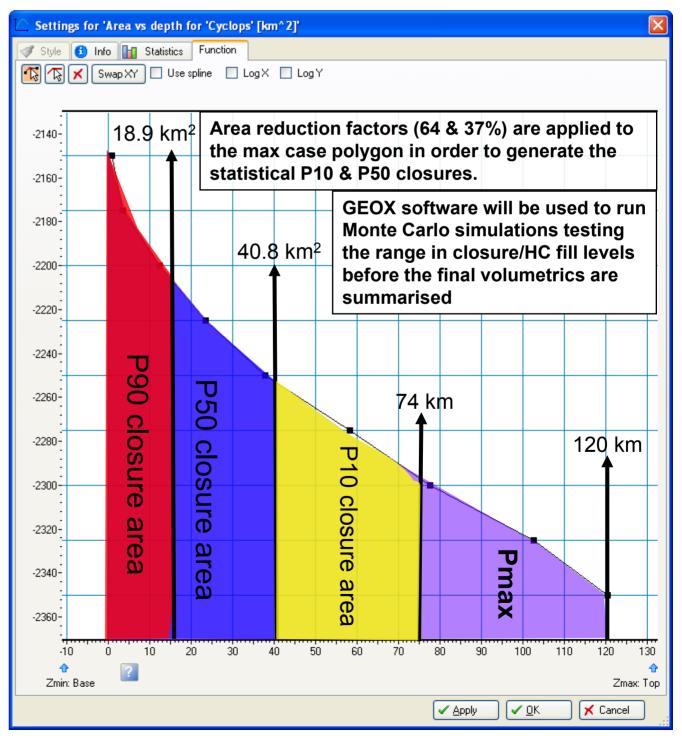
= 50%

#### **Areal distribution of prospect**





- Top Sandnes Fm interpreted sections overlaying the Pmax, P50 & P10 areal closure polygons for the Cyclops prospect
- Eroded crest is 4km<sup>2</sup> in area this has been taken into account when calculating the area vs depth trends
- Re-interpretation using the newly purchased seismic data allowed the closure areas to be redefined



#### **Volumetric summary - Inputs**



Parameter [units]	Туре	Mean	Std d	F90	F50	F10
Area of Closure [km2]	StrBeta	44.2	21.7	18.9	40.7	74.7
Reservoir Thickness [m]	Norm	72.5	10.3	59.1	72.5	85.9
Geometric Factor [decimal]	Const	0.45	0.0	0.45	0.45	0.45
Net sand fraction [decimal]	Unif	0.45	0.087	0.33	0.45	0.57
Net reservoir fraction [decimal]	Const	1.0	0.0	1.0	1.0	1.0
Porosity [decimal]	Const	0.22	0.0	0.22	0.22	0.22
Trap Fill [decimal]	Const	1.0	0.0	1.0	1.0	1.0
Oil Saturation [decimal]	Const	0.64	0.0	0.64	0.64	0.64

- Area and reservoir parameters used in the final Cyclops prospect volumetrics
- Reservoir parameters derived from petrophysical analysis defined earlier

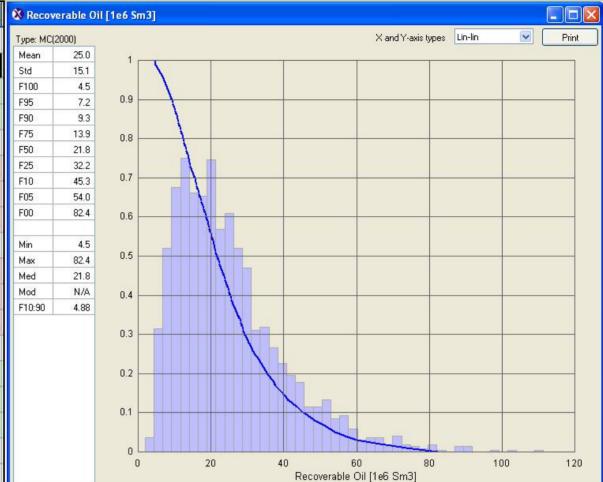
Parameter [units]		Туре	Mean	Std d	F90	F50	F10
Oil Form. Factor (Bo) [m3/Sm3]		Unif	1.5	0.23	1.18	1.5	1.82
Gas Oil Ratio [Sm3/Sm3]		Const	18.0	0.0	18.0	18.0	18.0
Recovery factor oil [decimal]		Triang	0.4	0.041	0.345	0.4	0.455
Recovery factor assoc. gas [de	cimal]	Triang	0.5	0.041	0.445	0.5	0.555

 Final fluid parameters used in the Cyclops prospect oil case volumetrics as defined by the in house reservoir engineer

#### **Volumetric summary**



Resource type	Dist.type	Mean	Std d	P90	P50	P10	Recov	rerab
Oil [1e6 Sm3]							Type: MC(	
Accumulation size above Minimum Volume	MC(2000)	25.0	15.1	9.3	21.8	45.3	Mean Std	1
Cond. segment potential	MC(2000)-r	3.94	10.91	0.0	0.0	17.57	F100 F95	
Uncond. segment potential	MC(2000)-r	3.94	10.91	0.0	0.0	17.57	F90	
Non Assoc. Gas [1e9 Sm3]							F75 F50	2
Accumulation size above Minimum Volume	Const	0.0	0.0	0.0	0.0	0.0	F25	3
Cond. segment potential	Const	0.0	0.0	0.0	0.0	0.0	F10 F05	5
Uncond. segment potential	Const	0.0	0.0	0.0	0.0	0.0	F00	8
Assoc. Gas [1e9 Sm3]				0.0000.0000			Min	
Accumulation size above Minimum Volume	MC(2000)	0.562	0.332	0.207	0.489	1.011	Max Med	2
Cond. segment potential	MC(2000)-r	0.0886	0.2436	0.0	0.0	0.3951	Mod	1
Uncond. segment potential	MC(2000)-r	0.0886	0.2436	0.0	0.0	0.3951	F10:90	4
Condensate [1e6 Sm3]					100000			
Accumulation size above Minimum Volume	Const	0.0	0.0	0.0	0.0	0.0		
Cond. segment potential	Const	0.0	0.0	0.0	0.0	0.0		
Uncond. segment potential	Const	0.0	0.0	0.0	0.0	0.0		
Total Resources [1e6 Sm3 OE]	MC(2000)	25.6	15.4	9.5	22.3	46.3		
Total Hesodices [160 3113 02]	MC(2000)	23.0	13.4	3.3	22.5	40.5		



- Area distribution factor applied in areal closure calculations
- Reservoir parameters taken from petrophysical analysis of nearby wells
- Oil fill levels from basin and migration modelling monte carlo analysis
- Oil fluid parameters from nearby discovery well data
- Result is an increase in recoverable resources when compared to the pre-award application summary
  - These increases are due to more accurate trap distribution as a result of re-mapping & more detailed reservoir parameters gained from petrophysical evaluation (more positive than first expected)

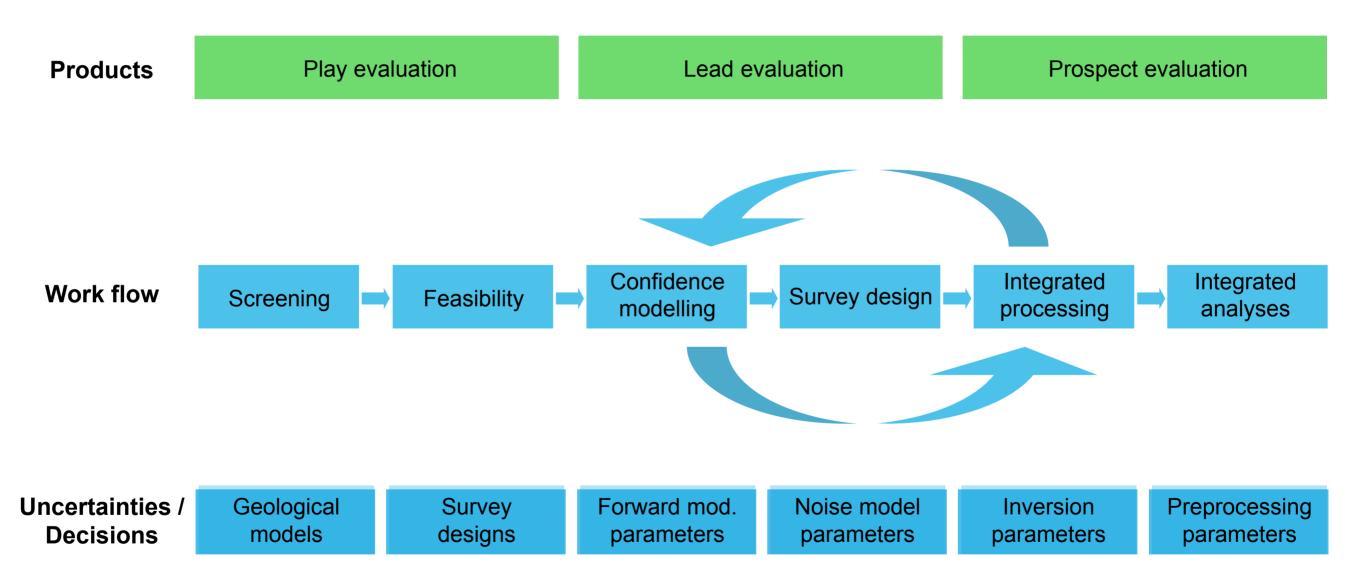
18% chance of success (Pre EM update)



