

Play fairway mapping

- Key to successful exploration

Play fairway mapping is an excellent tool for screening and ranking acreage, whether for licensing round applications, asset acquisition or disposal.

With increased exploration efforts, it is an effective way of reducing risk.

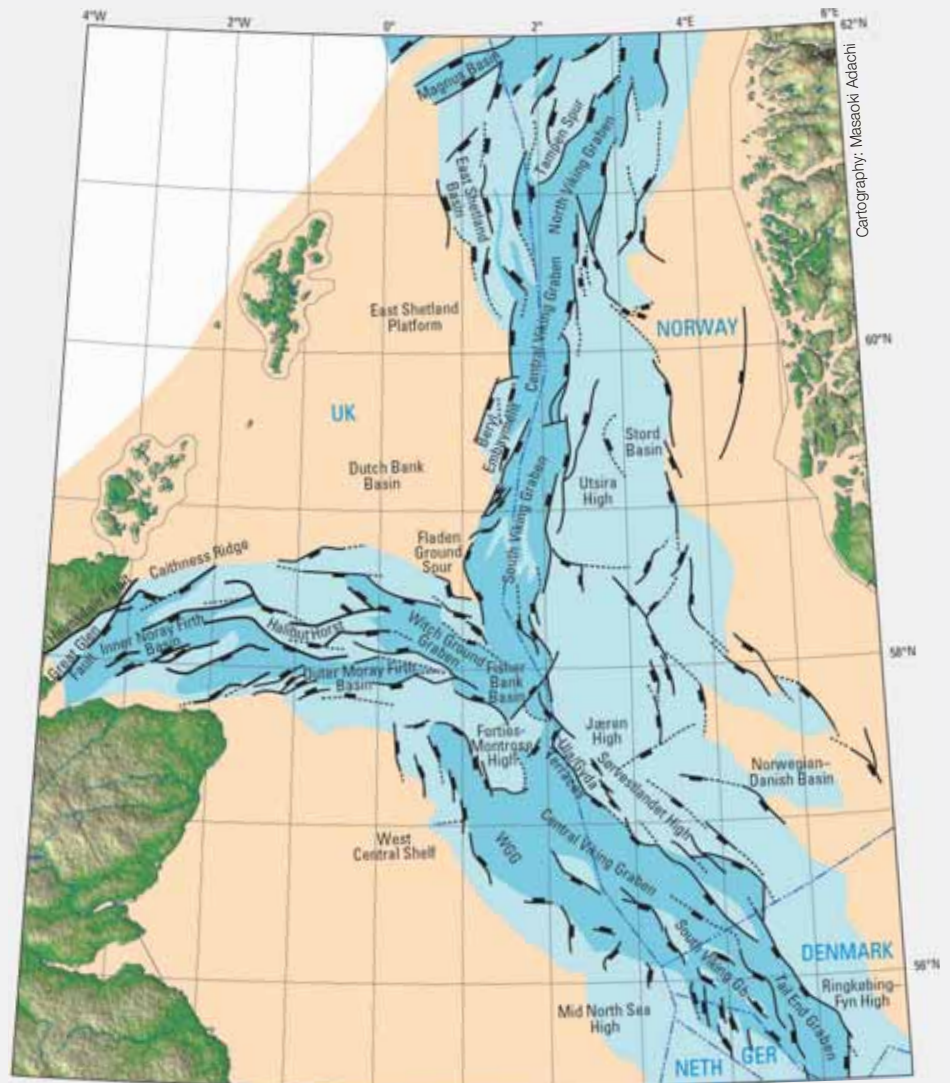
*David Mudge and
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The decline in oil and gas production in the North Sea has initiated an intense debate on how to quantify the remaining "yet-to-find" resources in the region. It has also encouraged the Norwegian and UK governments to look at ways of making more acreage available through annual licensing rounds and releases of fallow and other previously licensed blocks.

Within a short space of time, these initiatives have led to a strong response from industry with re-licensing of much of the released open acreage. There has also been significant interest in the exploration of licensed acreage that has been only partially explored or not reviewed for a number of years, leading to an increase in company activity through farm-in, cross-assignment or takeover.

Historically, the UK/Norway median line has acted as a barrier to exploration with different stratigraphic terminologies being applied to rocks on either side, and seismic and geological maps terminating at the median line. Use of a stratigraphic framework spanning this political barrier enables North Sea plays to be mapped as continuous depositional systems, enhancing the value of the resulting interpretations and also allowing an uninterrupted view of prospectivity along the median line.

Detailed analysis of North Sea stratigraphy shows that non-marine, shelf, slope and basal sediments are often represented within individual sequences. This combination of stratigraphic complexity and subtle structuring provides the ideal scenario for a long drawn-out tail of exploration activity as the more difficult plays are explored and understood, and new discoveries made.



