Developing Tight Gas in a Mature Basin - United Kingdom North Sea*

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Abstract

Numerous undeveloped gas discoveries remain undeveloped in the UK Southern North Sea despite their common proximity to production infrastructure. The UK Oil and Gas Authority estimates 3.8 TCF of gas is currently stranded in the basin, mostly in discoveries in low permeability sandstones, each with less than 100 BCF of potential recoverable resource and is implementing a strategy to 'Maximise Economic Recovery'. However, technical advances in well productivity, combined with the point in the economic cycle are driving development plans. Significant ullage in a nearby late-life pipeline (LAPS) will not be available beyond 2023 without developing additional gas, so time is of the essence. One such development project is outlined in this article which is projected to produce up to 400 BCF in conjunction with 1 GW of wind-hybrid electricity. Production would amount to 2% of the UK's power needs and 4% of its indigenous gas production by 2022.

In the central part of the Southern Gas Basin in the UK is a major inverted basin where the primary reservoir, the Early Permian Rotliegendes aeolian-dominated sandstone, has been deeply buried and uplifted during the Tertiary inversion of the Sole Pit Basin. This has led to significant burial diagenesis, including illitization that has reduced unstimulated well productivity to sub-economic levels. Recent use of horizontal multi-hydraulically fractured wells in the Clipper South Field has demonstrated the commerciality of developing these tight reservoirs. Horizontal hydraulically fractured wells testing dry gas at over 20 mmscpfd compare better than unstimulated wells testing at less than 1 mmscfpd. OK Energy has built a portfolio of tight gas assets in neighbouring acreage and is proposing development of a hub and up to four satellites. The development of these reserves depends on several factors all aligning at the same time in order to create a good economic outcome: proven tools to overcome low permeability issues, low cost drilling and other capex, industry synergies, access to under-utilised infrastructure and strengthening gas prices.

ICE2018
International Conference & Exhibition

Developing Tight Gas in a Mature Basin

UK North Sea

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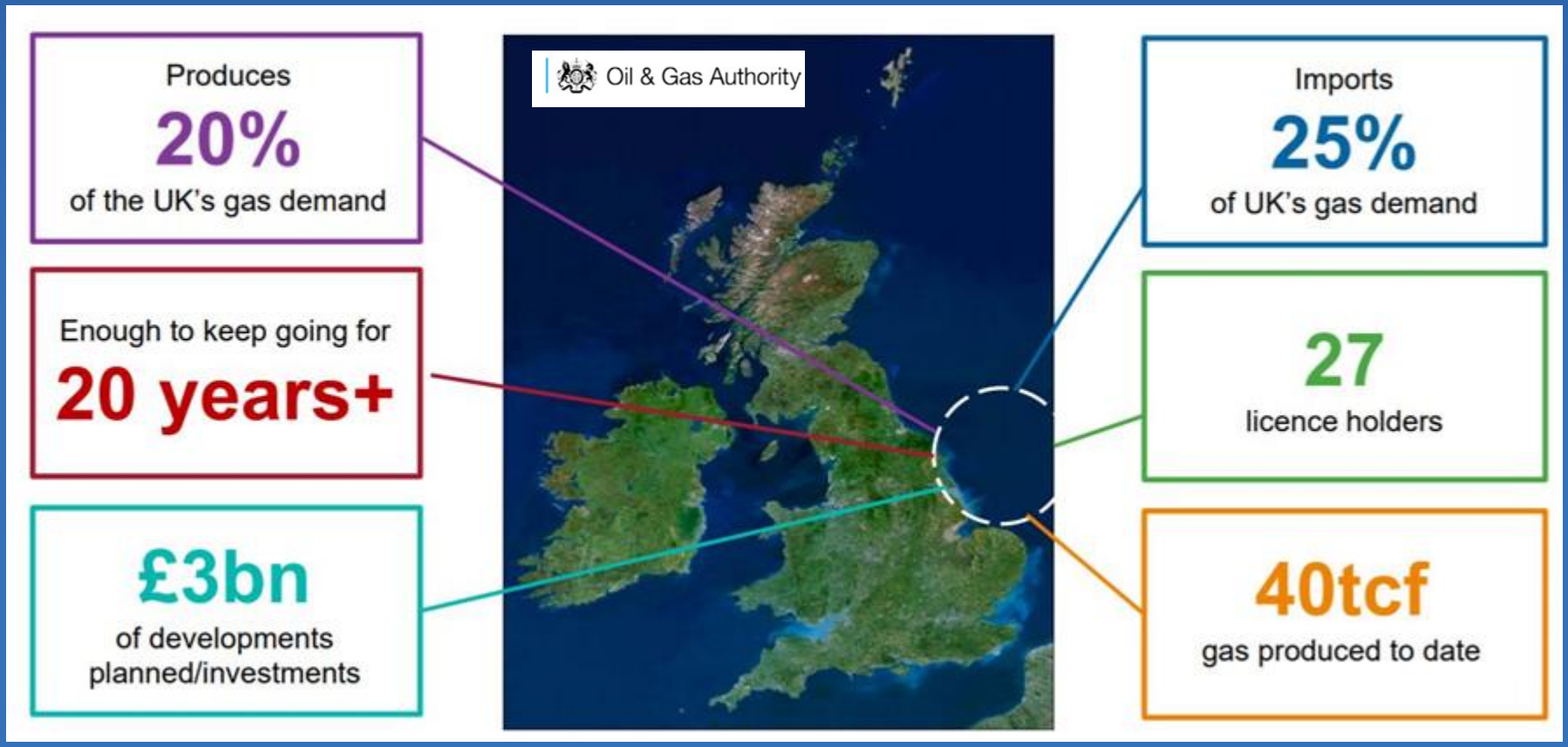
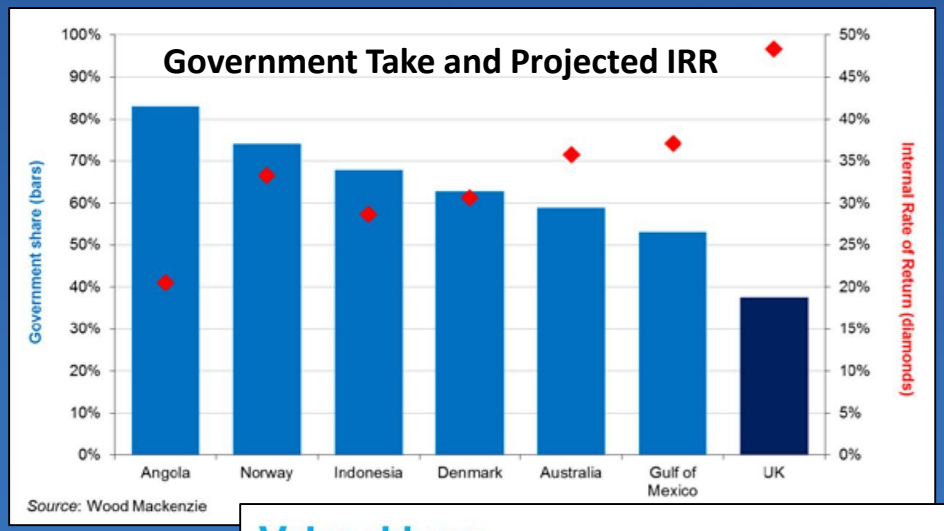
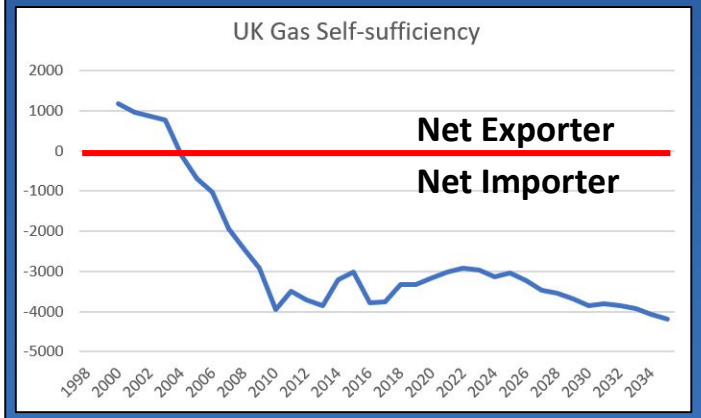
AAPG