## **CSEM** evaluation



#### Products, work flow and uncertainties/decisions





# **CSEM** phase II study inputs

#### **Bathymetry along the CSEM survey line**

-140 -145 -150

-155 -160 -165

-170 -175

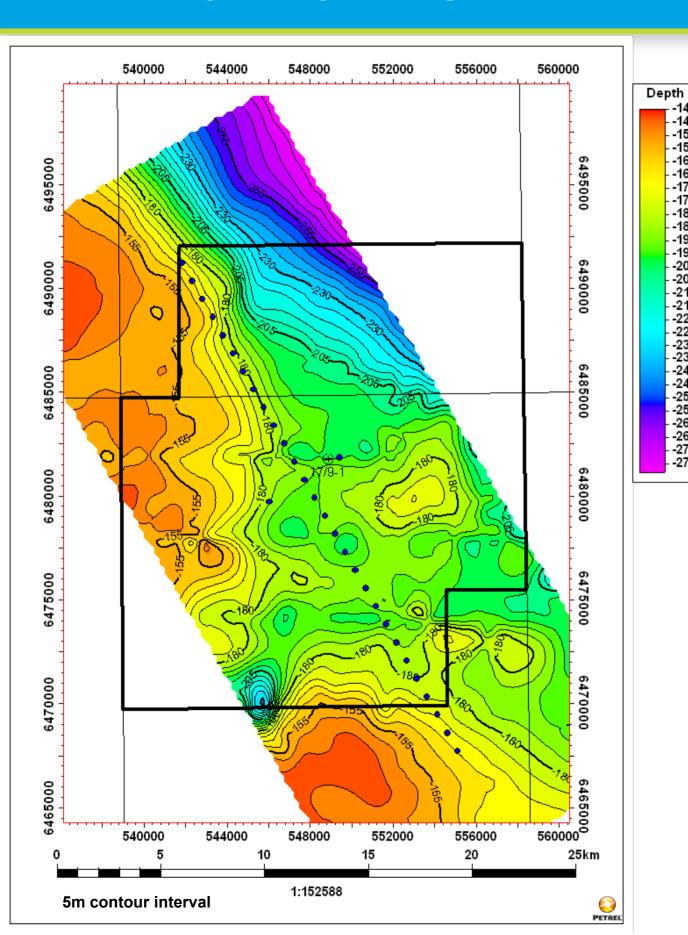
-180 -185

-190 -195

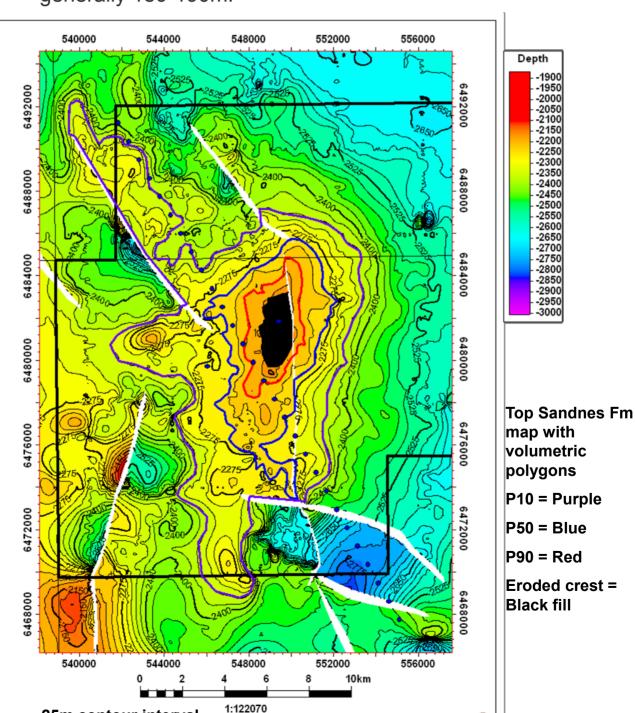
-200 -205 -210 -215 -225 -235 -240 -245 -250 -255 -260 -270 -275

25m contour interval



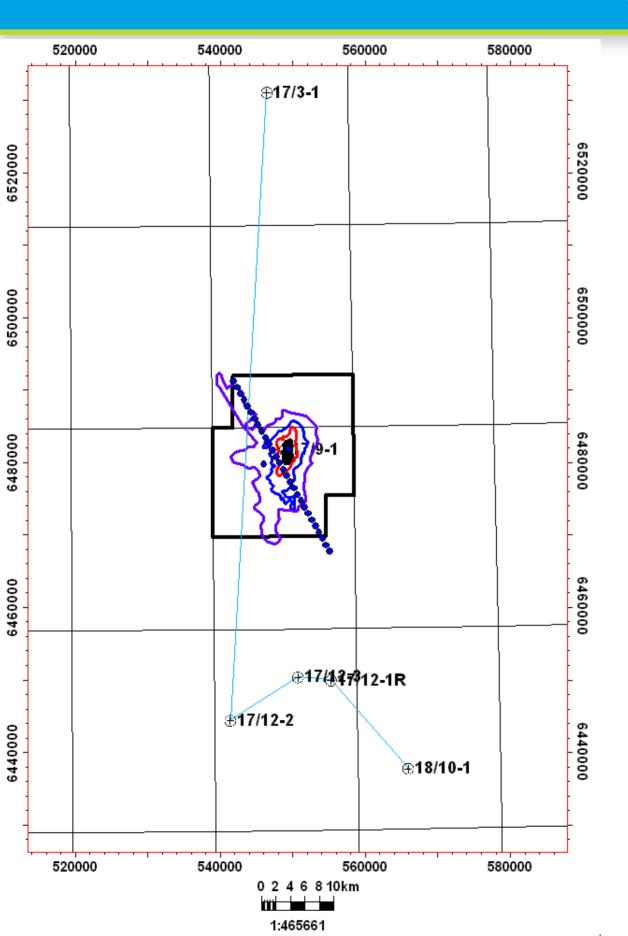


- Bathymetry map (mbmsl) displayed in the region of the CSEM survey line
- Contour interval is 5m it can be seen that the bathymetry varies by up to 25m along the line
- Over the main prospective area the water depth is generally 180-190m.



#### Wells studies for resistivity correlation

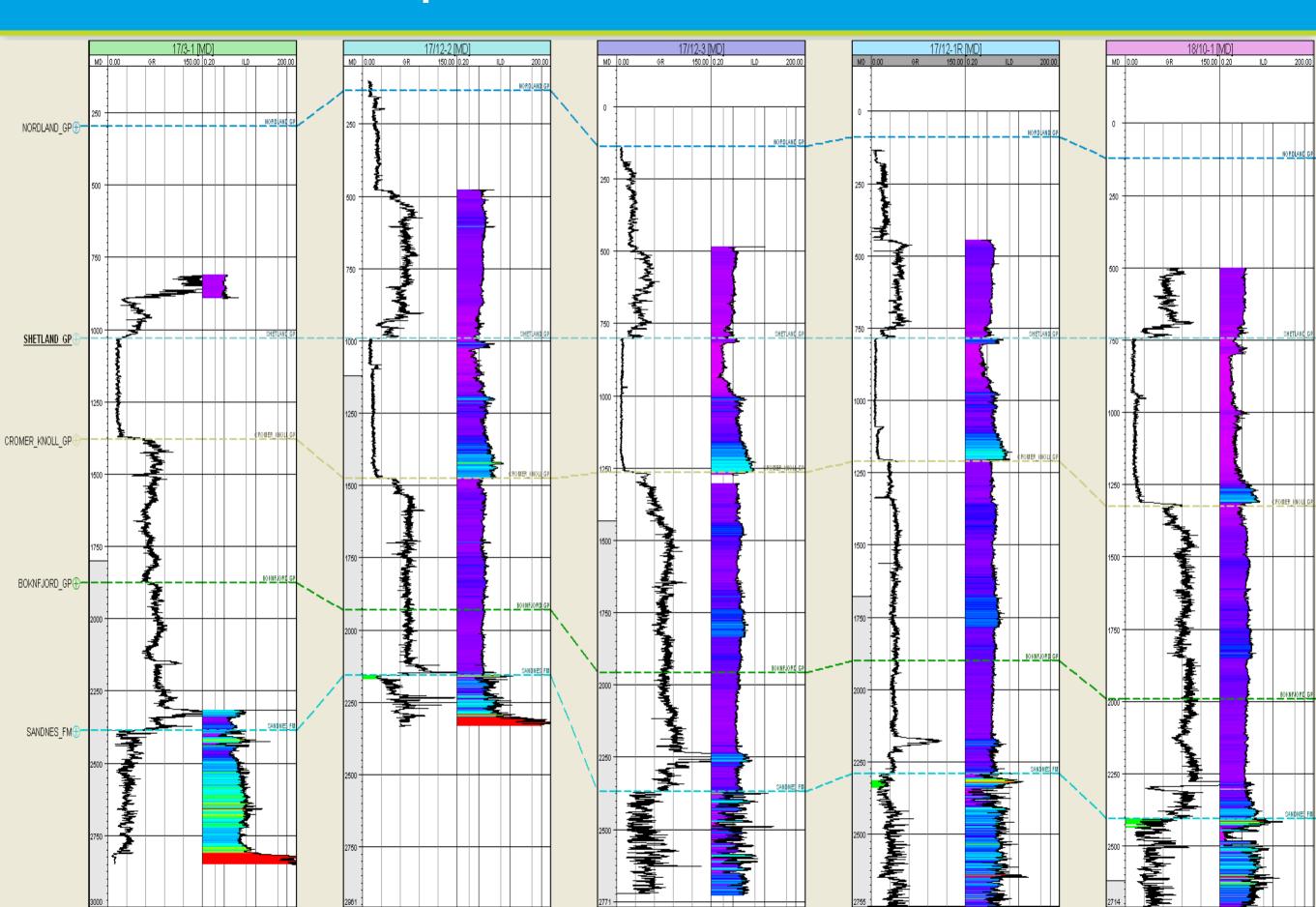




- Well 17/3-1 is a small, non-commercial gas discovery to the North of Cyclops. A 2m gas column was discovered within the Sandnes Fm
- 17/12-1R (Bream), 17/12-2 (Brisling) & 18/10-1 are all oil discoveries with 30m, 13m and 30m oil columns respectively within the Sandnes and underlying Bryne Fm's.
- 17/12-2 is a dry well with Sandnes Fm reservoir present.
- These wells show a sufficient range in resistivity for the main geological horizons and can therefore be used to predict the most likely resistivity range over the Cyclops prospect CSEM survey line.

