The importance of stratigraphic plays in the undiscovered resources of the UKCS

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Unreleased seismic data courtesy of:
CGG Veritas, Fugro Group, PGS, Shell & WesternGeco
Introduction

- Historical perspective: UKCS fields & discoveries (as of end 2005)

- Review of stratigraphic plays & play maturity in pre-rift to post-rift play groups
  - *pre-rift*: reservoirs typically sheet-like, stratigraphic entrapment uncommon
  - *syn- & post-rift*: stratigraphic entrapment in deep-water systems of major importance

- Conclusions – the future is stratigraphic…
UKCS discovered recoverable reserves: 53.5 BBOE
(at end 2005, Proven + Probable + Possible)

UKCS undiscovered recoverable reserves: 4.4 – 8.7 – 19.4 BBOE
(at end 2005)

Maturing………
but not in old age yet
UKCS technical success rate (to end 2005)

2248 exploration wells drilled to end 2005
Technical success rates:
  1964-2005 average = 31%
  2001-2005 average = 36%
Trap types in UKCS fields and discoveries

Proportional: numbers of fields

- 81% structural
- 12.5% Combination
- 6.5% Stratigraphic

Proportional: in-place volumes

- 75% structural
- 20% Structural
- 5% Combination
- 20% Stratigraphic

UKCS discovered recoverable reserves: 53.5 BBOE
(at end 2005, Proven + Probable + Possible)
UKCS fields & discoveries size distribution chart (end 2005)

Distribution of structural traps and stratigraphic/combination traps

IN PLACE VOLUMES
UKCS discoveries – stratigraphic context
Trap types in UKCS fields and discoveries

- 43 plays defined
- 15 play groups
- 7 gross plays
Palaeozoic: 22% of discovered recoverable reserves. 2.5% are combination traps.

Rotliegend play

Carboniferous plays (North Sea)

Basement, Devonian, Carboniferous & Permian plays
Pre-rift: Carboniferous (e.g. Southern North Sea)

Sub-Permian erosional traps of effectively sheet-like fluvial sands
Three proven sub-regional intraformational seals
Pre-rift: Lower Permian Rotliegend (e.g. Southern North Sea)

Rotliegend Group schematic facies development, Southern North Sea Basin
Pre-rift: Lower Permian Rotliegend (e.g. Southern North Sea)
Pre-rift: Triassic - Lower Jurassic

11% of discovered recoverable reserves. 4% occur in combination traps

Predominantly fluvial plays

Skagerrak~Cormorant~Statfjord (oil) plays

Triassic-Lower Jurassic: 11% of discovered recoverable reserves. 4% occur in combination traps

Predominantly fluvial plays

Bunter~Hewett~Sherwood (gas) plays
Pre-rift: Triassic - L Jurassic (e.g. West of Shetland)

Strathmore discovery, block 205/26, East Solan Basin (up-dip erosional truncation trap)

After Herries et al (1999)
Pre-rift: Middle Jurassic

Middle Jurassic: 21% of discovered recoverable reserves. 2% occur in combination traps

Fluvio-deltaic to shallow marine plays
Pre-rift: Middle Jurassic (e.g. Brent play)

Brent Field, block 211/29, East Shetland Basin

Syn-rift: Upper Jurassic

Upper Jurassic plays

Deep-water play only

- Structural
- Combination
- Stratigraphic

Upper Jurassic: 20% of discovered recoverable reserves. 25% occur in stratigraphic and combination traps

Shallow marine plays – mainly structural
Deep marine plays – 51% stratigraphic/combination
Syn-rift: Upper Jurassic (e.g. Brae/Miller)

Field outlines

Overlapping fans

Syn-rift: Upper Jurassic (e.g. Moray Firth)

Lead featured on DTI Promote UK 2005 CD
Syn-rift: Upper Jurassic (e.g. Fulmar play)

West Central Shelf, UK CNS:
Stratigraphic play of Fulmar Formation within embayments formed above dissolving salt diapirs e.g. Kittiwake and Dauntless fields. Triassic Skagerrak sandstone forms a secondary reservoir.
Post-rift: Lower Cretaceous

Lower Cretaceous: 4% of discovered recoverable reserves. 78% occur in stratigraphic and combination traps

Deep marine sandstone plays
Post-rift: Lower Cretaceous plays (e.g. Moray Firth)

Highlander Field, block 14/20, Outer Moray Firth

Post-rift: Lower Cretaceous plays: Central Graben

After Milton-Worssell et al. 2006
Post-rift: Lower Cretaceous deep-water play, West of Shetland

Prospect featured on DTI Promote UK 2005 CD
Post-rift: Lower Cretaceous deep-water play, West of Shetland

Prospect featured on DTI Promote UK 2005 CD
Post-rift: Upper Cretaceous

Upper Cretaceous: >1% of discovered recoverable reserves. 23% occur in combination traps

Deep marine play (Chalk), limited to Central North Sea
Post-rift: Upper Cretaceous, Central North Sea