UK Southern North Sea
Strategic conventional gas basin

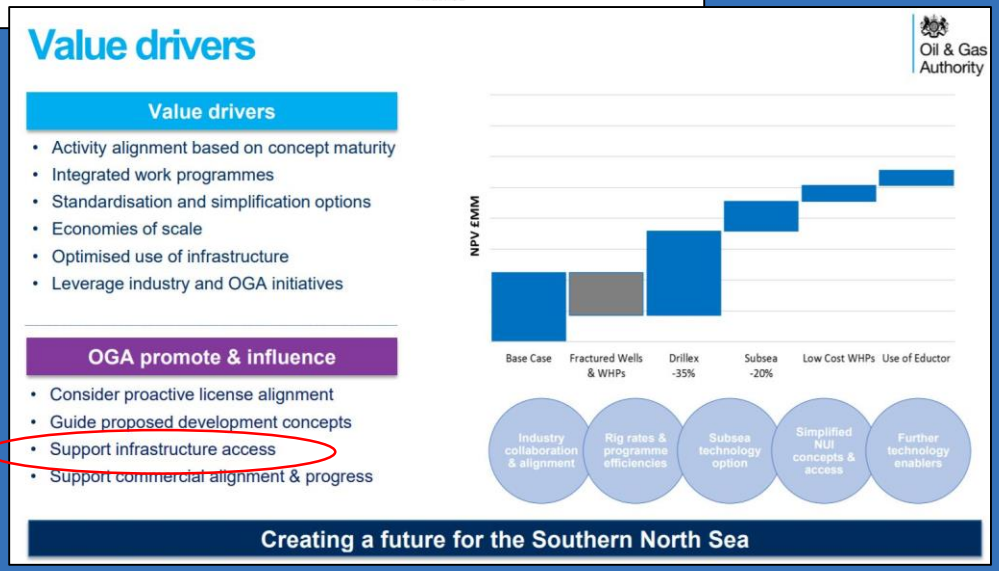


Commercial Case for UK Gas



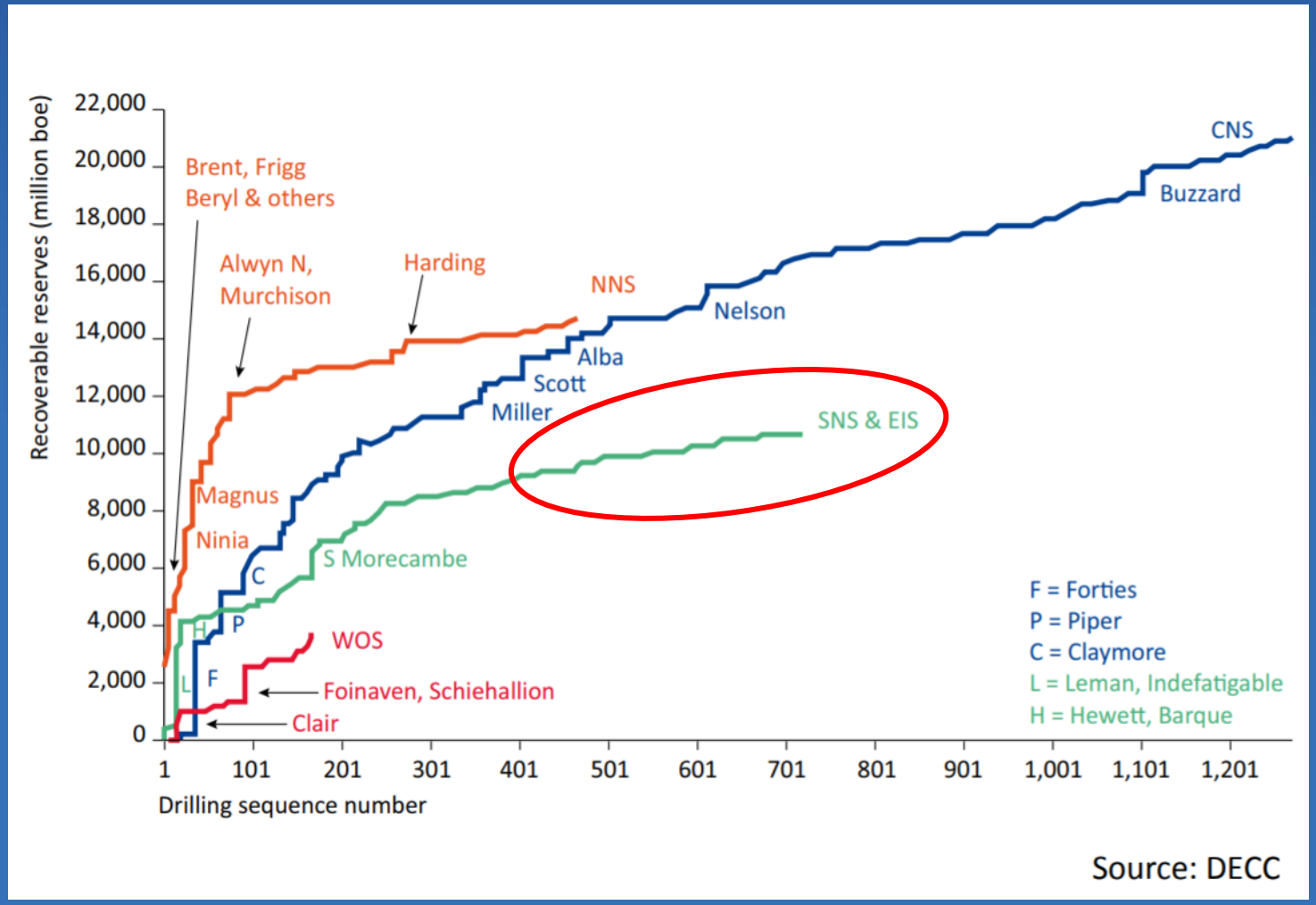


No realistic potential for reversing import dependency

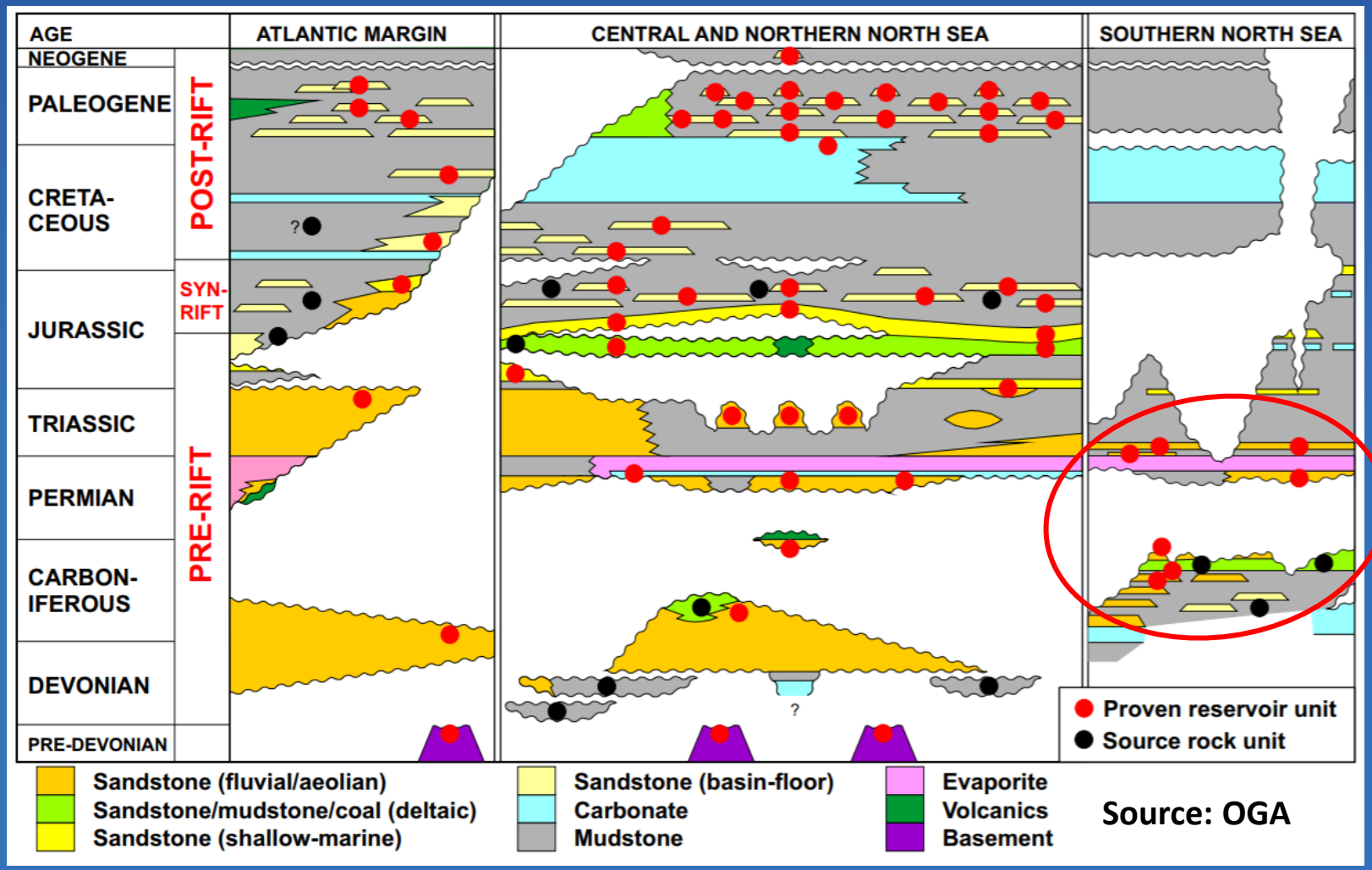


Government initiatives to Maximise Economic Recovery

SNS is a highly mature basin…



… with relatively limited play types



2TCF undeveloped gas in existing plays

SNS strategic priorities

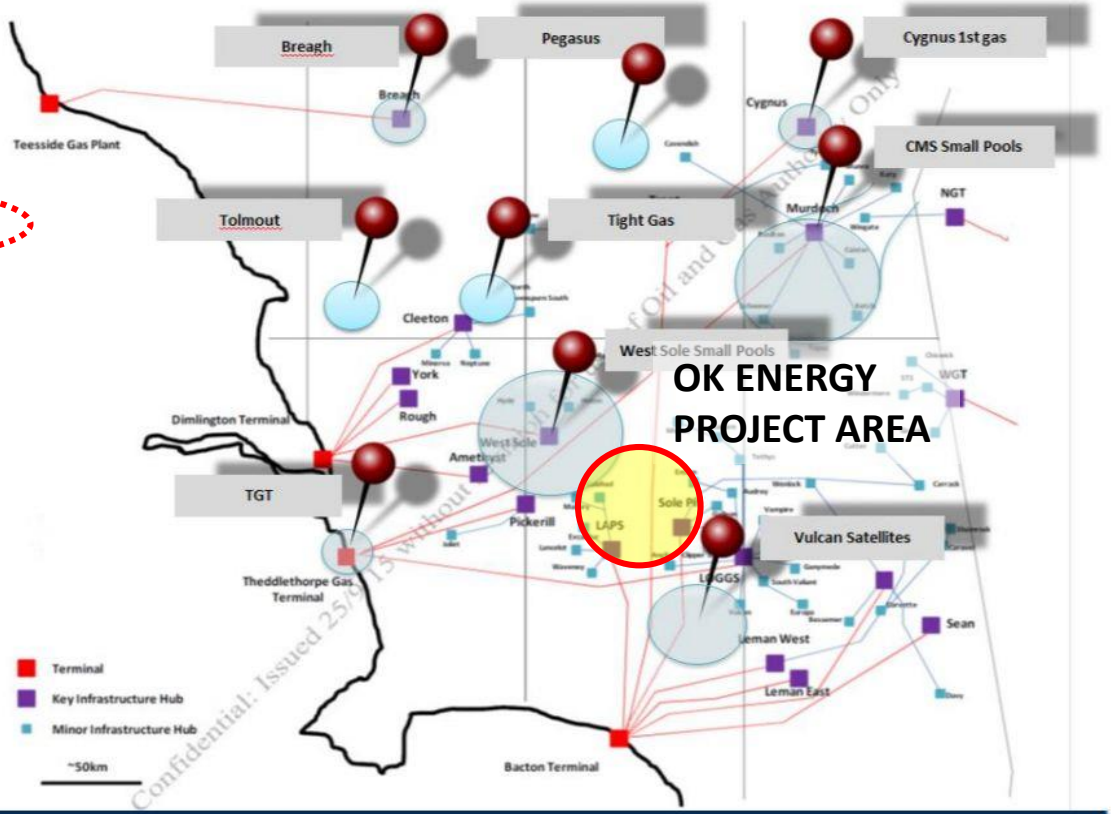
Oil & Gas Authority

Significant potential remains

- **3.7 tcf** remaining from current assets
