THE IMPORTANCE OF STRATIGRAPHIC PLAYS IN THE UNDISCOVERED RESOURCES OF THE UKCS

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Introduction

This paper analyses the demographics of existing United Kingdom Continental Shelf (UKCS) fields and discoveries as a means of assessing which plays are likely to offer the greatest untapped potential for stratigraphic traps. The talk is illustrated with examples of proven and untested stratigraphic traps.

As of end 2003, 82% of the oil and gas fields and discoveries on the UKCS have been found in structural traps, 12% have been found in combination structural/stratigraphic traps and only 6% in stratigraphic traps (Fig. 1). Current DTI estimates of the UKCS undiscovered reserves range between 4.1 – 8.9 – 21.3 x10^9 barrels of oil equivalent (BOE) and are based on a prospect mapping approach (DTI 2004). Complementary to such estimates, the discovery curve for the entire UKCS shows a maturing, but not yet fully mature profile (Munns *et al*. in press).

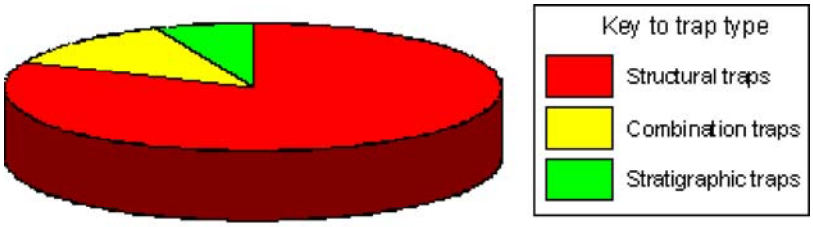


Fig. 1 Proportional trap types within all UKCS fields and discoveries

As a result of 38 years of exploration activity, the majority of the structural traps have been tested in the UK North Sea. Remaining substantial structural traps in the UK North Sea are likely to lie at considerable depth, such that reservoir quality, high-pressure and high-temperature risks render them less attractive to exploration taking into account current technology and economic considerations.

There has been relatively little direct exploration for stratigraphic traps on the UKCS. Several unexpected major discoveries have been made in stratigraphic and combination traps whilst drilling to deeper, structural targets (e.g. Britannia, Scapa, Highlander). Difficulty in recognizing these on seismic data is a major factor in the higher level of risk and uncertainty associated with stratigraphic traps. Sophisticated seismic data analysis, in particular amplitude-versus-offset (AVO) techniques, has proved highly valuable at the development stage, but has not always been reliable to exploration, particularly in the West of Shetland area (Loizou *et al*. in prep.). The Buzzard Field, an Upper Jurassic stratigraphic pinch-out/dip trap discovered in 2001, is an outstanding success story credited to application of traditional methods of seismic interpretation, leading to the development of a strong conceptual model (Doré & Robbins in press).

We have assigned the 660 fields and discoveries (including technical discoveries) found on the UKCS by end 2003 to 43 plays within 15 play groups, and further condensed them into 7 gross plays in order to determine the relative importance of stratigraphic entrapment by play. The majority of stratigraphic and combination traps occur in association with syn-rift (Upper Jurassic) and post-rift plays.

Pre-rift stratigraphic potential

Stratigraphic entrapment is relatively rare in Middle Jurassic and older strata, because of the sheet-like geometry and basin-wide distribution of many of the pre-rift reservoirs. Combination traps in the pre-rift plays generally involve major erosional truncation (e.g. Auk Field). Analysis of the existing

pre-rift UKCS fields and discoveries shows that there are no purely stratigraphic traps, and 3% of the traps are combination. The proportions of combination traps within the Palaeozoic, Lower Jurassic-Triassic and Middle Jurassic play groups are 2%, 4% and 3% respectively (Fig. 2).