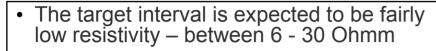
#### Well correlation panel



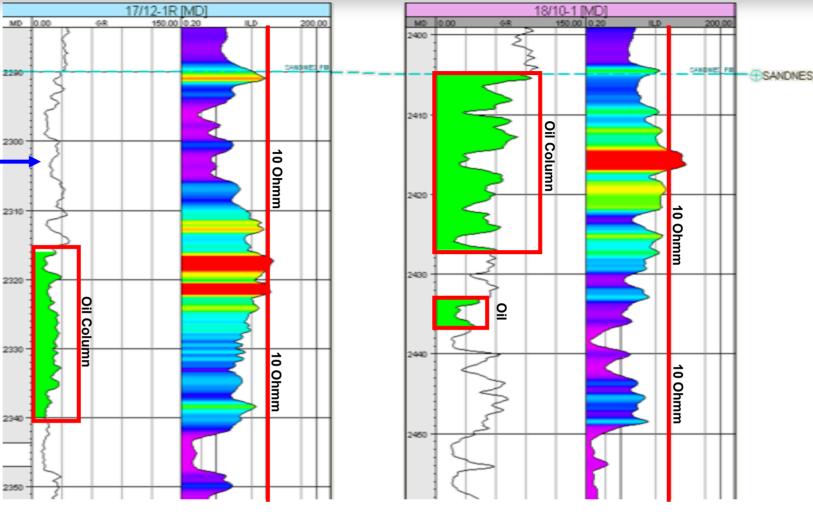


#### Considerations for EM modelling

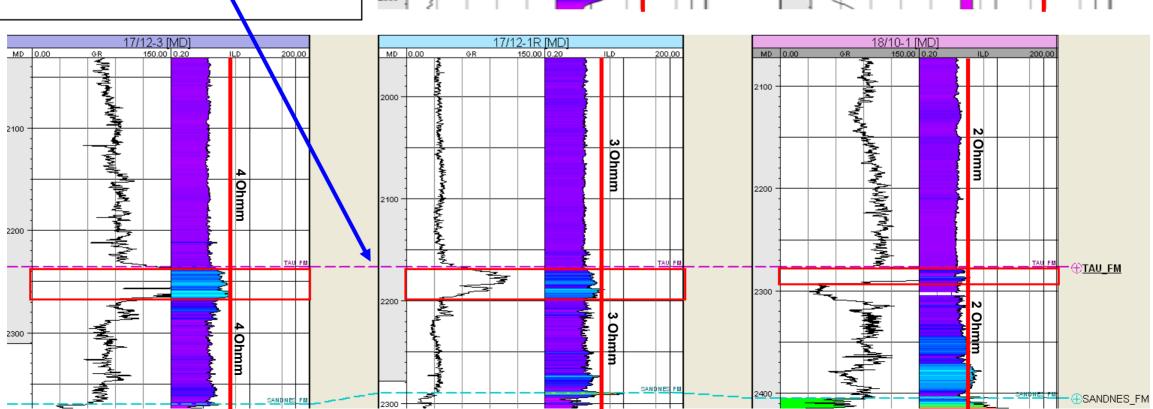




- The peaks in the resistivity curve correlate with the higher quality sands (see correaltions with gamma ray pattern)
- The Tau Fm sits within the modelled interval 'Top Bonkfjord Gp. To Top Sandnes Fm.'. This layer shows variable resistivities regionally and can display average resistivities of up to 4.5 Ohmm in up to 30m sections.
- The initial model averages out the Tau Fm resistivity distribution and this fits with many of the wells in the area however if the CSEM inversions show additional resistive distribution within this model layer it can be broken down further. (This was proven not to be an issue post-inversion study)



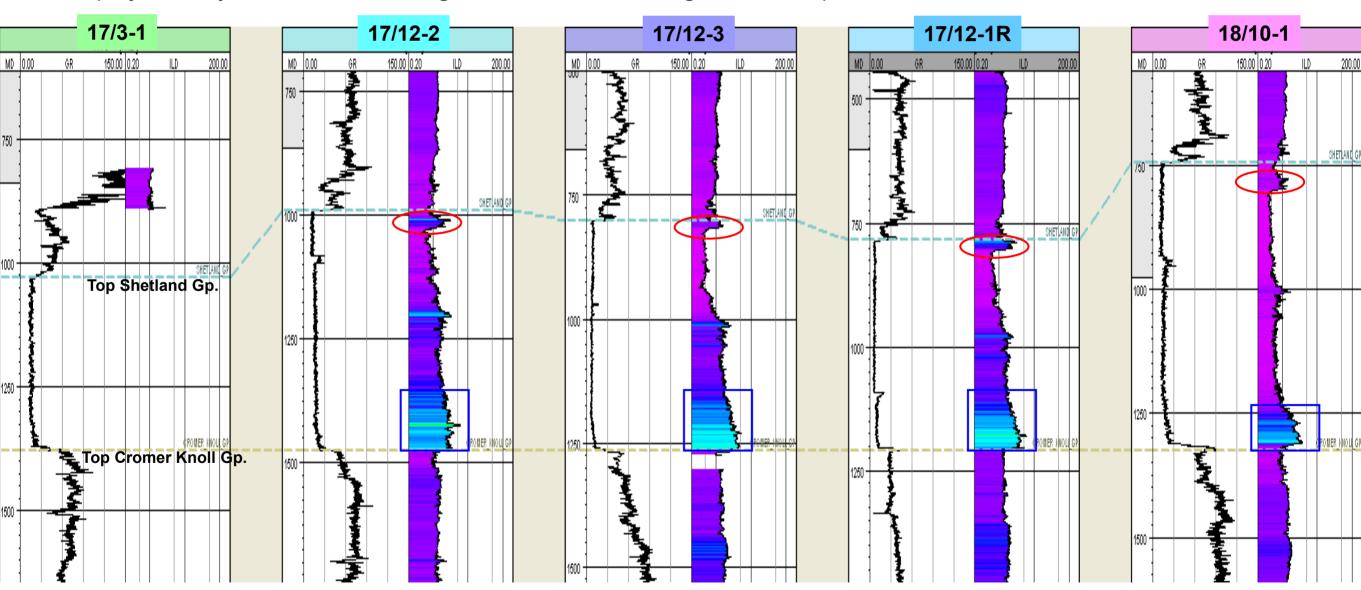
Tau Fm characterised by V high Gamma response and an increase in resistivity (Tau Fm is a coal based source rock)



#### Considerations for EM modelling continued



- Chalks in the Tor Fm (just beneath Top Shetland Gp.) and Hod Formation (Directly above the Top Cromer Knoll Gp.) appear regionally and can sometimes display moderate resistivities (up to a maximum of 4 Ohmm).
- The Top Shetland to Top Cromer Knoll layer suggested for modelling is designed to account for this variability as the resistivities increase with depth towards the base of the layer (where the Hod Fm. begins to influence the resitivity).
- Smaller resistive bodies may be present due to the Tor Fm and these were monitored during the inversions to account for any false positive CSEM anomalies associated with thier presence. Generally this Fm. displaysed only low resitivities though and further modelling was not required.



Background Resistivity Profile (P50 case) Target Resistivity and Thickness Ranges HORDALAND\_GP(+) SANDNES FM Paleocene 1.5 ohmm SHETLAND\_GP 1.5 - 3.5 ohmm (transition with depth) BRYNE FM CROMER\_KNOLL\_GP(11) SOLA\_FM(+) ASGARD\_FM(+) 1.75 - 2 ohmm range BOKNFJORD\_GP( Filled target depicted by green on gamma log -1.3 - 1.75 (1.6) Ohmm P10 = 30 Ohmm, P50 = 20 Ohmm & P90 = 10 Ohmm (potential Tau Fm presence may induce a P10 = 70m, P50 = 40m & P90 = 25m slightly higher resistivity band near the TAU\_FM( base of this layer - max 4 Ohmm) EGERSUND\_FM SANDNES\_FM(+)\* Color interpolation: ○ HSV (Max) 7**D** O HSV (Min) 2 - 4.5 (3.5 av) ohmm RGB Emphasize 6**D** Non linear gradient Highly anisotropic final model layer It is recommended that anisotropy is build into the modelling for this layer in consideration of this FJERRITSLEV\_FM(#) HEGRE\_GP( ----'Near Top Triassic marker'

#### **Modelling parameter summary**



• Summary of modelling parameter along seismic 2D section GLDI-92-206 (displayed on the following 2 slides)

		Estimated Resistivity	
Layer	P90	P50	P10
1		Water	
2	1.25	1.5	1.75
3	1.25 - 2.5 Ohmm	1.5 - 3.5 Ohmm	1.75 - 4.0 Ohmm
	Trend increases with depth	Trend increases with depth	Trend increases with depth
4	1.75 Ohmm	2.0 Ohmm	2.25 Ohmm
5	1.3 Ohmm	1.6 Ohmm	1.75 Ohmm
6	2.5 Ohmm	3.5 Ohmm	4.5 Ohmm
	ANISOTROPIC LAYER	ANISOTROPIC LAYER	ANISOTROPIC LAYER
Target	Immediately below the top of Layer 5	in the background model	1