- **2.9 tcf** from further drilling in current fields
- **2.1 tcf** discovered undeveloped new fields

SNS focus

- Promote exploration and appraisal activity
- Deliver major developments and projects
- Protect critical infrastructure
- Support marginal and small pool developments
- Tight gas collaboration across the basin
- SNS Energy Hub: GTW opportunities
- Efficient decommissioning



Creating a future for the Southern North Sea

Vast Majority of Undeveloped Reserves in Permian Rotliegendes Play…

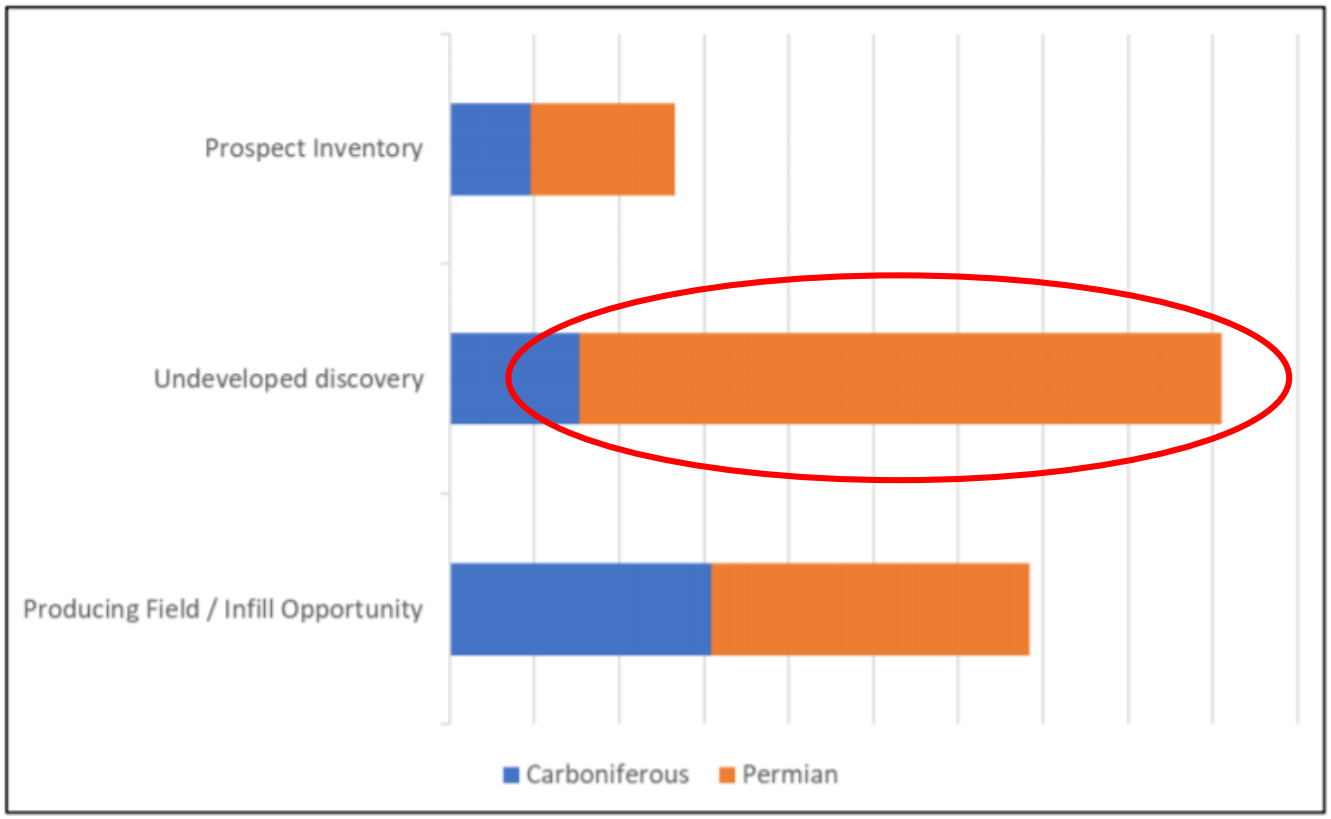
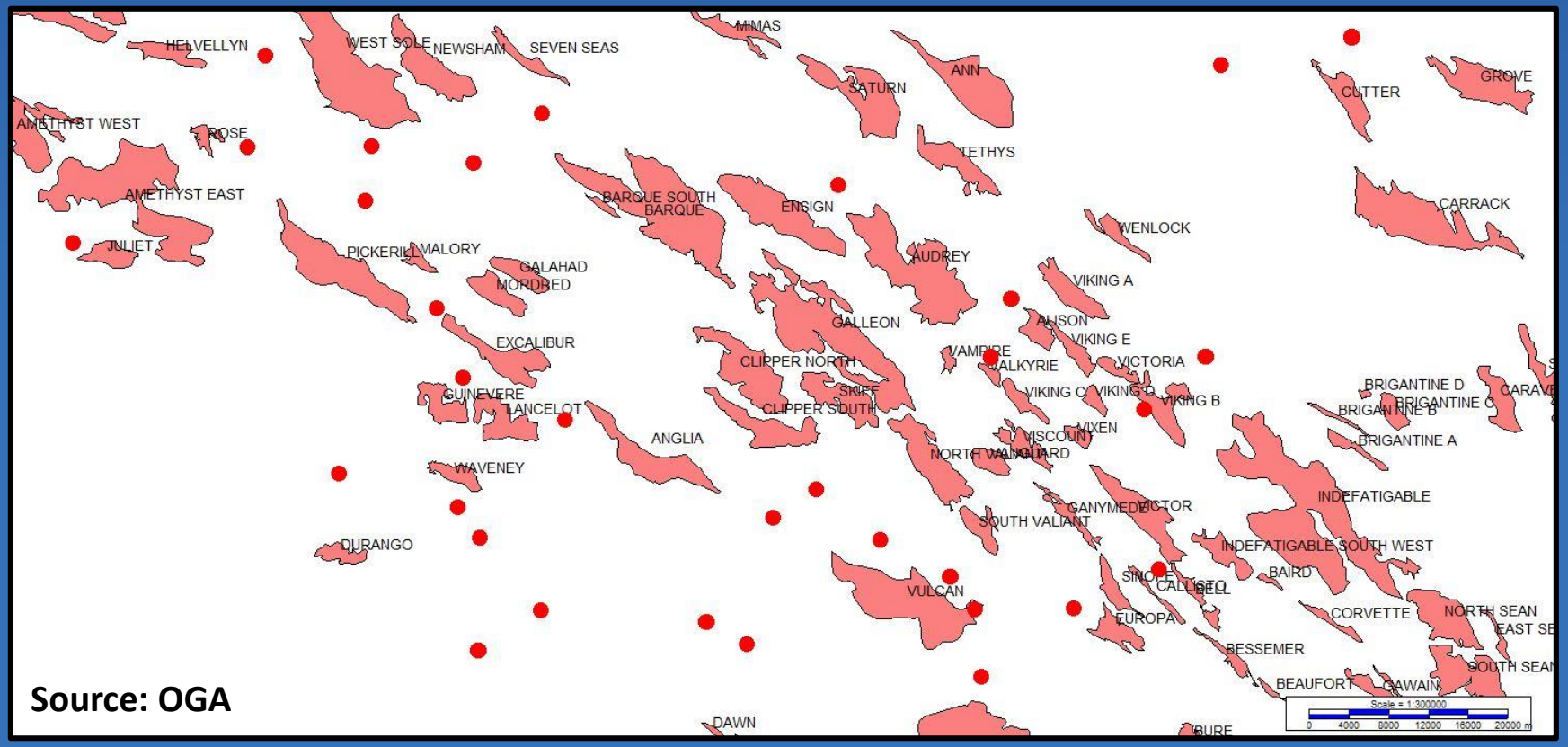