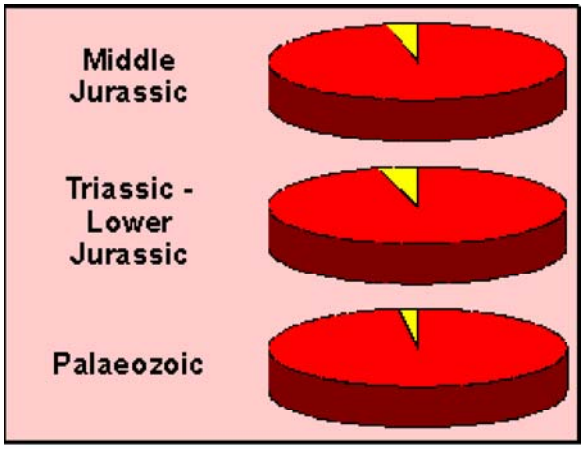


Fig. 2 Proportional trap types within pre-rift fields and discoveries (key as Fig. 1)

Discovery curve data for the pre-rift reservoirs suggests that the Middle Jurassic play is very mature, or 'creamed' (Munns et al. in press). The Triassic-Lower Jurassic and Permian plays are relatively mature, whilst the Carboniferous play has a distinctly immature profile (Fig. 3).

Palaeozoic reservoirs span a wide range of sedimentary environments. Volumetrically, the most important plays are fluvial in the Devonian and Carboniferous, and aeolian in the Permian. Although the future potential for non-structural pre-rift traps appears to be limited, Carboniferous plays in particular offer significant opportunities for the presence of stratigraphic traps. In the UK Southern North Sea, for example, largely untested potential remains for exploration of Carboniferous fluvio-deltaic sandstone reservoirs in those sub-Permian truncation traps where there is no structural closure at base Permian level, but where a Carboniferous intraformational seal performs critical lateral closure. Three important sub-regional seals have been identified within the Carboniferous of the UK Southern North Sea (Munns *et al*. in press).

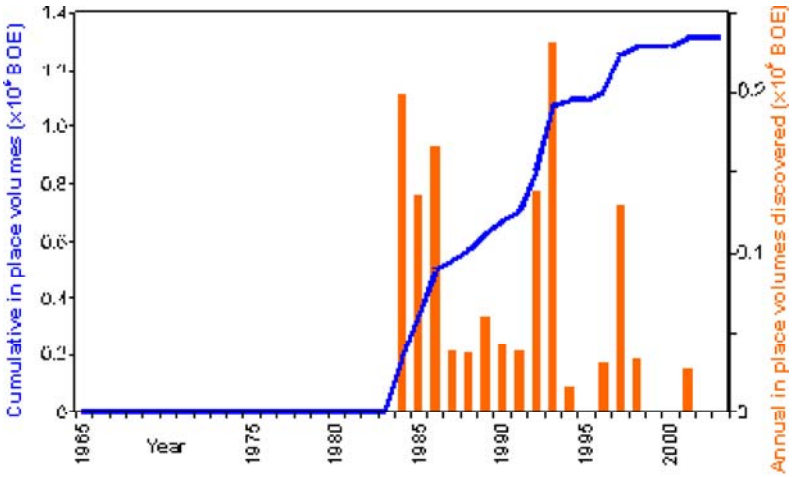


Fig. 3 Discovery curve for the Carboniferous play group

Syn-rift stratigraphic potential

Upper Jurassic syn-rift reservoirs include both shallow marine sandstones and deep-water mass-flow deposits. Shallow marine sandstones such as the Piper and Fulmar formations are mostly disposed in structural traps (e.g. Piper and Fulmar fields), and there is only limited potential for further stratigraphic discoveries in syn-rift shallow marine reservoirs.However, the geometry and lateral distribution of syn-rift deep-water mass-flow deposits are highly conducive to at least partial stratigraphic entrapment, since they are interbedded with mudstones of the Kimmeridge Clay Formation. Of the existing fields and discoveries with syn-rift reservoirs, 24% are located in stratigraphic and combination traps (Fig. 4). Taking into account only deep-water syn-rift reservoirs, the proportion of both stratigraphic and combination traps is 48%.

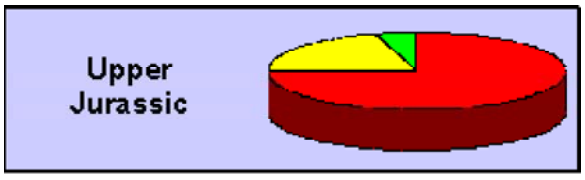


Fig. 4 Proportional trap types within syn-rift fields and discoveries (key as Fig. 1)

Discovery curve data indicate that the Upper Jurassic deep-water play is not yet mature (Fig. 5). Despite the profile flattening during the 1990's, discoveries made in the last three years show a rejuvenation of the play.