The northern North Sea is a major hydrocarbon province dominated by an extensive system of rift basins filled with a thick succession of Palaeozoic to Tertiary sediments. These basins comprise the Viking Graben, Central Graben and Witch Ground Graben, which are bounded by stable platform areas with thinner sedimentary cover, and contain long-lived basement highs. A series of extensional tectonic episodes has created a large number of tilted Jurassic fault blocks and other structural traps within the basins and a widespread Upper Jurassic organic shale has provided a high-quality regional source rock. Cretaceous and Tertiary plays are associated with more subtle structural and stratigraphic trapping. Sandstones occur throughout the stratigraphic column, and chalk and limestone reservoirs are also present.

A two-part strategy

North Sea acreage availability and the recent strong oil price have stimulated exploration activity. However, oil companies, whether established North Sea explorers or new entrants, need to know where remaining prospectivity is located and how they can evaluate the risk associated with exploring this acreage. The most effective way to answer these questions and to assess the remaining hydrocarbon potential of North Sea acreage is to follow a two-part strategy: a first phase using play-based geological mapping to locate areas of regional prospectivity, and a second phase involving the evaluation of acreage within these fairways leading to the assessment of local prospectivity at the block and prospect scale.

In 2003 PGL, working with established and new-entrant North Sea operators recognised the need to do something different. Ternan was established with the primary purpose of undertaking regional studies using the play fairway technique with the objective of helping potential investors in the North Sea to get up to speed rapidly with the regional picture.

Play fairway mapping

Play fairway mapping provides an effective means of defining remaining hydrocarbon potential in a mature basin such as

Regional evaluation identifies play fairways and helps to assess exploration risk associated with geological parameters such as reservoir, topseal and hydrocarbon charge. Detailed interpretation is then required to identify potentially drillable prospects, and local presence and effectiveness of reservoir and topseal.



the North Sea, which contains a large number of plays and has had a long history of exploration drilling. It also allows the prospectivity of individual blocks to be assessed anywhere in the basin. Play evaluation is based on rigorous stratigraphic analysis that provides a consistent framework for mapping regional reservoir, topseal and hydrocarbon charge. At least 20 plays can be mapped, using a database of more than 2000 UK and Norwegian wells.

Each of these plays contains at least one field with more than 100 million barrels of

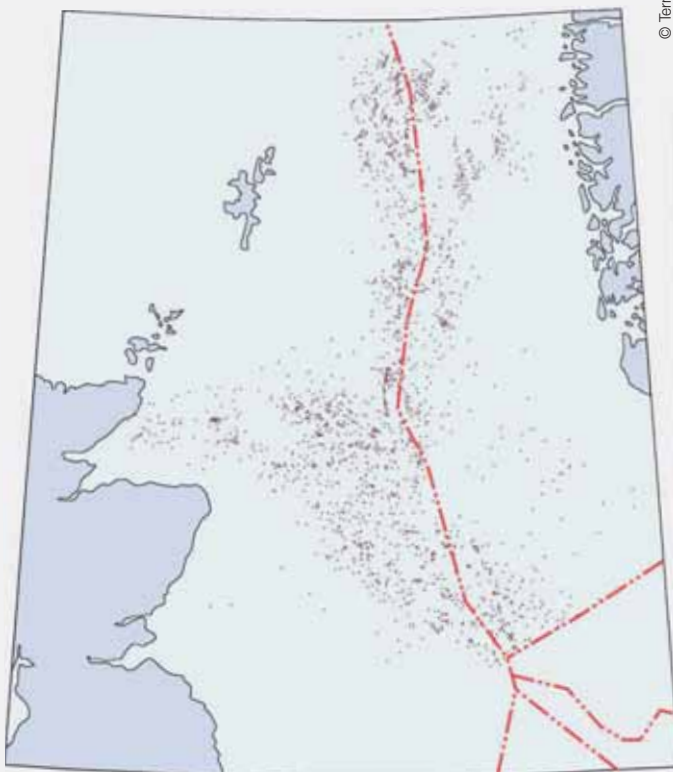
oil equivalent reserves (apart from Lower Palaeozoic, Carboniferous and post-Middle Eocene intervals). The plays are present in both the UK and Norwegian sectors and much of their remaining prospectivity lies within the Central Graben-Viking Graben system which straddles the UK/Norway median line.