Figure 4: distribution of SNS tight gas opportunities by geology (OGA)

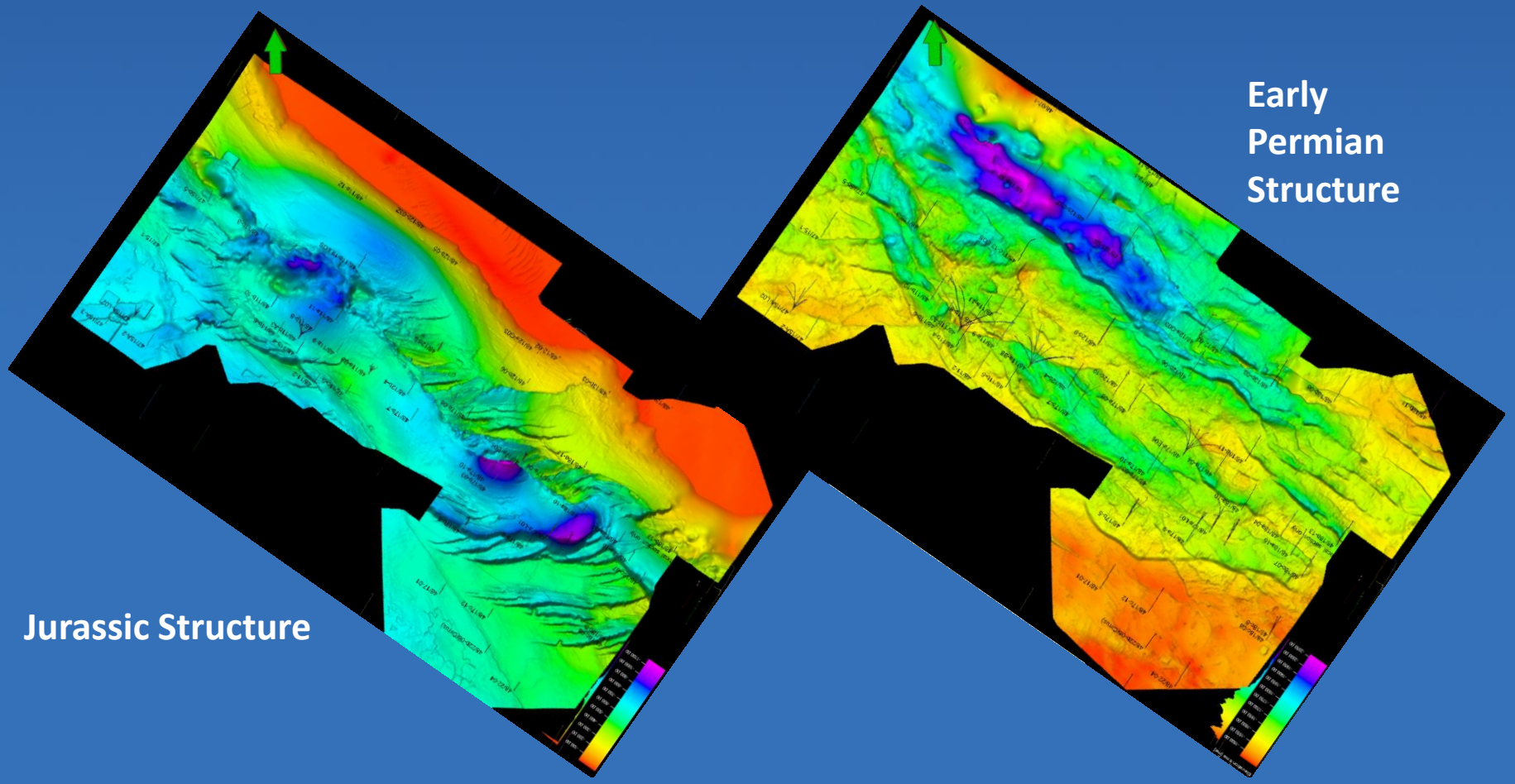
Large number of individual gas discoveries in Permian Rotliegendes Play



Source: OGA

Rotliegendes Reservoir Challenges

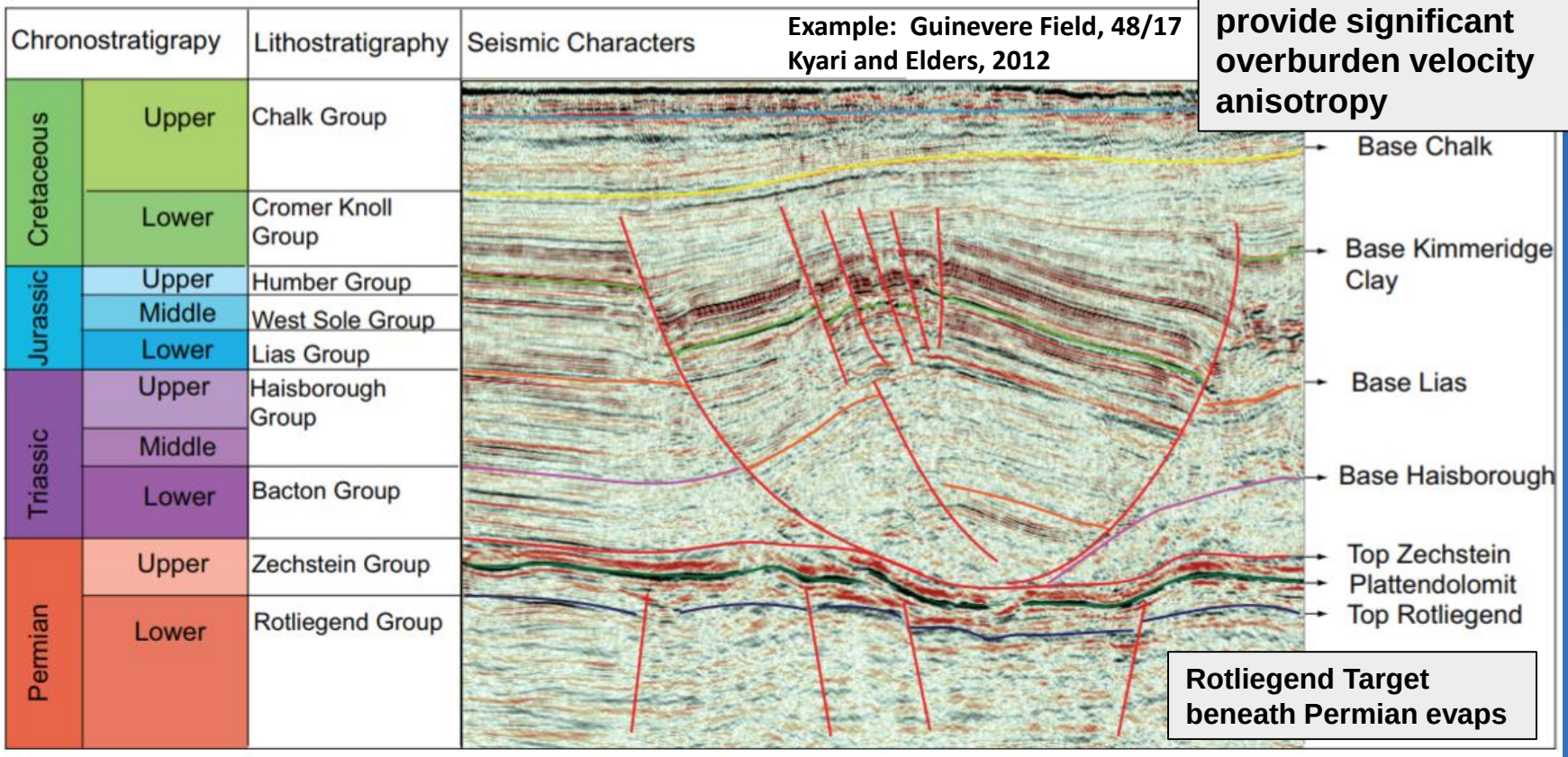
Depth Conversion – Structural Discordance



Rotliegendes Reservoir Challenges

Depth Conversion

Widespread Mesozoic remnant grabens provide significant overburden velocity anisotropy