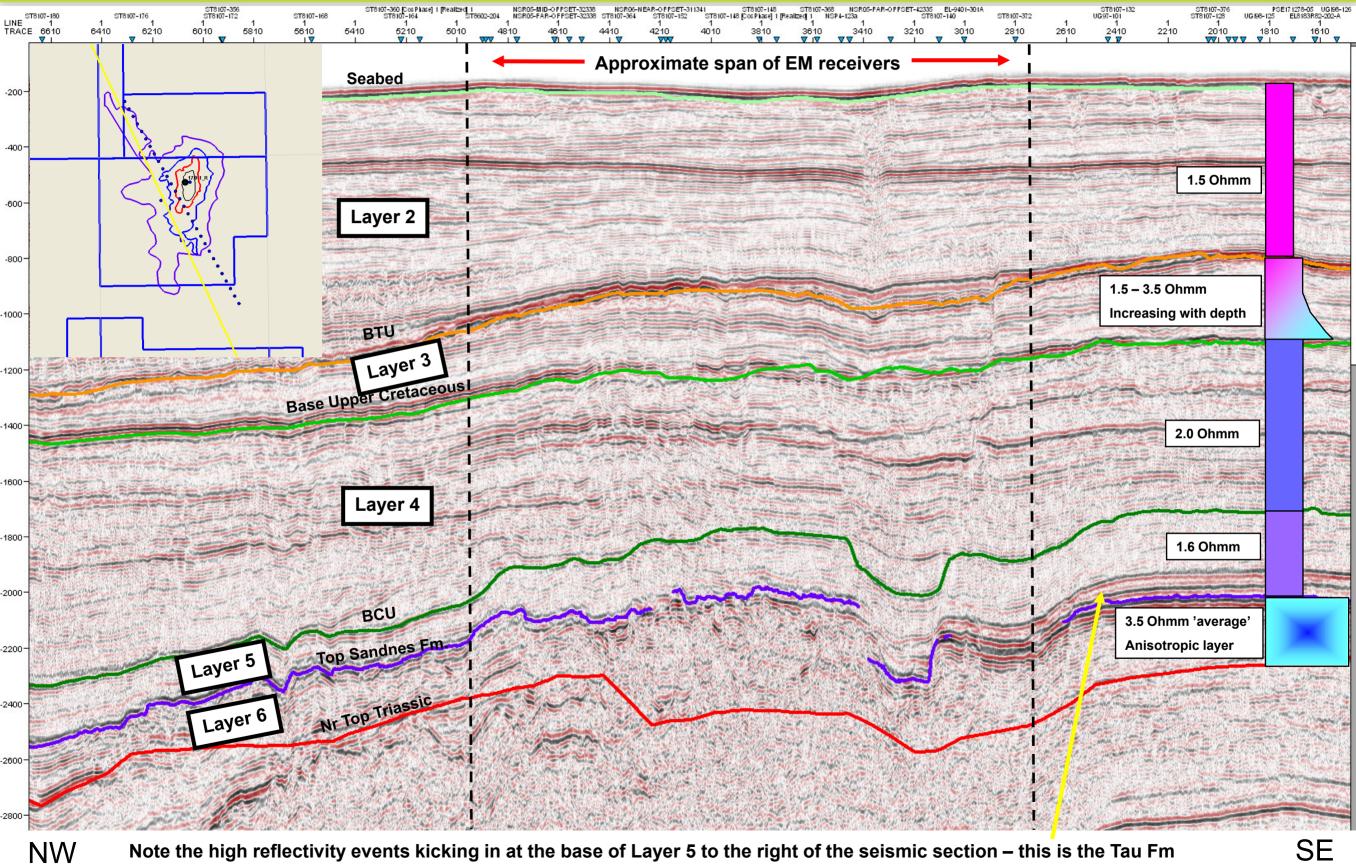
Target thickness and resistivity ranges:

P90 = 10 Ohmm, P50 = 20 Ohmm & P10 = 30 Ohmm

P90 = 25m, P50 = 40m & P10 = 70m

#### Near parallel seismic section to EM line (TWT)

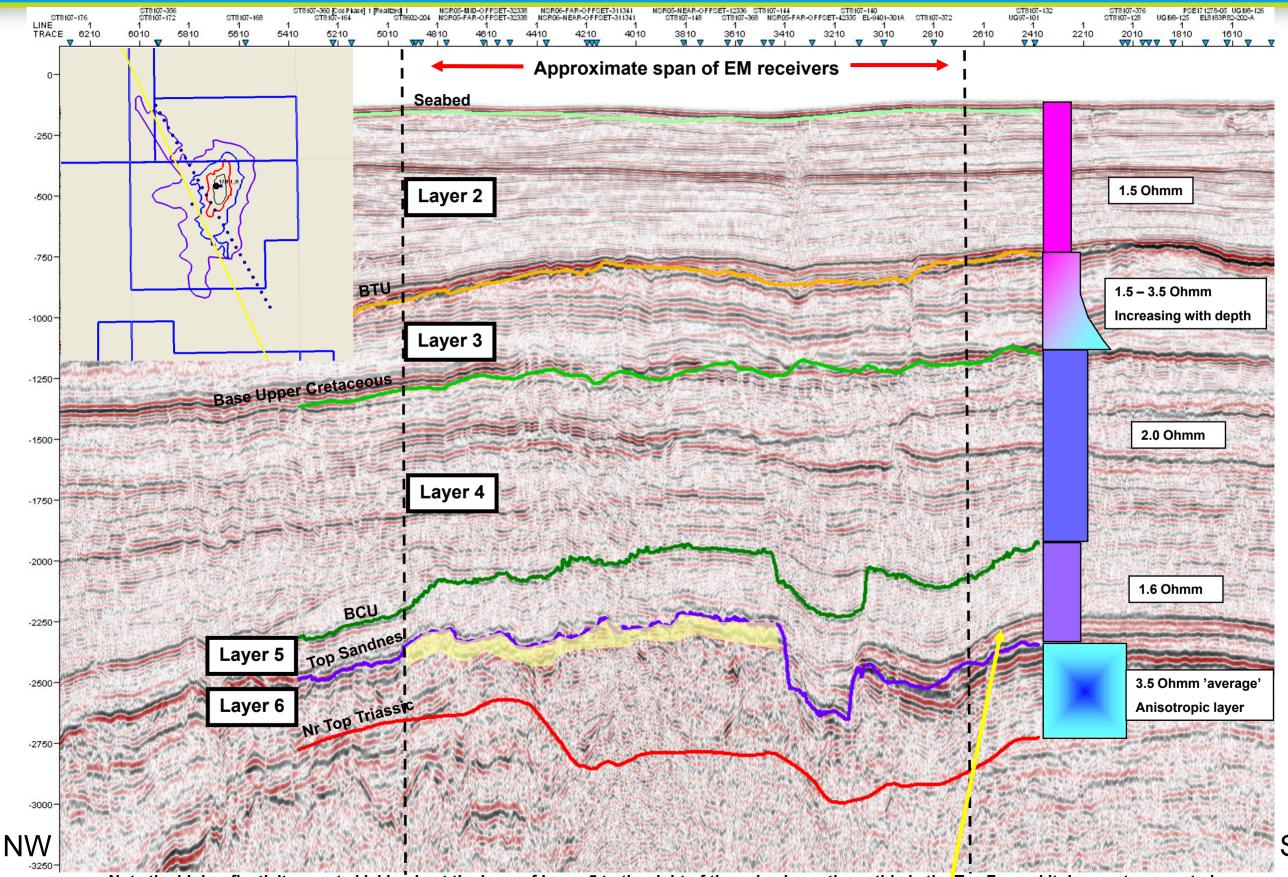




Note the high reflectivity events kicking in at the base of Layer 5 to the right of the seismic section – this is the Tau Fm and it does not appear to be present directly over the prospect

# Near parallel seismic section to EM line (depth in m)





Note the high reflectivity events kicking in at the base of Layer 5 to the right of the seismic section – this is the Tau Fm and it does not appear to be present directly over the prospect. Target is outlined in Yellow – bear in mind the line orientation compared to the CSEM survey line though!!!!



## **CSEM Phase II analysis**

- Data acquisition, processing and inversion



#### Resume

- Pre acquisition modelling suggest a scenario with a good quality hydrocarbon filled sand will be detectable using CSEM
- High quality CSEM data was acquired in 2008
- Full data processing and interpretation have been acomplished inhouse
- Data analysis does not indicate the presence of a hydrocarbon filled reservoir at expected target location



#### **Agenda**

- Pre acquisition modelling
- Summary of data acquisition
- Normalized MVO & difference in PVO plots
- 3D inversion result
- Result summary



September 2007

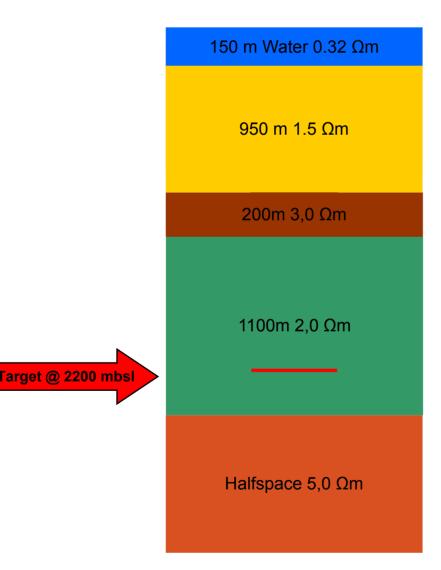
# Results of EM Feasability study Cyclops, Norwegian Sea,

**Author: Peter Gelting** 



#### Modelling Inputs: background resistivity

Background resistivity model (isotropic):

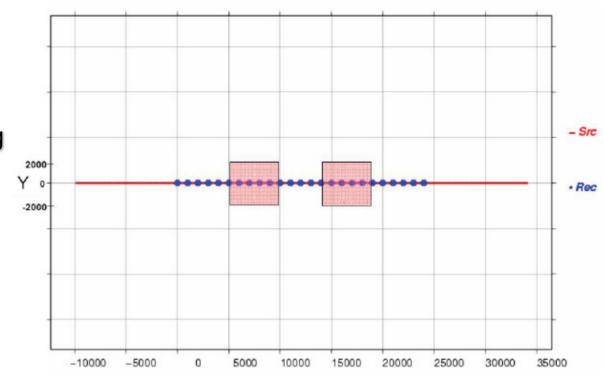


- One potential target a 2050 meter below mudline (water depth is 150 meter)
- The prospect geometry has been simplified to two wedges with a geometry of 5 km x 4 km x 40 to 80 m. The wedges are separated by a 4 km hole. This represents acquiring EM data along a crosscut through "Doughnut shaped structure".
- Prospect geometries captured in a grid of resolution 250 x 250 x 25 m (X Y Z)
- The key uncertancy for the prospect is the target resistivity. Petrologic well studies in the area has shown that a HC filled target is likely to have an average resistivity of approximately 30 ohm\*m (P50). Depending of the actual net/gross fraction of a HC filled sand the resistivity is estimated to vary between 10 and 100 (P90 and P10).