Most of the syn-rift deep-water sandstone combination traps were initially drilled as structural traps (e.g. South Brae), but subsequently proved to be larger than pre-drill prognosis, due to closure enhancement by an element of stratigraphic pinch-out.Many of the Upper Jurassic deep-water sandstone reservoirs that occur within entirely stratigraphic pinch-out traps are located above the flanks of an underlying structural trap, and were discovered through serendipity (e.g. Hot Lens reservoirs at Tartan and Highlander fields).

Traps formed by combination of dip closure and stratigraphic pinch-out may occur in both intra-basin and basin-margin settings. Typically, such traps are subtle and may not be directly identifiable from seismic data, thus requiring the development of a well-grounded conceptual model. On the southern margin of the Moray Firth rift basins, the giant Buzzard Field represents the first major discovery in a basin margin pinch-out play (Doré & Robbins in press). Buzzard is the largest oil discovery in the North Sea since 1984, and its size clearly demonstrates that those more subtle, complex traps remaining to be found are not necessarily smaller than existing structural traps. Munns *et al*. (in press) recognized leads with a similar up-dip pinch-out geometry elsewhere in the Moray Firth rift basins.

Post-rift stratigraphic potential

UKCS fields and discoveries within post-rift reservoirs contain the largest proportion of stratigraphic and combination traps (51% overall), with the greatest ratio of stratigraphic/combination to structural traps recorded from the reservoirs of Lower Cretaceous age (Fig. 6).

Despite broadly post-rift style basin development during the Early Cretaceous, deep-water sandstones continued to be deposited in response to local extensional faulting and inversion, probably under a strike-slip tectonic regime (Copestake *et al.* 2003). Seventy-six percent of UKCS Lower Cretaceous fields and discoveries occur in combination or stratigraphic traps (Fig. 6). Discoveries within the Lower Cretaceous play are almost exclusively limited so far to the Moray Firth area of the Central North Sea between Captain Field in the west and Britannia Field in the east. Additional undrilled potential on this play exists within the Central Graben to the south (Milton-Worssell *et al*. in prep., Morgan & Went 2003), and the Viking Graben to the north (Oakman in press).

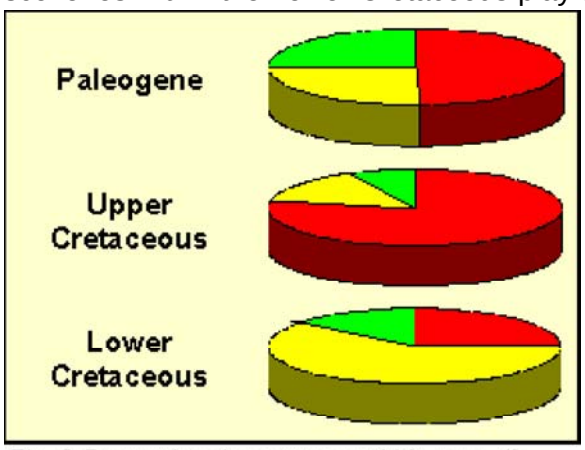
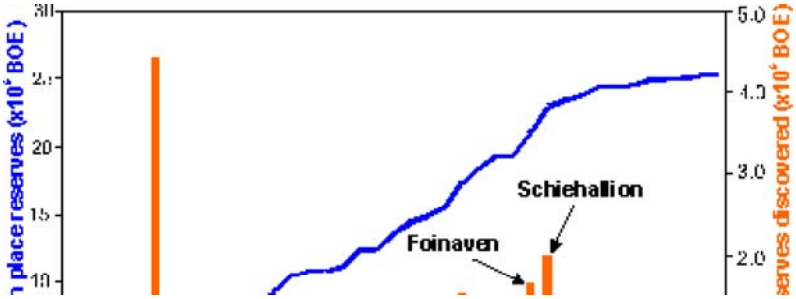


Fig. 6 Proportional trap types within post-rift fields and discoveries (key as Fig. 1)

Twenty-five percent of UKCS Upper Cretaceous Chalk fields have an element of non-structural trapping (Fig. 6). Partial stratigraphic entrapment, as evidenced by tilted oil-water contacts, is due to a combination of post-emplacement structuration and very low lateral permeability preventing remigration. There has been little exploration on this play in recent years, but our improved understanding of the unusual trapping mechanisms involved offers hope for future exploration opportunities.