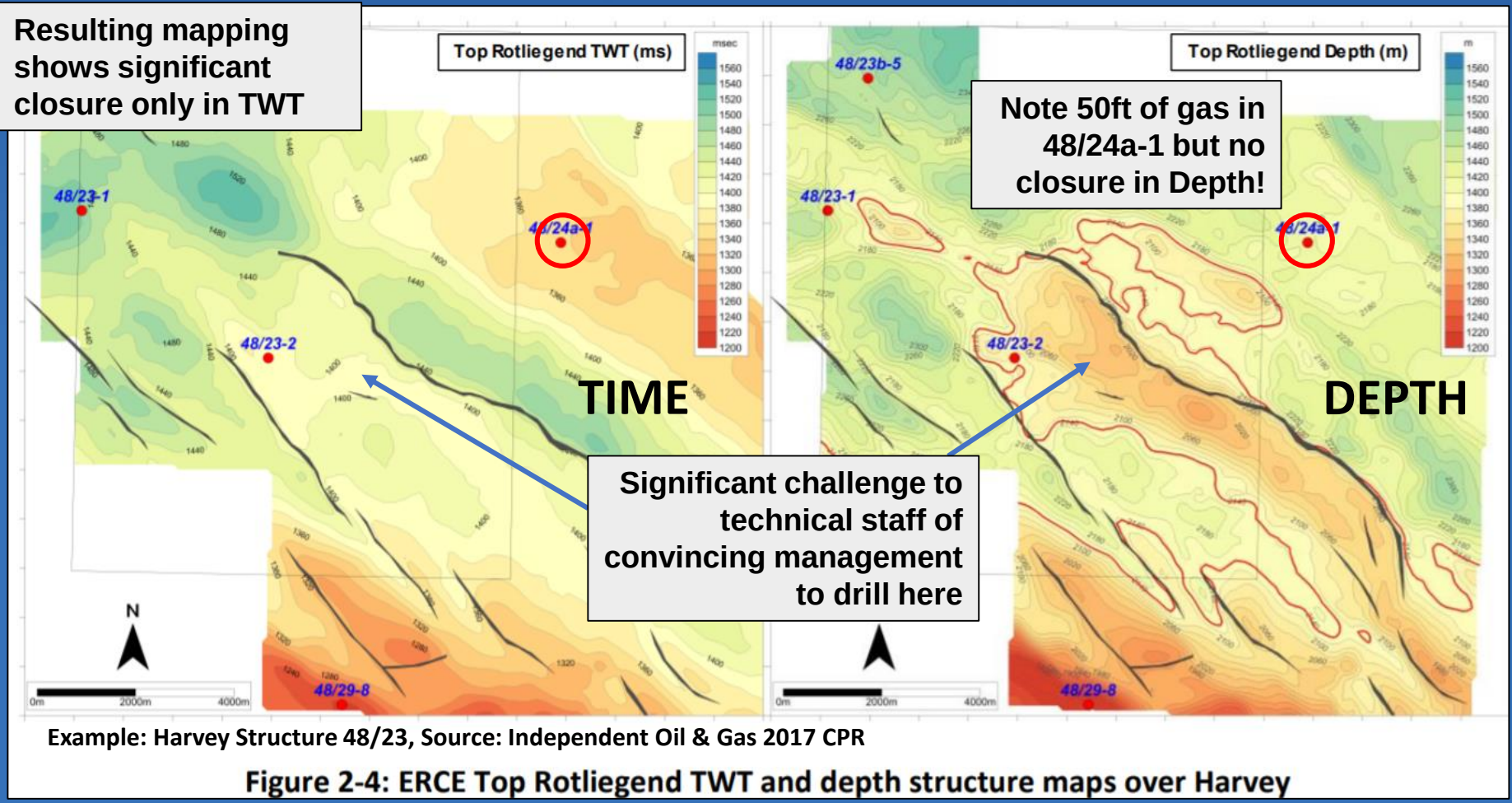


Seismic horizons picked and stratigraphy of Guinevere field,Southern North Sea.

Rotliegendes Reservoir Challenges

Depth Conversion – Example 1

Resulting mapping shows significant closure only in TWT



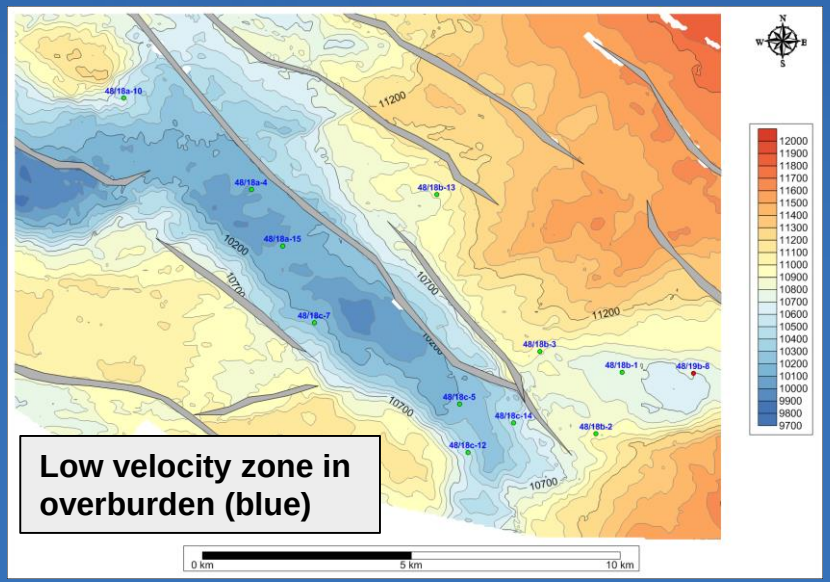
Example: Harvey Structure 48/23, Source: Independent Oil & Gas 2017 CPR

Figure 2-4: ERCE Top Rotliegend TWT and depth structure maps over Harvey

Rotliegendes Reservoir Challenges

Depth Conversion – Example 2

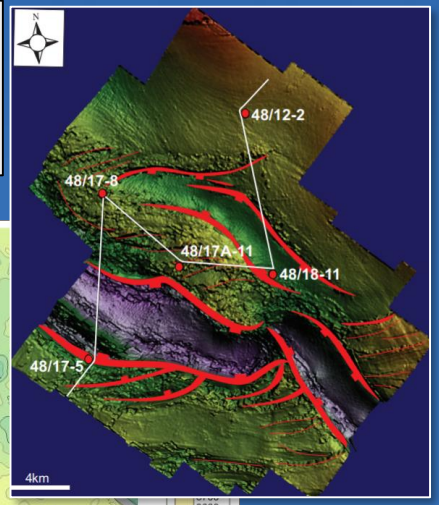
Anisotropy boundaries proved too sharp for PSDM to accurately image.
Decision taken to go back to first principles and layer-cake depth convert time data

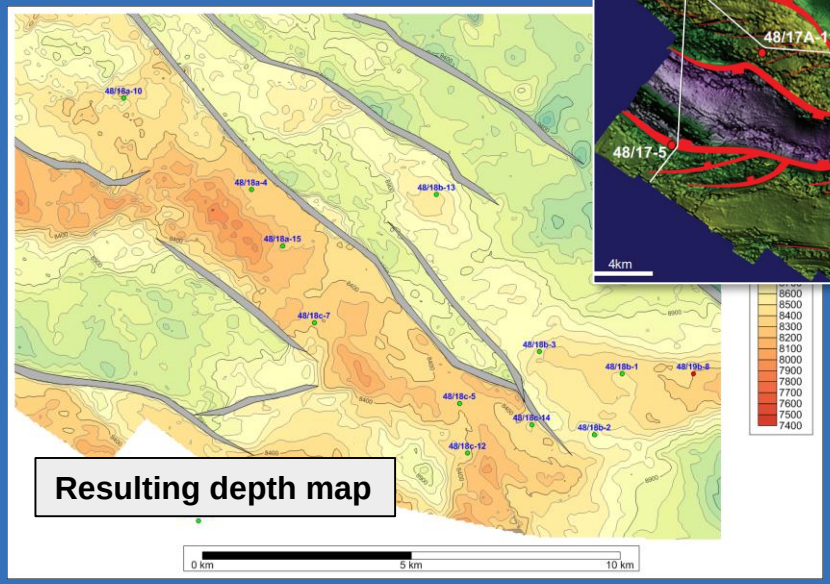


Low velocity zone in overburden (blue)

Velocity contrast between graben and unfaulted areas is over 20%

Mesozioc faults want to trend WNW instead of underlying Palaeozoic NW fabric, so results in stepping of grabens