#### **Modelling Inputs: Survey layout**

- A 1D survey line oriented across the target
- Total number of 25 receivers are evenly spaced along the line
- Standard survey configuration -
  - At least 5 Rx outside the target on each side
  - 10 km source towing before the first and after the last receiver
  - Receiver spacing of 1 km
  - Source positions every 250 m
  - Source antenna length 250 m
  - Source current 1500 A at each frequency
  - Source frequencies of 0.15, 0.25, and 0.4 Hz examined.
     Only optimal frequency displayed and used in inversion





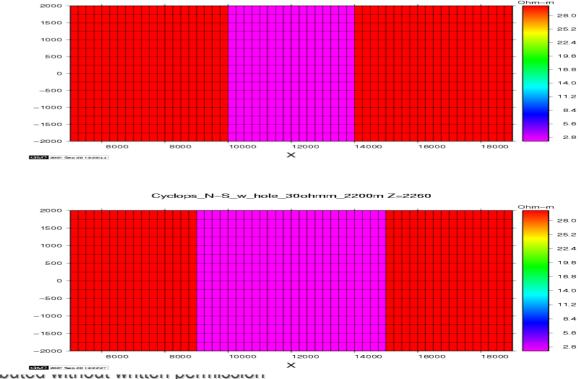
#### **Modelling Input for prospect**

- One potential target at 2050 m below mud line.
- Target geometries have been simplified to have a maximal thickness of 80 meters thinning down to 40 meters thickness towards central high.
- Prospect geometries captured in a grid of resolution 250 x 250 x 40 m (X Y Z)
- The prospect resistivity is a key uncertainty. Modeling has been carried out with 9 ohm\*m, 30 ohm\*m and 100 ohm\*m. Basecase resistivity is estimated to be 30 ohm\*m. The basecase results are displayed here.
- 3 different source frequencies have been modelled to optimize the target response (only optimal displayed)

#### **Sideview of target**

#### Cyclops N-S w hole 30ohmm 2200m Y=-125 Ohm-m 2200 28.0 2210 25.2 2220 22.4 2230 19.6 16.8 2240 14.0 2250 11.2 2260 84 5.6 2270 2.8 18000 6000 8000 12000 14000 16000 Χ GMD 2007 Sep 20 13:15:54

#### Topview at upper and lower targetlevel

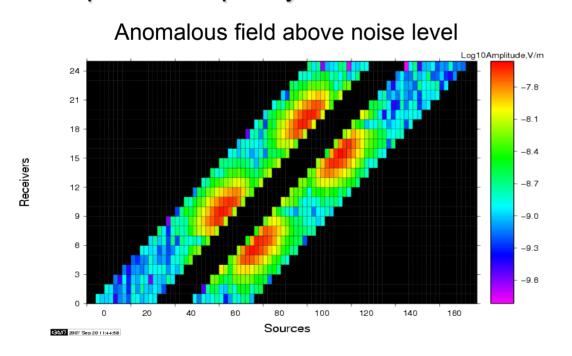


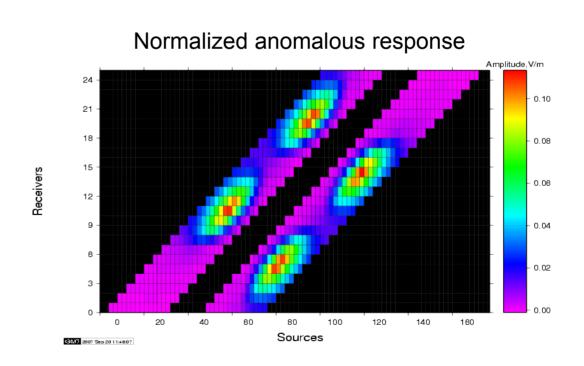
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#### **Signal Analysis**

- Amplitude of anomalous field (generated by target) for all receiver and source positions (left figure)
- The normalized anomalous response descripes the relative difference between the target response response and the background signal for all receiver and source positions (right figure)
- The fields are masked so only data above noise level is displayed
- Optimum frequency 0.25 Hz





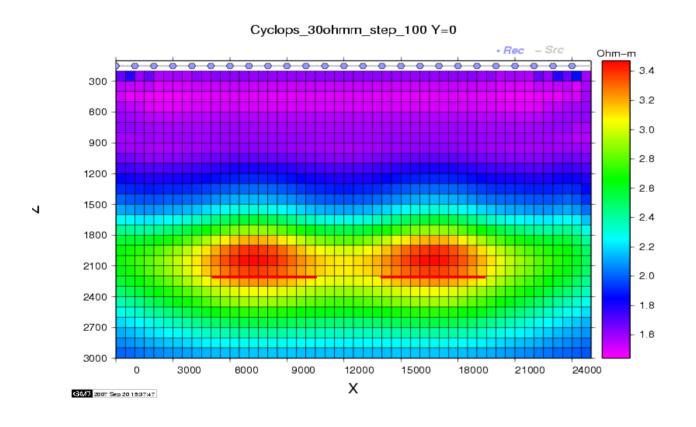
The amplitude of the anomalous field is up to 15 times stronger than the estimated noiselevel at optimal offsets, so that the signal-to-noise ratio is concidered acceptable.

The anomalous signal normalised by that of the background is up to 11% which is concidered weak but detectable.



#### **Inversion Result**

Results of inversion plotted at step 100:

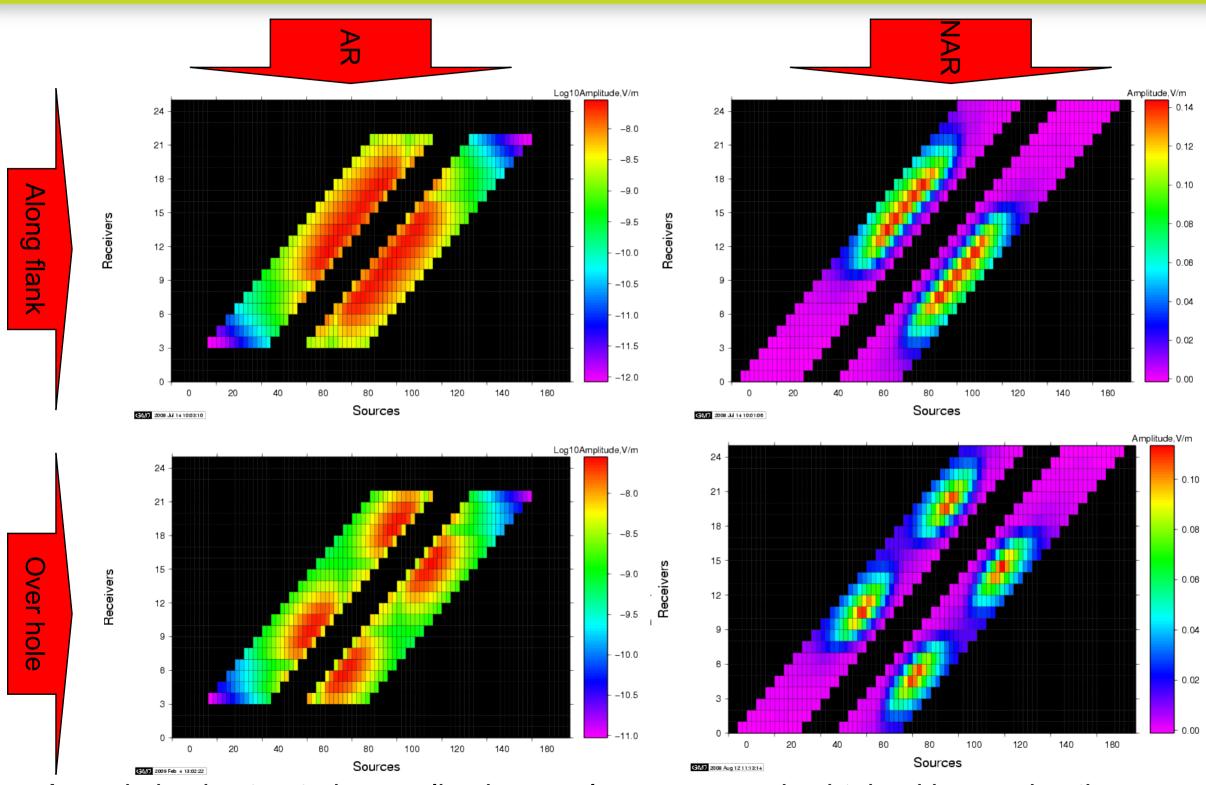


- Target resolved with good contrast
- Location resolved
- Lateral extent resolved and targets deliniated
- Depth of response not exatly resolved in this simplistic model

RESULTS SUMMARY	Poor	Acceptable	Good
S/N-ratio		X	
Inversion			X
Overall Risk evaluation		X	

#### **Survey layout modification**





A maximized saturated normalized anomalous response is obtained by running the survey line along the flank. Several receivers now record significant response above noise level.



# Summary of survey geometry and data acquisition

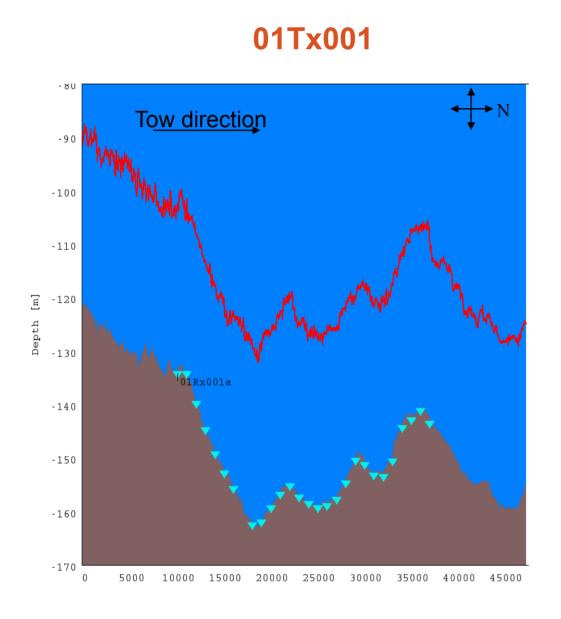


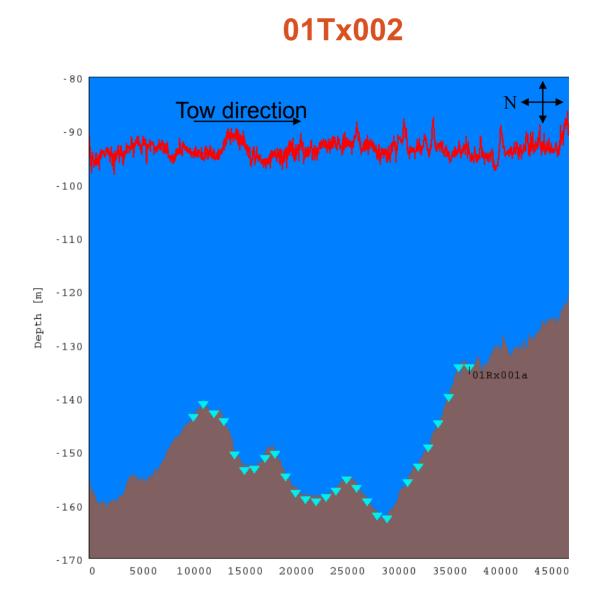
#### **RGT Summary of operations**

Rx positioning	Excellent	
Tx-positioning	Great feather angle (feather angle follows tidal currents)	
Source perfomance	Stable source throughout tow	
Receiver perfomance	High quality data (1 Rx deliver no data)	
General operational perfomance	Good, but weather downtime occured. Very low MT noise level throughout survey	