Constriction trap
e.g. Halfdan, but low effective permeability

Hydrodynamics likely to be of key importance in subtle traps

After Megson & Harding (2001)
Post-rift: Upper Cretaceous, Central North Sea

Chalk primary reservoir development, Lindesnes Ridge, Norwegian Central Trough
After Oakman & Partington (1998)
Post-rift: Upper Cretaceous, Central North Sea

e.g. Edda Field (Norway):
Productive limits of field are approximately delineated by the seismic amplitude anomaly seen at top Tor Formation

UK Central North Sea example

From BGS poster presented at DTI Chalk Workshop 2005
Post-rift: Upper Cretaceous - Rockall Basin

Turonian play:
(cf. Faroe-Shetland Basin) Localised mass-flow sands shed off basin margin identified from seismic amplitude anomaly.

From DTI Promote UK 2007 CD
Post-rift: Paleogene

Paleogene plays

Paleogene: 22% of discovered recoverable reserves, 50% of which occur in stratigraphic and combination traps

Predominantly deep marine plays, but fluvio-deltaic plays locally important
Post-rift: Paleogene plays (e.g. Northern North Sea)

From DTI Promote UK 2007 CD
Post-rift: Paleogene plays (e.g. Central North Sea)

Everest Field: (blocks 22/9 & 22/10) lateral pinchout of stacked deep-water sands onto the Jaeren High

After O'Connor & Walker, 1993
Post-rift: Paleocene stratigraphic lead, West of Shetland

Faroe-Shetland Basin, UK:

Detached base of slope mound of Colsay Sandstone Member (Moray Group).

Lead featured on DTI Promote UK 2007 CD
Post-rift: Eocene Tay stratigraphic lead, CNS

Lead featured on DTI Promote UK 2004 CD
Post-rift: Eocene Tay stratigraphic lead, CNS

Lead 22/26A

- Top Tay Formation
- Base of Tay upper unit
- Top Balder Formation
- Top Upper Cretaceous

Seismic data courtesy of WesternGeco & Shell

Lead featured on DTI Promote UK 2004 CD
Post-rift: Mid-Eocene fan, West of Shetland
Post-rift: Eocene stratigraphic lead, Rockall Basin

Lead 132/8A

Top Boulder Formation
Eocene channel
Paleocene-early Eocene basalts and volcanioclastics

MC3D seismic data courtesy of PGS

Lead featured on DTI Promote UK 2007 CD
The future is stratigraphic....

**Trap types** within discovered resources, discovery curves and geological models for each play have been considered to estimate the proportion of stratigraphic traps in the undiscovered resource population.

<table>
<thead>
<tr>
<th>Trap type</th>
<th>Post-rift</th>
<th>Syn-rift</th>
<th>Pre-rift</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Paleogene</td>
<td>Upper Jurassic</td>
<td>Triassic - Lower Jurassic</td>
</tr>
<tr>
<td></td>
<td>Upper Cretaceous</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Cretaceous</td>
<td></td>
<td>Palaeozoic</td>
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</tbody>
</table>

**Estimated % of total Yet-to-Find in stratigraphic and combination traps**

- **33%**
- **17%**
- **5%**
Conclusions: I

19% of the UK’s discovered resources are located within stratigraphic or combination traps; 51-78% of deep-water mass flow reservoirs occur in full or partial stratigraphic traps.

Few substantial structural traps remain in the UK North Sea, except at considerable depth with attendant reservoir quality, high pressure and high temperature risks.

Pre-rift plays offer little stratigraphic potential, focused mainly in Carboniferous plays.

Upper Jurassic syn-rift and Cretaceous to Paleogene post-rift deep-water plays offer the greatest potential for stratigraphic entrapment.

Around 50% of the UK’s undiscovered resources are predicted to lie in stratigraphic or combination traps.

**DTI Undiscovered recoverable resources:** 4.4 – 8.7 – 19.4 BBOE
Conclusions: II

There has been relatively little direct exploration for stratigraphic traps until recently.

A significant number of stratigraphic traps have been found through serendipity.

A high proportion of recent Offshore Round licence application prospects and leads had a stratigraphic component.

Successful exploration for stratigraphic traps will rely on well-grounded conceptual models for reservoir distribution to predict trap configuration and well-constrained use of seismic techniques such as long-offset acquisition and AVO where appropriate.
UKCS fields & discoveries size distribution chart (end 2005)

Distribution of structural traps and stratigraphic/combination traps

IN PLACE VOLUMES

Number of discoveries

Field/discovery size (x10^6 BOE in place)

Possible total population of accumulations in stratigraphic and combination traps
UK undiscovered resources: geographic distribution

From DTI Promote UK 2007 CD
UKCS undiscovered resources: risk levels

Undiscovered Oil and Gas Resources in the UKCS shown at different levels of Geological Risk

Level for DTI estimate

- upper estimate
- central estimate
- lower estimate

From: www.dti.og.gov.uk