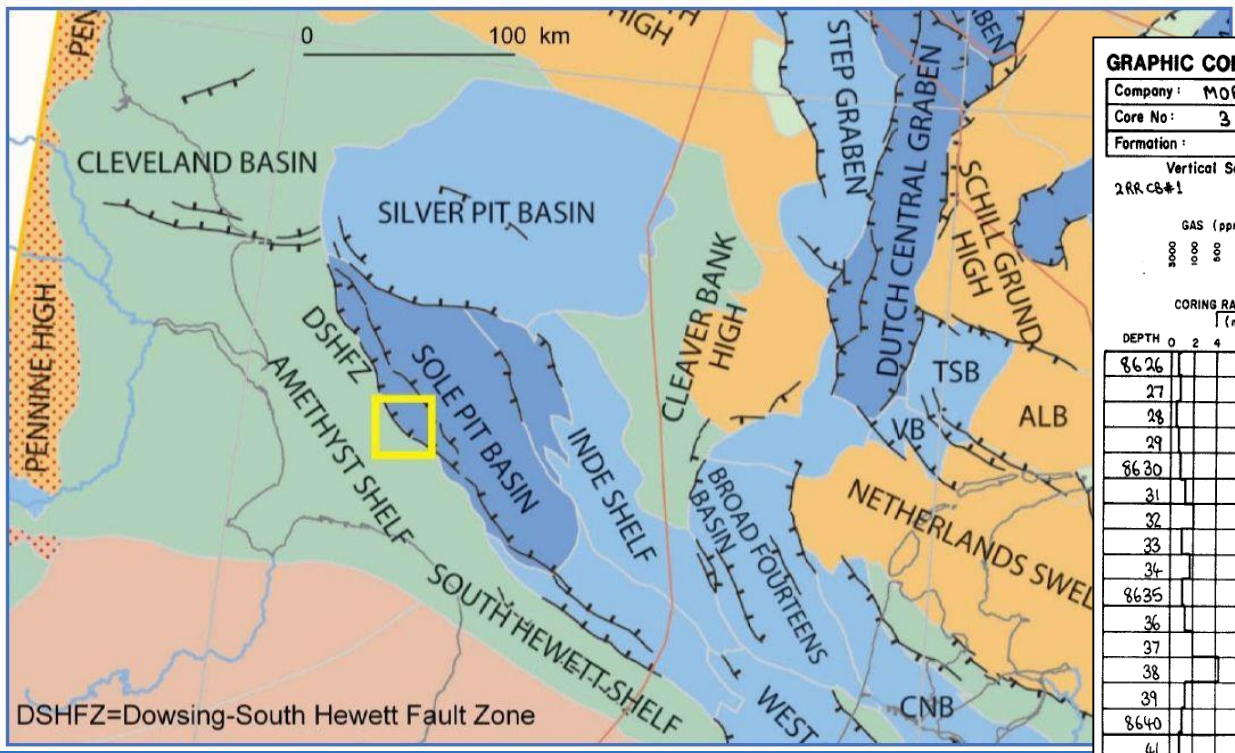


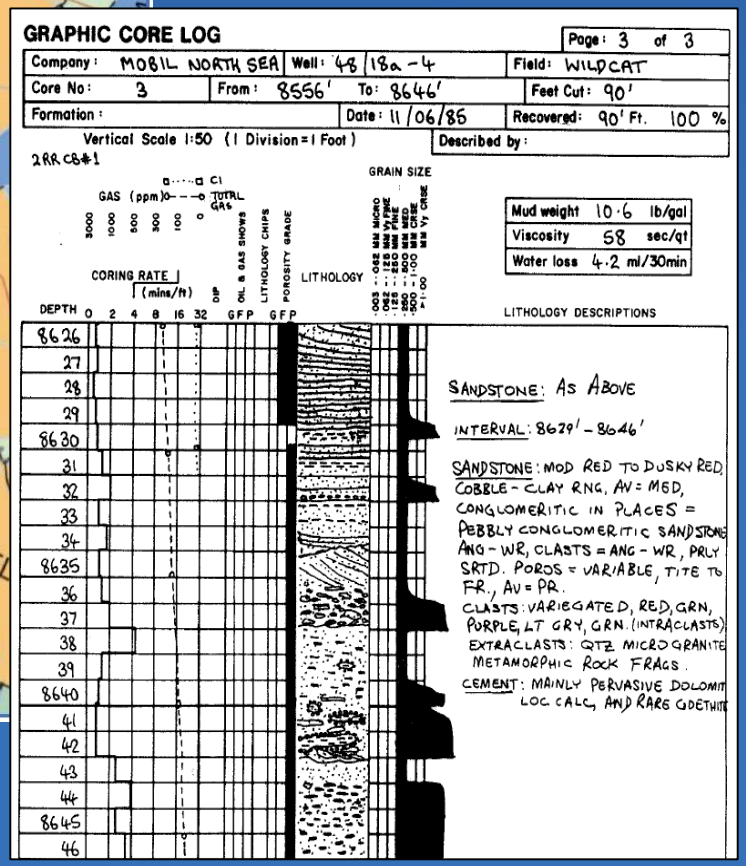


Resulting depth map

Rotliegendes Reservoir Challenges

Pre-inversion diagenesis




GRAPHIC CORE LOG

Page: 3 of 3

Company: MOBIL NORTH SEA | Well: 48/18a-4 | Field: WILDCAT

Core No: 3 | From: 8556' To: 8646' | Feet Cut: 90'

Formation: | Date: 11/06/86 | Recovered: 90' Ft. 100 %

Vertical Scale 1:50 (1 Division = 1 Foot) | Described by:

2RR C&S#1

GAS (ppm) | TOTAL GAS | CORING RATE (mins/ft) | DEPTH | LITHOLOGY | GRAIN SIZE | POROSITY GRADE | OIL & GAS SHOWS | LITHOLOGY CHIPS

Mud weight	10·6 lb/gal
Viscosity	58 sec/qt
Water loss	4·2 ml/30min

LITHOLOGY DESCRIPTIONS

SANDSTONE: AS ABOVE

INTERVAL: 8629' – 8646'

SANDSTONE: MOD RED TO DUSKY RED, COBBLE – CLAY RNG, AV = MED, CONGLOMERITIC IN PLACES = PEBBLY CONGLOMERITIC SANDSTONE ANG – WR, CLASTS = ANG – WR, PRLY SRTD. POROS = VARIABLE, TITE TO FR., AV = PR.

CLASTS: VARIEGATED, RED, GRN, PURPLE, LT GRY, GRN. (INTRACLASTS); EXTRACLASTS: QTZ MICRO GRANITE METAMORPHIC ROCK FRAGS.

CEMENT: MAINLY PERVASIVE DOLOMIT LOC CALC, AND RARE GOETHITE

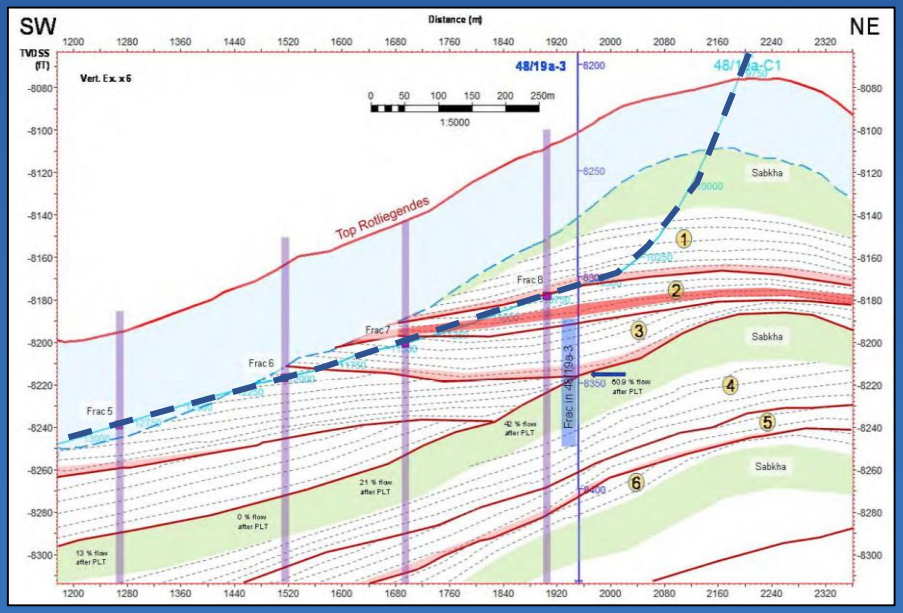
Significant pre-inversion burial in the Sole Pit has degraded the initially excellent dune facies sands of the Rotliegendes to c.10% Φ, sub mD K.

The Low Perm Problem

- Tight Rotliegend vertical wells have historically tested at around 3mmscfpd
- Post-frac 10mmscfpd – sub-economic for sub-50bcf reserve cases

EXAMPLE 'OLD SCHOOL' WELL ECONOMICS			
Well Initial			10mm
Number of Wells			1
Reserves	bcf		31
Revenue	£mm		157
Capex	£mm		68
Opex	£mm		91
Pre-TCF	£mm		3
Tax	£mm		0
ATCF	£mm		3
NPV10	£mm		-9
IRR	%		1%
Payback	Years		

Solving the Low Perm Problem



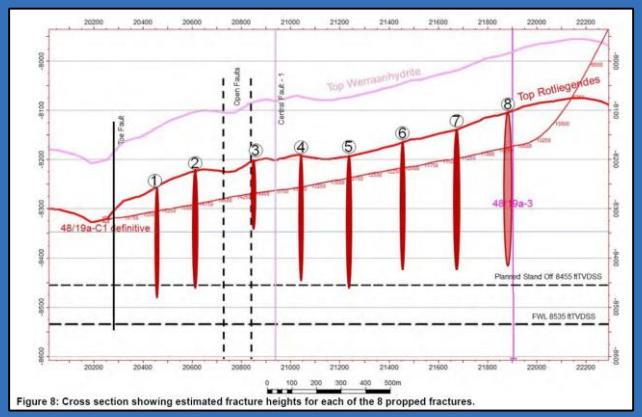


Figure 8: Cross section showing estimated fracture heights for each of the 8 propped fractures.