#### Sourceline configuration







Bathymetry along the towlines. Blue triangles represent the receivers and the redline represents the source track. 2 tow lines was conducted Tx001 have fixed altitude (standard setup). Tx002 have contant tow depth. This setup allows for detailed bathymetry analysis



#### Receiver drop accuracy

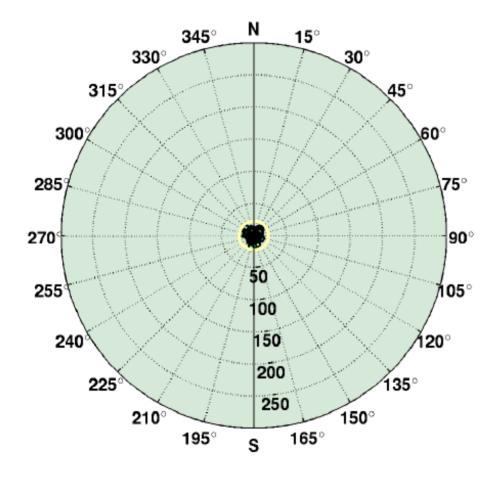


Figure 2: Receiver drop positions, deviations from planned positions - CYCL01

#### 1.2 Receiver Setup as Iaid - CYCL01

Table 6: Receiver Setup as laid – SLS01											
	5444			Position			om planned				
Rx ID	Rx ID DAU Components		Easting [m]	Northing [m]	Depth [m]	pos Range [m]	ition Bearing [deg]				
01Rx001a	09072	Exy,Hxy	555109.3	6467709.1	134.2	9	197				
01Rx002a	10064	Exy,Hxy	554617.0	6468580.8	134.1	8	203				
01Rx003a	08056	Exy,Hxy	554130.9	6469456.9	139.7	2	120				
01Rx004a	10120	Exy,Hxy	553638.7	6470322.7	144.7	6	162				
01Rx005a	10082	Exy,Hxy	553149.3	6471199.7	149.1	4	63				
01Rx006a	08053	Exy,Hxy	552657.6	6472062.5	152.8	7	147				
01Rx007a	09047	Exy,Hxy	552171.3	6472934.7	155.7	10	110				
01Rx008a	09071	Exy,Hxy	551665.8	6473805.9	159.4	6	248				
01Rx009a	08075	Exy,Hxy	551174.0	6474674.7	162.5	6	237				
01Rx010a	10085	Exy,Hxy	550686.1	6475530.1	161.9	18	186				
01Rx011a	08079	Exy,Hxy	550191.7	6476411.5	159.3	8	213				
01Rx012a	09067	Exy,Hxy	549710.0	6477287.4	156.7	6	96				
01Rx013a	10038	Exy,Hxy	549213.0	6478159.9	155.1	2	0				
01Rx014a	08040	Exy,Hxy	548705.2	6479032.9	157.3	17	287				
01Rx015a	08082	Exy,Hxy	548225.3	6479907.2	158.4	10	333				
01Rx016a	10025	Exy,Hxy	547746.0	6480773.0	159.2	9	58				
01Rx017a	10087	Exy,Hxy	547242.1	6481643.1	158.9	6	323				
01Rx018a	08071	Exy,Hxy	546748.4	6482506.9	157.7	7	261				
01Rx019a	10027	Exy,Hxy	546258.5	6483369.3	154.6	10	207				
01Rx020a	09023	Exy,Hxy	545761.6	6484249.5	150.4	11	284				
01Rx021a	10026	Exy,Hxy	545283.4	6485116.7	151.1	3	95				
01Rx022a	08043	Exy,Hxy	544796.3	6485996.6	153.2	13	41				
01Rx023a	08051	Exy,Hxy	544296.2	6486865.4	153.4	8	355				
01Rx024a	09086	Exy,Hxy	543808.7	6487729.4	150.5	4	57				
01Rx025a	10119	Exy,Hxy	543304.1	6488601.5	144.3	11	294				
01Rx026a	09087	Exy,Hxy	542820.0	6489474.1	142.8	7	344				
01Rx027a	08084	Exy,Hxy	542324.1	6490337.0	141.1	7	270				
01Rx028a	10061	Exy,Hxy	541842.7	6491193.4	143.4	14	165				
01Rx029a	08038	Exy,Hxy	546040.9	6479713.1	151.3	16	310				
01Rx030a	08066	Exy,Hxy	549437.8	6481840.5	158.5	10	42				
			Rem								

General Receiver info							
Sampling	50 Hz for all Rx						
Drop position accuracy	As per Data Acquisition Standards						
Other							



#### Receiver perfomance CYCL01Tx001a

Table: Data- and hardware quality assessment for individual channels - CYCL01Tx001a

Rx ID	DAU ID	Ex1	Ex2	Ey1	Ey2	Hx1	Hy1	Drift [ppb]
01Rx001a	09072	OK	OK	OK	OK	OK	OK	15.09
01Rx002a	10064	OK	OK	OK	OK	OK	Light	23.83
01Rx003a	08056	OK	OK	OK	OK	OK	OK	-3.01
01Rx004a	10120	OK	OK	OK	OK	OK	OK	12.69
01Rx005a	10082	OK	OK	OK	OK	OK	OK	1.36
01Rx006a	08053	OK	OK	OK	OK	OK	OK	20.48
01Rx007a	09047	OK	OK	Heavy	OK	OK	OK	27.74
01Rx008a	09071	No Data	N/A					
01Rx009a	08075	Light	OK	OK	OK	OK	Light	-8.23
01Rx010a	10085	OK	OK	OK	OK	OK	OK	8.22
01Rx011a	08079	OK	OK	OK	OK	OK	OK	-4.45
01Rx012a	09067	Noise	Light	OK	OK	OK	OK	5.1
01Rx013a	10038	OK	OK	OK	OK	OK	OK	-42.34
01Rx014a	08040	OK	OK	OK	OK	OK	OK	18.33
01Rx015a	08082	Light	OK	OK	OK	OK	OK	-4.48
01Rx016a	10025	OK	OK	OK	OK	OK	OK	-16.31
01Rx017a	10087	OK	OK	Light	Light	OK	OK	-9.73
01Rx018a	08071	Light	OK	OK	OK	OK	OK	15.36
01Rx019a	10027	OK	OK	OK	OK	OK	OK	-25.2
01Rx020a	09023	OK	OK	OK	OK	OK	Light	17.17
01Rx021a	10026	Light	Light	OK	OK	OK	OK	-2.56
01Rx022a	08043	OK	OK	OK	OK	OK	OK	-3
01Rx023a	08051	OK	OK	Light	OK	OK	OK	4.44
01Rx024a	09086	OK	OK	OK	OK	OK	OK	10.55
01Rx025a	10119	OK	OK	OK	OK	OK	OK	3.37
01Rx026a	09087	OK	OK	OK	OK	Light	OK	15.23
01Rx027a	08084	Light	Light	Light	OK	Light	OK	17.84
01Rx028a	10061	ÖK	OK	ÖK	OK	ÖK	OK	5.79
01Rx029a	08038	OK	OK	OK	OK	Heavy	Light	11.2
01Rx030a	08066	Light	OK	Noise	OK	OK	Light	17.42
				Remarks				

Table: Final quality assessment - Summed and rotated - CYCL01Tx001a

Table: Final quality assessment - Summed and rotated - CYCL01Tx001a							
Rx ID	Rotated	Angle [deg]	E-data	H-data	Remarks		
01Rx001a	E+H	-150.66	Good	Excellent			
01Rx002a	E+H	-160	Excellent	Good			
01Rx003a	E+H	-81.42	Excellent	Excellent			
01Rx004a	E+H	-49.56	Excellent	Excellent			
01Rx005a	E+H	-109.1	Excellent	Excellent			
01Rx006a	E+H	-66.26	Excellent	Good			
01Rx007a	E+H	-23.72	Excellent	Excellent			
01Rx008a	-	-	No Data	No Data			
01Rx009a	E+H	-31.69	Excellent	Good			
01Rx010a	E+H	-75.22	Excellent	Excellent			
01Rx011a	E+H	-31.02	Excellent	Excellent			
01Rx012a	E+H	-98.67	Excellent	Excellent			
01Rx013a	E+H	-111.9	Excellent	Excellent			
01Rx014a	E+H	-46.99	Good	Excellent			
01Rx015a	E+H	4.42	Good	Excellent			
01Rx016a	E+H	-18.67	Excellent	Excellent			
01Rx017a	E+H	-61.78	Good	Excellent			
01Rx018a	E+H	-86.73	Excellent	Excellent			
01Rx019a	E+H	-72.5	Excellent	Excellent			
01Rx020a	E+H	-8.76	Excellent	Excellent			
01Rx021a	E+H	-164.78	Excellent	Excellent			
01Rx022a	E+H	36.81	Excellent	Excellent			
01Rx023a	E+H	-136.02	Excellent	Excellent			
01Rx024a	E+H	8.32	Excellent	Excellent			
01Rx025a	E+H	60.18	Excellent	Good			
01Rx026a	E+H	-9.03	Excellent	Excellent			
01Rx027a	E+H	-41.77	Good	Excellent			
01Rx028a	E+H	-48.14	Excellent	Good			
Remarks							

Rotation only applies to horizontal components (x,y)