The majority of Paleogene reservoirs are deep-water sandstones whose geometry commonly lends itself to stratigraphic entrapment. Hence, half of all UKCS Paleogene hydrocarbon discoveries occur in traps with full or partial stratigraphic entrapment (Fig. 6). Purely stratigraphic traps are most commonly detached lobes of mass-flow sandstones with 4-way dip closure resulting from a combination of sedimentary mounding and differential post-depositional compaction of the encasing mudstones (e.g. Frigg Field).Sophisticated seismic techniques appear to work well on Paleogene reservoirs in the UK North Sea. However, in the West of Shetland area, the use of AVO as a hydrocarbon predictor in Paleogene plays has been less successful (Loizou *et al*. in prep.). In the North Sea Eocene deep-water sandstone play, almost all of the fields and discoveries occur in stratigraphic or combination traps. Mounded geometries are common within palaeogeomorphic traps (e.g. Frigg and Guillemot fields), and remobilized or injected channel sands provide a locally important Eocene deep-water sandstone play (e.g. Alba Field).

The Paleogene discovery curve has a maturing profile (Fig. 7).



Summary

Eighty-one percent of existing UK Continental Shelf (UKCS) fields and discoveries are located within

structural traps, 6% occur within
purely stratigraphic traps, and 12% lie within combination structural/stratigraphic traps. The majority of stratigraphic and combination traps occur in association with syn-rift (Upper Jurassic) and post-rift plays. Proportions of stratigraphic and combination traps within pre-rift, syn-rift and post-rift plays average 3%, 24% and 51% respectively. Lower Cretaceous fields and discoveries, almost exclusively deep-water sandstone plays, demonstrate the highest proportion of stratigraphic entrapment of all, with 76% located within stratigraphic and combination traps. This is closely followed by Paleogene deep-water plays at 50%, and Upper Jurassic deep-water plays at 48% of such traps.

Many of the major discoveries in stratigraphic traps were found by chance, since there has been relatively little direct exploration for stratigraphic plays. Plotting the UKCS discovered data on a size distribution chart shows that the structural traps give rise a rather mature, lognormal-type distribution, whereas the stratigraphic and combination traps describe a more irregular distribution that hints at significant yet-to-find potential (Fig. 8).

The discovery curve for the entire UKCS has a maturing signature. However, discovery curves for individual plays provide evidence for resurgence, especially in the Carboniferous, Upper Jurassic deep-water, Lower Cretaceous, Upper Cretaceous and Paleogene plays.

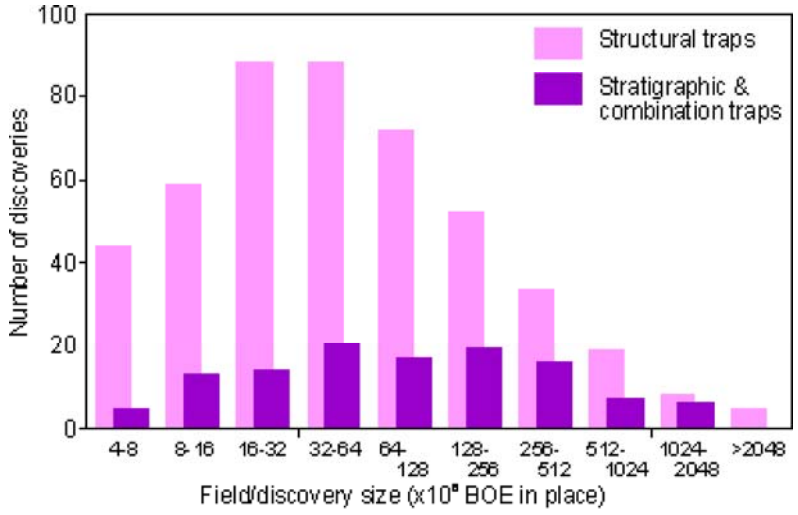


Fig. 8 Size distribution chart for UKCS structural and stratigraphic/combination fields and discoveries

Exploration on the UKCS has moved into a new era of primarily searching for subtle stratigraphic plays within both stratigraphic and combination traps. Deep-water sandstone stratigraphic plays within the syn- and post-rift sequences offer the greatest potential for substantial new resources. Of the forecast 4.1 to 21.3 x 10^9 BOE recoverable UKCS yet-to-find (DTI 2004), we estimate that at least 50% is located within stratigraphic traps.

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Presented at PETEX 2004, UK Petroleum Systems Session