Source: Shaoul J *et al*, 2013, SPE

Highly successful recent development - Clipper South

Horizontal multi-fracced wells – target 30mmscfpd initial per well

Hi perm streaks 10mD along dune foresets

Fractures generally closed, compartmentalised

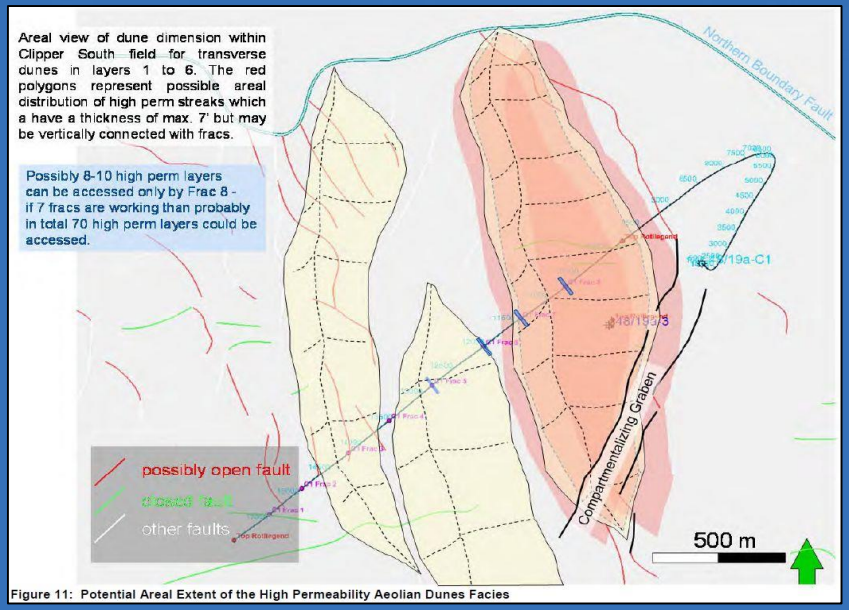


Figure 11: Potential Areal Extent of the High Permeability Aeolian Dunes Facies

Solving the Low Perm Problem

Clipper South discovery well tested 3mmscpd post-frac

First unstimulated horizontal well tested at 1.5mmscpfd

Field was given up for dead in 1992

20 years later - First multi frac (8) horizontal well drilled and came on-stream at 43mmscfpd

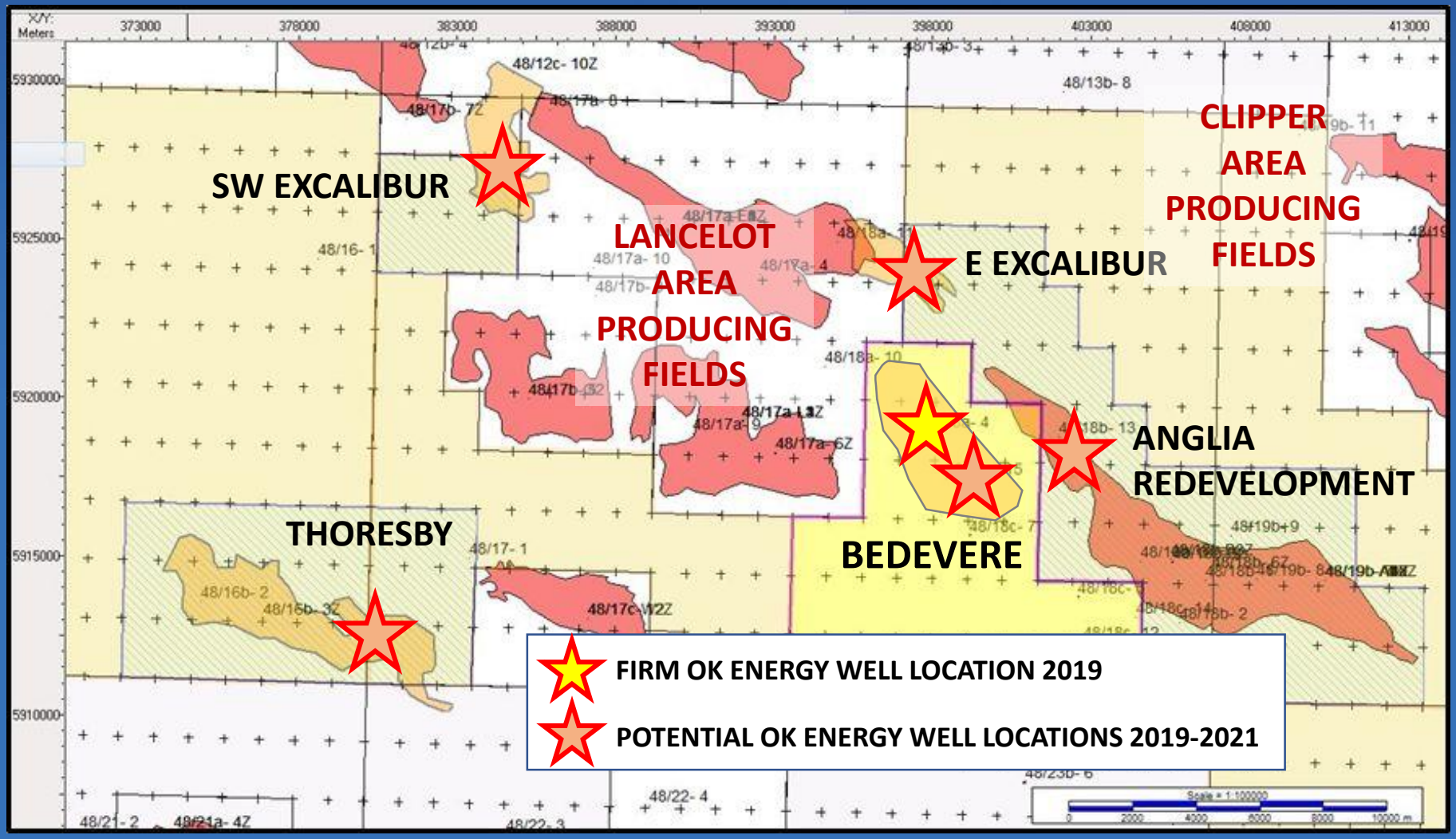
Current field production 60-80mmscfpd

There is more where that came from – up to 2.1 TCF worth*

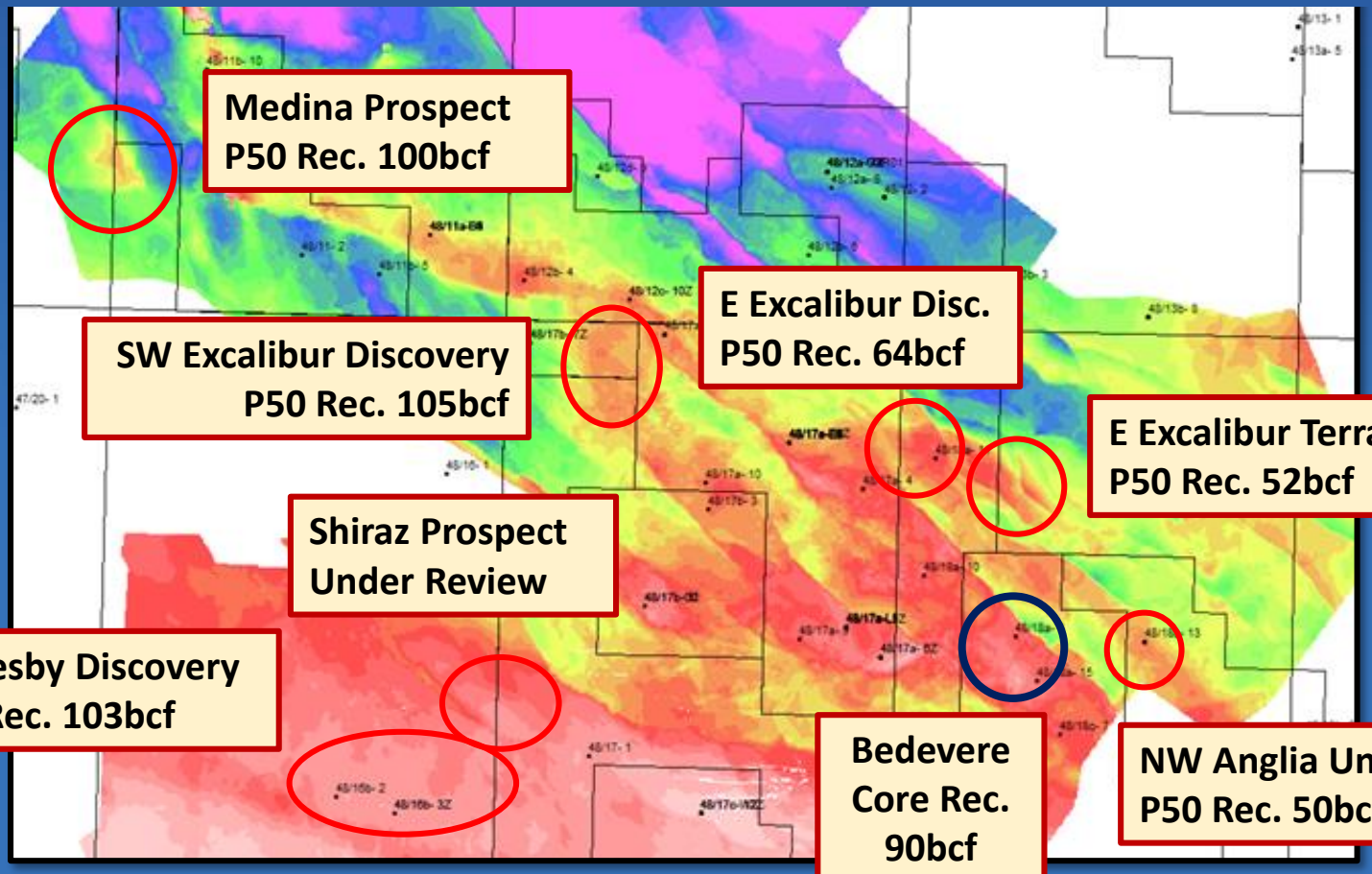
With the advances in tight gas, it is rapidly becoming low hanging fruit