## Receiver perfomance CYCL01Tx002a

Table: Data- and hardware quality assessment for individual channels – CYCL01Tx002a								
Rx ID	DAU ID	Ex1	Ex2	Ey1	Ey2	Hx1	Hy1	Drift [ppb]
01Rx001a	09072	OK	OK	OK	OK	OK	OK	15.09
01Rx002a	10064	OK	OK	OK	OK	Noise	Light	23.83
01Rx003a	08056	OK	OK	OK	OK	OK	OK	-3.01
01Rx004a	10120	OK	OK	OK	OK	OK	OK	12.69
01Rx005a	10082	OK	OK	OK	OK	OK	OK	1.36
01Rx006a	08053	OK	OK	OK	OK	OK	OK	20.48
01Rx007a	09047	OK	OK	OK	OK	OK	OK	27.74
01Rx008a	09071	No Data	N/A					
01Rx009a	08075	OK	OK	OK	OK	OK	OK	-8.23
01Rx010a	10085	Noise	Light	OK	OK	OK	OK	8.22
01Rx011a	08079	OK	OK	Light	OK	OK	OK	-4.45
01Rx012a	09067	Noise	Light	OK	OK	OK	OK	5.1
01Rx013a	10038	OK	OK	OK	OK	OK	OK	-42.34
01Rx014a	08040	OK	OK	OK	OK	OK	OK	18.33
01Rx015a	08082	Light	OK	OK	OK	OK	OK	-4.48
01Rx016a	10025	OK	OK	OK	OK	OK	OK	-16.31
01Rx017a	10087	OK	Ok	Light	OK	OK	OK	-9.73
01Rx018a	08071	OK	OK	Noise	Light	OK	OK	15.36
01Rx019a	10027	Light	Light	Light	OK	OK	OK	-25.2
01Rx020a	09023	OK	OK	OK	OK	OK	OK	17.17
01Rx021a	10026	Light	OK	OK	OK	OK	OK	-2.56
01Rx022a	08043	OK	Light	OK	OK	OK	OK	-3
01Rx023a	08051	OK	OK	Light	OK	OK	OK	4.44
01Rx024a	09086	OK	OK	OK	OK	OK	OK	10.55
01Rx025a	10119	Light	Light	OK	OK	OK	Light	3.37
01Rx026a	09087	Light	Light	OK	OK	OK	ΟK	15.23
01Rx027a	08084	OK	OK	OK	OK	OK	OK	17.84
01Rx028a	10061	OK	OK	Light	Light	OK	OK	5.79
01Rx029a	08038	Noise	Light	Light	OK	Heavy	Light	11.2
01Rx030a	08066	Light	Light	ΟK	OK	Light	Noise	17.42
				Remarks				

01Rx008a did not contain any data.

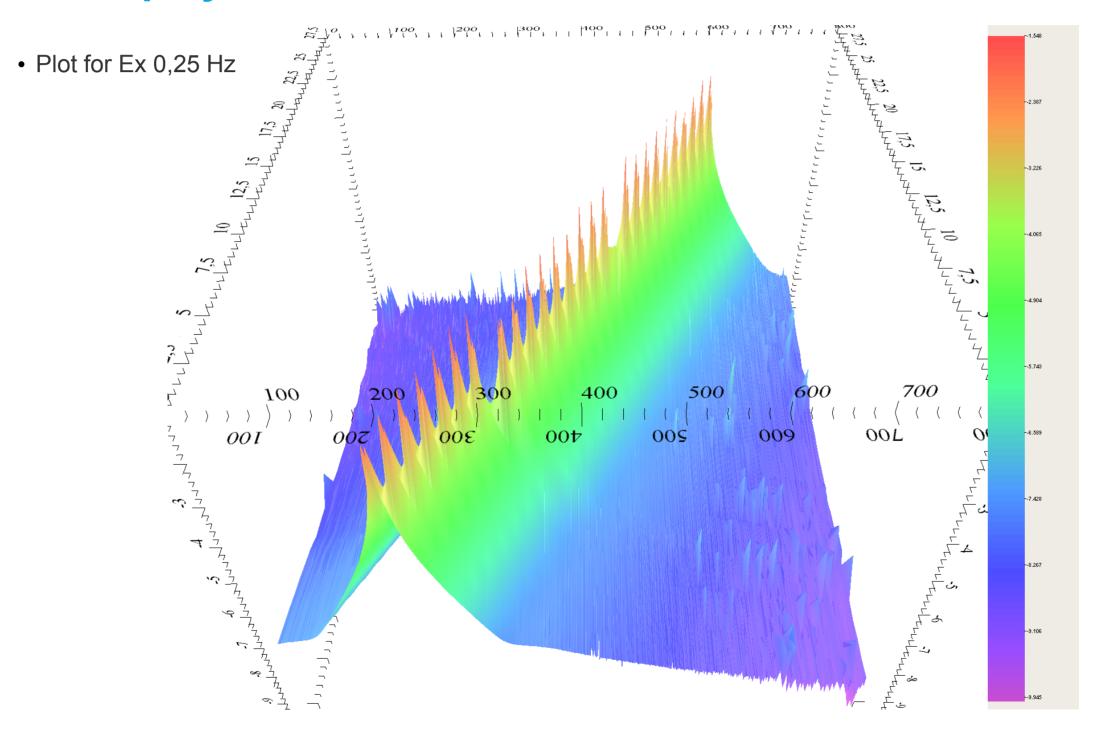
Rx ID	Rotated	Angle [deg]	E-data	H-data	Remarks		
01Rx001a	E+H	28.32	Excellent	Excellent			
01Rx002a	E+H	19.42	Excellent	Good			
01Rx003a	E+H	97.57	Excellent	Excellent			
01Rx004a	E+H	129.29	Excellent	Excellent			
01Rx005a	E+H	71.68	Excellent	Excellent			
01Rx006a	E+H	111.95	Excellent	Good			
01Rx007a	E+H	155.84	Good	Excellent			
01Rx008a	-	-	No Data	No Data			
01Rx009a	E+H	149.42	Excellent	Good			
01Rx010a	E+H	111.1	Excellent	Excellent			
01Rx011a	E+H	150.75	Excellent	Excellent			
01Rx012a	E+H	81.42	Excellent	Excellent			
01Rx013a	E+H	69.91	Excellent	Good			
01Rx014a	E+H	137.26	Excellent	Excellent			
01Rx015a	E+H	-176.02	Excellent	Excellent			
01Rx016a	E+H	161.59	Excellent	Excellent			
01Rx017a	E+H	117.52	Excellent	Excellent			
01Rx018a	E+H	95.04	Good	Excellent			
01Rx019a	E+H	106.42	Good	Excellent			
01Rx020a	E+H	-188.67	Excellent	Excellent			
01Rx021a	E+H	14.69	Excellent	Excellent			
01Rx022a	E+H	-140.62	Excellent	Excellent			
01Rx023a	E+H	49.56	Excellent	Excellent			
01Rx024a	E+H	-168.32	Excellent	Excellent			
01Rx025a	E+H	-120.71	Excellent	Excellent			
01Rx026a	E+H	173.89	Excellent	Excellent			
01Rx027a	E+H	137.35	Excellent	Excellent			
01Rx028a	E+H	130.8	Excellent	Excellent			
	Remarks						

Table: Final quality assessment - Summed and rotated - CYCL01Tx002a

Rotation only applies to horizontal components (x,y)

