The North Sea proved to be a new frontier for the oil companies when they first arrived.

They had been offshore before elsewhere in the world, but never in waters quite so stormy or deep.

They would try their existing technologies at first, but these were put to severe test and often failed.

New ways of doing things were needed if the oil was ever going to be recovered and given the specific problems they faced, the engineering required was colossal.
The challenges were met and now the North Sea has outperformed every other petroleum province in the world.

At an anticipated recovery factor of 46%, North Sea recoveries are top in class.

Average recovery factor worldwide: 22%
United States: 39%
Saudi Arabia: 23%

Global oil reserves - Recovery factors leave vast target for EOR Technologies.
• Top in class recovery factor of 46%
• But why?
• North Sea is a high-cost offshore area
• That doesn’t intuitively look right...
Factors favouring high oil recoveries in the North Sea

-Predominantly sandstone reservoirs

-Relatively minor component of carbonate reservoirs (mostly chalk too)

-Light oil and easier to produce
Oil price hike in 1973 quadrupled the oil price just before North Sea started up.

Made waterflooding economically attractive.

Most North Sea fields – waterflooded from start-up.
One other difference – many onshore fields are drilled on a grid pattern with a high density of well spacing.

It’s not practical to do this offshore - for a start well costs are up to 10x higher

Instead, offshore wells are carefully located to optimise sweep

Need to understand reservoirs in detail – has been a driver for new technology.
SOME OF THE NEW TECHNOLOGY SINCE THE UK NORTH SEA STARTED UP IN 1975

1970s  Routine use of 3D seismic (first survey shot by Exxon in 1967)

1980s  Start of routine horizontal well drilling

1980s  Increasing use of geostatistics in reservoir geology

1980s  Locate The Remaining Oil techniques developed

1990s  Common use of 3D computer models in reservoir geology

1990s  Vastly improved resolution of 3D seismic

1990s  Common use of 4D seismic

1990s  Implementation of Enhanced Oil Recovery techniques

1990s  Growing understanding of structural geology as applied to reservoirs

2000  Integrated reservoir management teams
‘Some very big fields were discovered early on in the North Sea and six of them provided over 60 per cent of the UK’s oil production in the first 10 years after 1975 – Forties, Brent, Ninian, Piper, Magnus and Beryl.

All of these fields are still producing in 2015 and between them have produced almost a third of the UK’s oil to date. They are the work-horses of the North Sea oil industry.’

Shepherd 2015, ‘Oil Strike North Sea’

So how are they doing today?
# THE BIG SIX – A SCORE CARD

<table>
<thead>
<tr>
<th>FIELD</th>
<th>PRODUCTION 2016 Billion barrels oil</th>
<th>Recovery Factor as of 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>FORTIES</td>
<td>2.74</td>
<td>~ 61%</td>
</tr>
<tr>
<td>BRENT</td>
<td>2.02</td>
<td>~ 53%</td>
</tr>
<tr>
<td>NINIAN</td>
<td>1.22</td>
<td>~ 47%</td>
</tr>
<tr>
<td>PIPER</td>
<td>1.09</td>
<td>~ 80%</td>
</tr>
<tr>
<td>MAGNUS</td>
<td>0.86</td>
<td>~ 56%</td>
</tr>
<tr>
<td>BERYL</td>
<td>0.84</td>
<td>~ 40%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>8.77</td>
<td></td>
</tr>
</tbody>
</table>

All but one currently above the 46% oil recovery factor for the North Sea
'After 25 years, reserves for large [UK] fields had grown by some 50% on average.'
R.W. Bentley, *Introduction to Peak Oil*

Source: DECC

https://itportal.decc.gov.uk/pprs/full_production.htm
Detailed integration of 4D seismic with reservoir characterisation

Batch drilling of infill wells to achieve economy of scale
BRENT FIELD - IMPROVED RECOVERY

Application of Locate The Remaining Oil (LTRO) Techniques

- Understand the large scale geological features that control flow
- Map the fluid contacts in each reservoir unit

Application of drilling technology – horizontal, extended reach and coiled tubing.

Late field life – the Brent field was depressurised and essentially turned into a gas field.
Application of Enhanced Oil Recovery techniques

- Water Alternating Gas
TOP IN CLASS – COULD TRY HARDER?

NORWAY OG21 STRATEGY – At one point had identified a stretch target of 55% recovery, now aiming to ‘break through the current level of 46%.’

STATOIL TARGET:  http://www.statoil.com

About recovery methods

Statoil has set world-leading targets for recovery factor, with a goal of 65% as an average for platform operated fields and 55% from subsea-operated fields.

UK OIL AND GAS AUTHORITY

1.2 Role of the OGA

The OGA’s role is to regulate, influence and promote the UK oil and gas industry to achieve its statutory principal objective of maximising the economic recovery of UK offshore oil and gas resources.
MY HOBBY HORSE - LOCATING THE REMAINING OIL (LTRO)

- Perhaps only six or seven geological features control reservoir connectivity and the location of reservoir dead ends in a typical oil field.

- These are large-scale features that may not be obvious unless you look for them.

- Necessary to integrate the geological framework with production data to do the work. Once you have established the framework controlling flow behaviour then you have a much better chance of working out where the remaining oil is to be found.

- I call LTRO the ‘missing workflow’ because as a procedure it is not integrated within existing geological modelling software.

- Yet it can be an excellent method for finding infill well targets in many reservoirs.

From Gill and Shepherd 2010
CONCLUSIONS

Through skill, technology, good timing and a bit of luck the North Sea has ended up with the best oil recoveries anywhere in the world.

If the oil price improves we might even be able to improve on this.

AND A FINAL THOUGHT....

If the global oil recovery factor is only 22% and the world has produced say 10% of the global oil resource – then improving the recovery factor by 10% would produce all the world’s oil all over again.

That would make the global oil recovery factor 32% and it would still be less than the North Sea where it is 46%....