* According to the OGA

Building a Critical Mass of Resource



500bcf within 20km

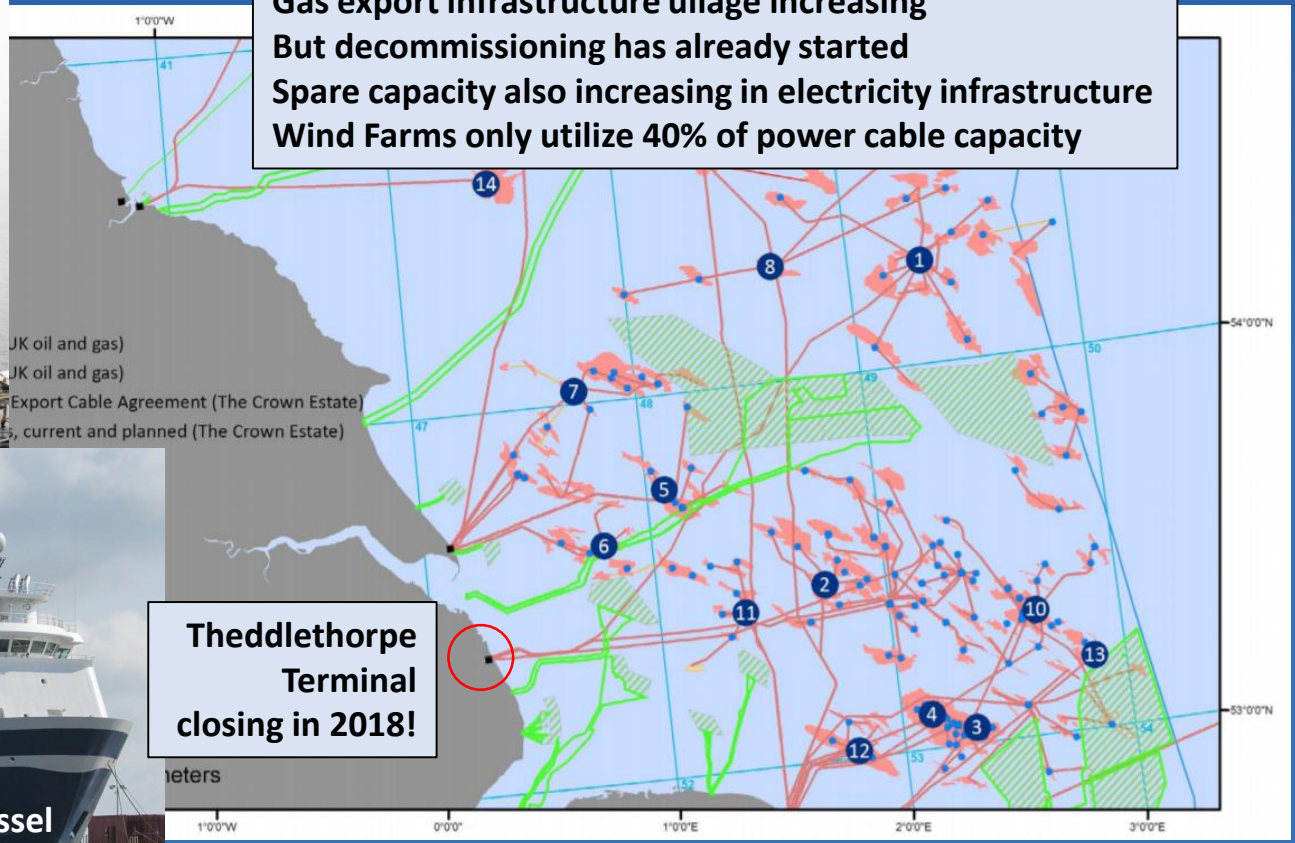


The ‘Use it or Lose it’ Case for Development

Target day rate for modern Jackups Q1 ‘19 North Sea sub $60k/day

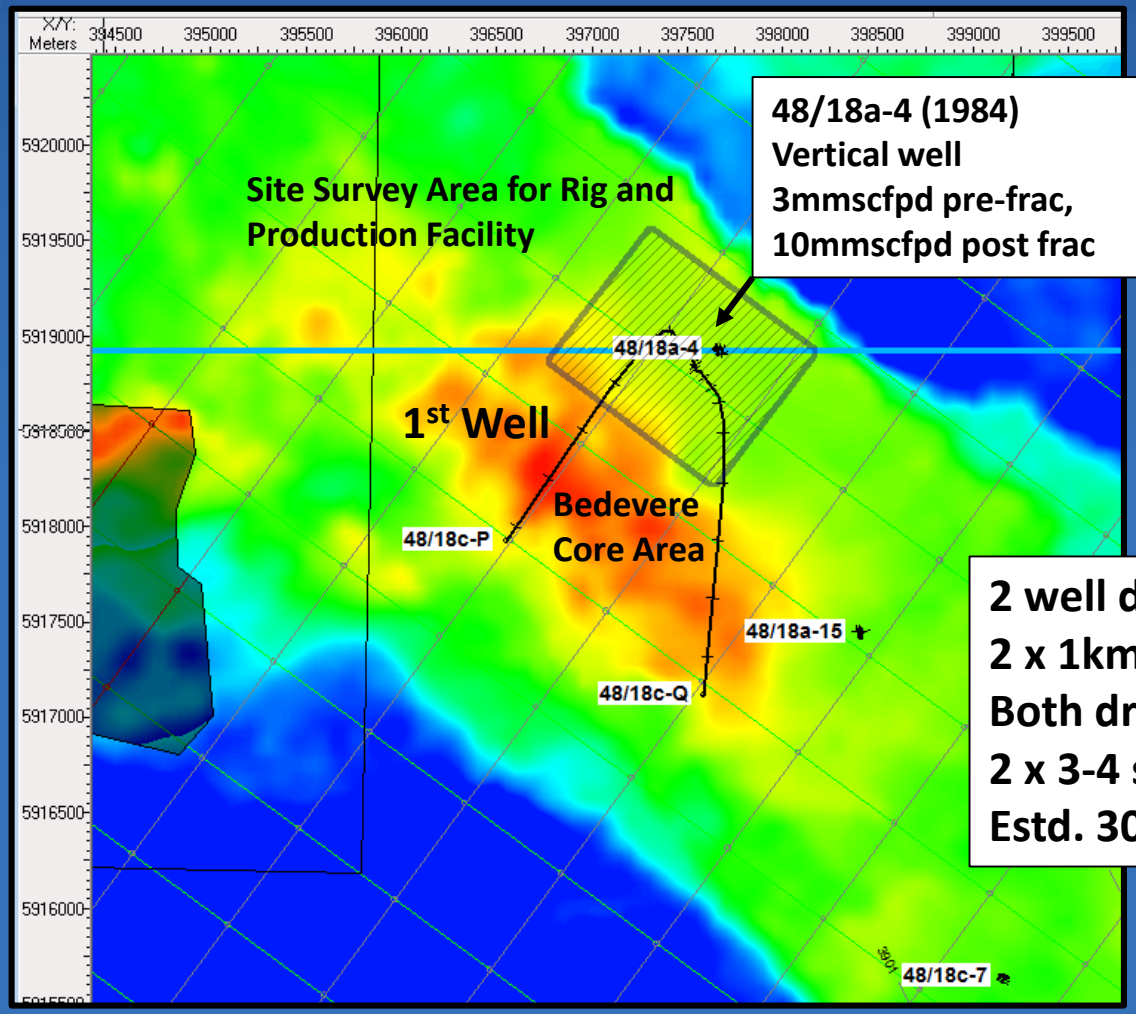
BH Frac Stimulation vessel
Slashing rig time for fraccing

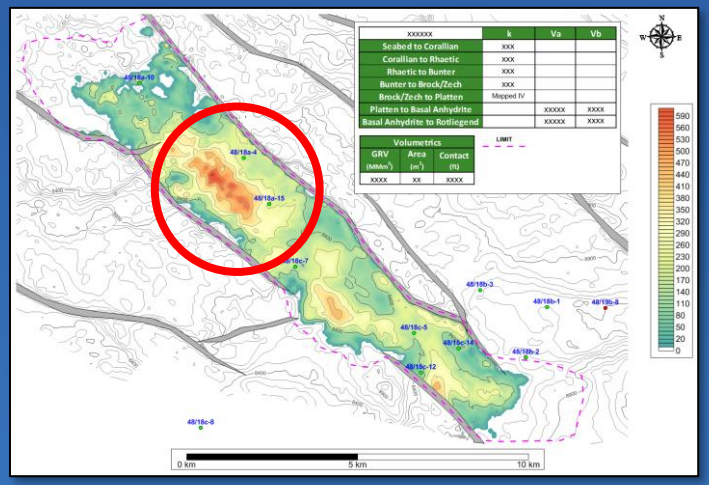
Gas export infrastructure ullage increasing
But decommissioning has already started
Spare capacity also increasing in electricity infrastructure
Wind Farms only utilize 40% of power cable capacity



Theddlethorpe Terminal closing in 2018!

First well planned for 2019





2 well development in P50 case
2 x 1km horizontals
Both drilled from close to #4 location
2 x 3-4 stage frac completions
Estd. 30mmscfpd per well initials

Summary

- UK Southern North Sea is a mature basin with limited new plays
- ‘Hiding in plain sight’ an estimated 2.1 TCF discovered resource
- Remaining undeveloped primarily because of reservoir quality issues and secondly because of depth conversion complexity
- Advances in multifracced wells transform field economics
- Hub concepts required to take advantage of significant ullage in gas export lines
- Current low drilling cost coupled with strong gas price futures and UK energy security are the key drivers