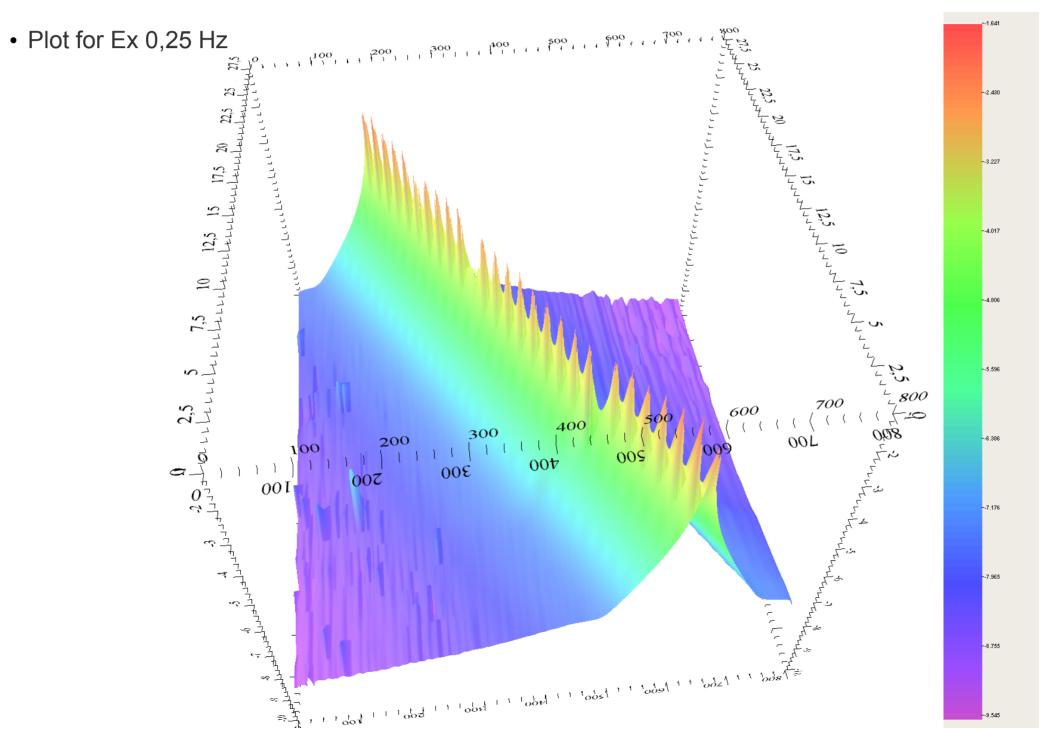


## 3D display of recorded data for Tx001





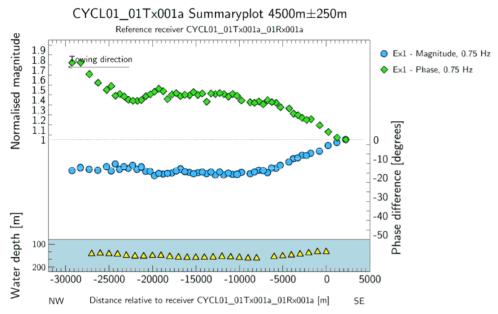
# 3D display of recorded data for Tx002



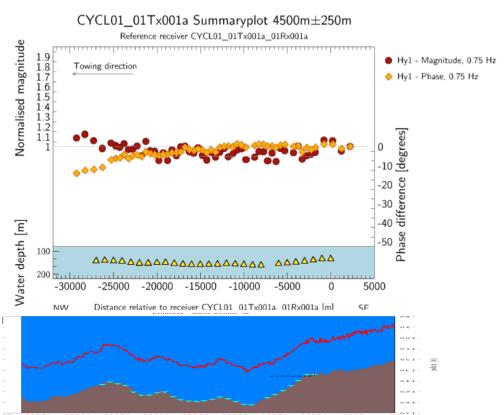


# Normalized MVO & Difference in PVO plots

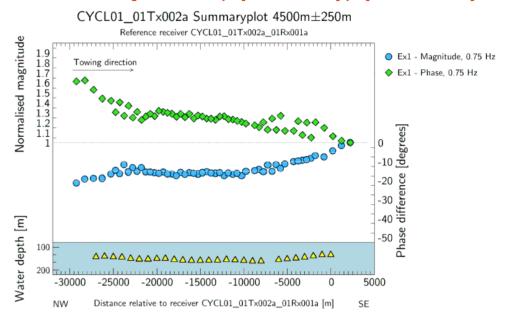
### Electric response, (4.5km), (0.75Hz)



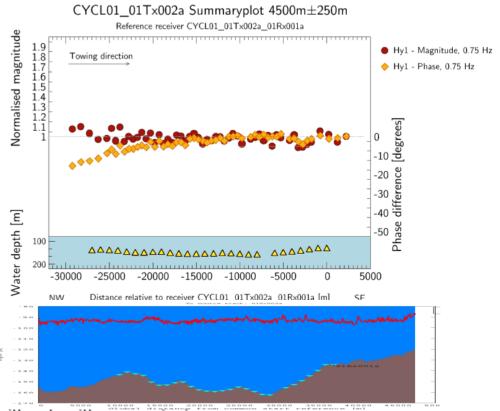
### Magnetic response, (4.5km), (0.75Hz)



### Electric response, (4.5km), (0.75Hz)



### Magnetic response, (4.5km), (0.75Hz)



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### **Summary of MVO & PVO plots**

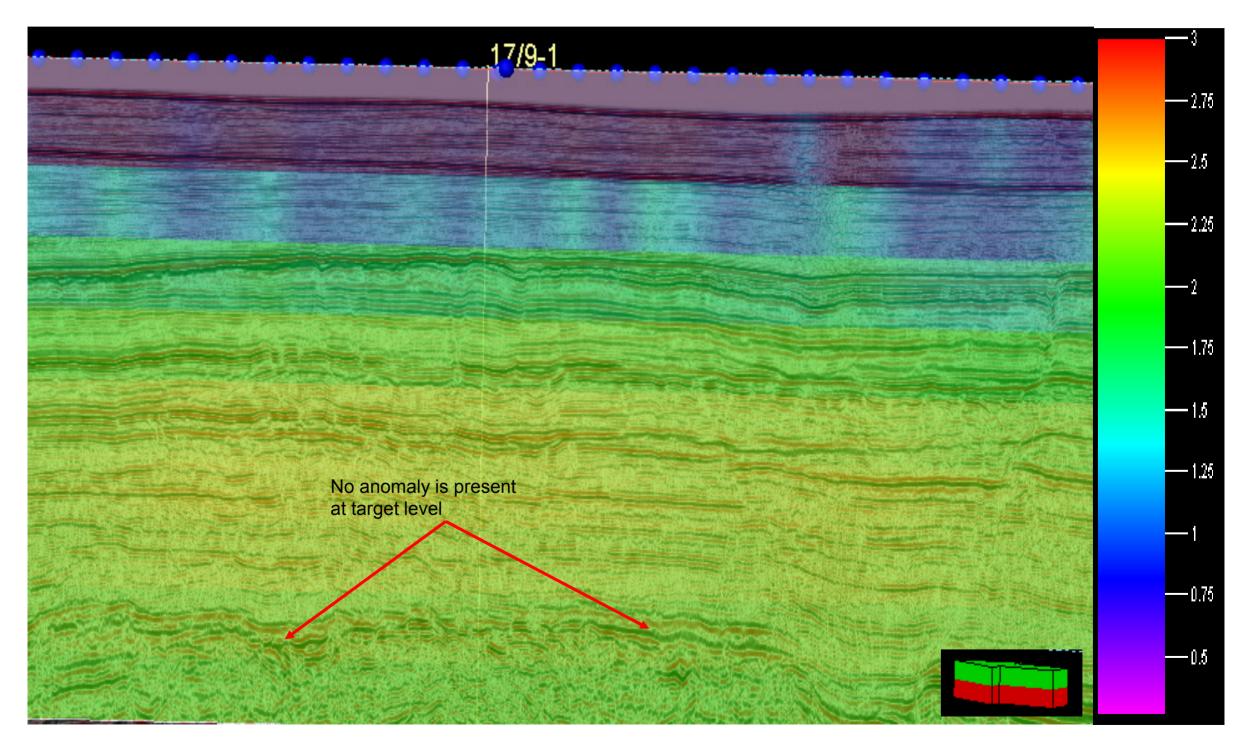
- Data shows an overall good quality
- A trend with increasing response towards southeast, the response is consistent with increasing amplitude and decreasing phase.
- The response increases with increasing frequency up to 1.75 Hz
- The response correlates with the bathymetry and values are in the same order of the calculated bathymetry induced response differences



# 9. 3D INVERSION



## Inversion result displayed on parallel seismic line seismic





# **SUMMARY**

## **EM line: 01CYCL**



### Value Comments

Geology evaluation				
Water depth (<500, 500-1000, >1000m)	>200			
Bathymetry (flat, dipping, varying)	Dip/vary ing			
Background Resistivity from 1 (easy) to 3 (complex)	2			
Expected target response (high, med, low)	low			
Quality Summary				
Control of Geologic Setting from 1 (good) to 3 (poor)	1	Uncertainty in resistivity but control of geology from seismic data		
MVO and PVO (normalized response) from 1 (strong) to 6 (weak)	5	Correlates to bathymetry		
Raw data from 1 (good) to 3 (poor)	2	Some source data navigation issues		
Inversion from 1 (good) to 3 (poor)	2			
Misfit from 1 (good) to 3 (poor)	2			
Inversion anomaly at target – Y or N:	N			
Intensity if anomaly is present from 1 (strong) to 3 (weak)	-			
Anomaly consistency from 1 (good) to 3 (poor)	-			
Positive Reliability (%)	75	Based on revised modelling using target resistivity of 30 Ohmm and thickness of 80 m		
Negative Reliability (%)	80	Structure could potentially cause response, confirmed by modelling		
Inversion anomaly outside target – Y or N:	N			
Intensity if anomaly is present from 1 (strong) to 3 (weak)				
If Y, can it be related to secondary prospectivity (Y/N)				
Positive Reliability (%)				
Negative Reliability (%)				
Summary (+3 is very pos., 0 is inconcl., -3 is very neg.)	-2			
Comments				
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## **Summary of Chance-Of-Success**

Pg	18%	percentage
Positive Reliability	75%	percentage
Negative Reliability	80%	percentage

### **Outputs:**

Updated COS - Positive	45%	percentage
Updated COS - Negative	6%	percentage

Pg:	Probability of geologic success as estimated today, i.e., without any additional information (EM or otherwise).
Positive Reliability	EM Reliability when HCs ARE present. In a situation in which, in reality, hydrocarbons exist at a given location, what is the probability that running an EM survey will allow us to correctly interpret that there are hydrocarbons present?
Negative Reliability	EM Reliability when HCs ARE NOT present. In a situation in which, in reality, hydrocarbons are not present at a given location, what is the probability that running an EM survey will allow us to correctly interpret that there are no hydrocarbons present?
Updated COS	The updated Chance of Success is calculated through a Bayesian approach. The updated positive and negative COS refers to the updated probability of success for respectively a positive and negative interpretation of the EM data

The updated Chance of Success for a thick hydrocarbon filled good quality reservoir is after the EM analysis updated to 6%

A low quality reservoir with a thin Hydrocarbon column may still be present

Units



# Licence summary and conclusions

## Summary – positive and negative aspects



#### • Pro:

- High resource potential (increased post application as a result of seismic interpretation work and reservoir parameters analysis)
- Nearby discoveries working petroleum system in area although small accumulations only.
- Some indications from seismic data relating to AVO anomalies

### • Con:

- High risk prospect (18% pre-CSEM update, 6% post-CSEM update)
- AVO indications are small in comparison to prospect totality possibly non commercial but difficult to track on current 2D grid
- High chance of reservoir deterioration as a result of diagenetic mixing with volcanics (extensive volcanics described by Furnes Et Al. (1982) extending up to 30km in the N-S direction and 20km in E-W direction
- No EM response detected optimistic case reservoir parameters expected to show clear EM response at prospect location however this is not observed in the real data. This suggests that poorer reservoir conditions may prevail meaning although EM cannot de-risk the prospect there is a chance the trap could still be filled (albeit under poorer reservoir conditions)

## PL456 conclusions – relinquishment decision 🗢 ROCKSOURCE

#### Conclusions:

- High risk prospectivity cannot be satisfactory de-risked further through the application of CSEM technology
- Partial stack analysis suggests that any seismic features showing dimming (typical oil filled class I AVO response) are small and are unlikely to be economically viable as stand alone prospects. The observed response may also be associated with the Bryne Fm coals
- The key risk elements reservoir presence/quality and source and migration still have significant associated risk and basin modelling work only slightly reduced the charge risk.
- The decision is to therefore relinquish licence PL456 as the geological risk associated with the prospect is too high for 3D seismic acquisition to be justified: the lack of a strong DHI (either seismic or CSEM) indicates that future work, even inclusive of 3D seismic data, will unlikely improve the overall prospect chance of success to a level required to make a drilling decision.