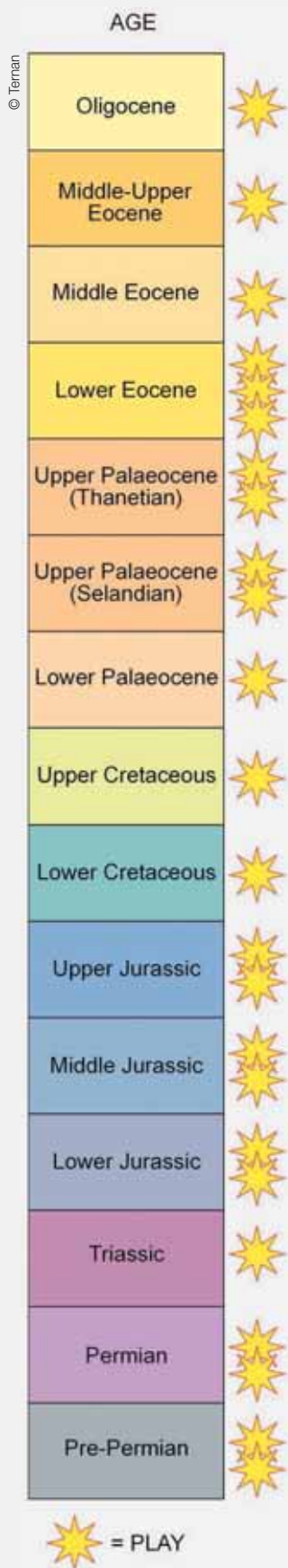
Play fairway mapping determines the geological controls and geographical extent of individual plays. A play can be defined as the combination of geological parameters that control the location of a



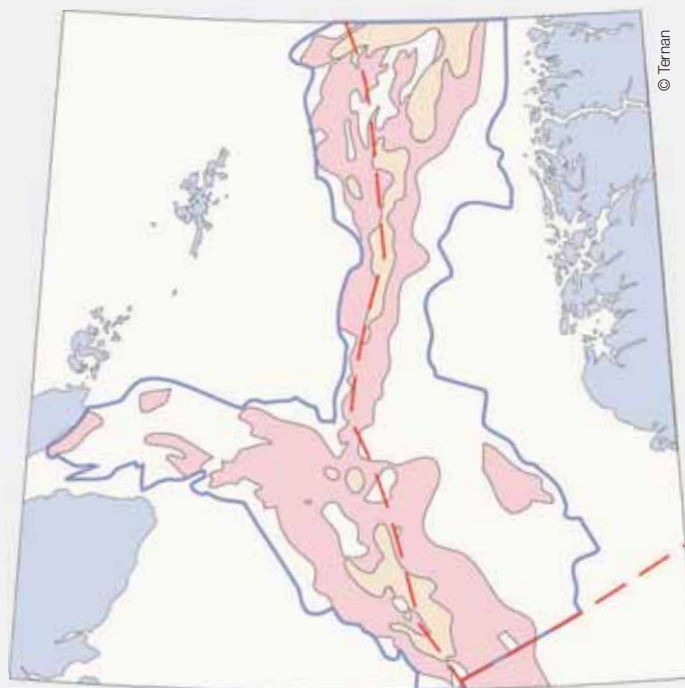
Ternan is named after the 5th Century Scottish saint who settled in Banchory, near Aberdeen. The company is a wholly owned subsidiary of PGL, a subsurface consultancy with broad North Sea expertise. PGL's ODM3™ software has played an essential role in creating the extensive digital well database that forms an integral part of the regional study output.

A database of over 2000 wells has been used to evaluate North Sea plays.





The North Sea differs from many other hydrocarbon provinces in having a wealth of plays throughout the stratigraphic column.



Integration of mapping over the median line improves understanding of plays and the hydrocarbon system overall.

hydrocarbon accumulation. Play fairway mapping relies on the identification of those components of a play that have a regional rather than local distribution. Distinguishing between local and regional geological parameters leads to a clearer understanding of the nature of these geological controls and so gives a more confident estimation of exploration risk at the prospect generation stage.

"A play can be defined as the combination of geological parameters that control the location of a hydrocarbon accumulation."

The regional parameters

In the North Sea, regional parameters are mapable over a number of quadrants or throughout the basin, whilst local parameters are defined at the block or prospect scale. The regional parameters for North Sea plays are reservoir, topseal and hydrocarbon charge. As reservoir is the most readily identifiable parameter, plays are usually named by reservoir. Hydrocarbon charge combines the presence of mature source rocks with the occurrence of a migration pathway into the reservoir. Local parameters that affect prospectivity at the block or prospect scale are trapping and local presence and effectiveness of reservoir and

top seal. In the North Sea trapping is the most important local parameter that can be mapped and is the easiest to risk. Topseal or reservoir erosion on the crest of tilted fault blocks may also be a factor at this scale

The prospectivity of any play can be evaluated from its fairway map. This is constructed by overlaying the regional distributions of reservoir, topseal and hydrocarbon charge for that play. The area of maximum prospectivity, where these three parameters are all favourably combined, is defined as the play fairway. Outside the fairway, areas of increasing exploration risk can be mapped as the regional parameters become suspect or unfavourable. The map also allows the degree of confidence associated with this exploration risk to be estimated. Within the fairway - where the regional risk for the play is low or zero - available acreage can be targeted for prospects using seismic mapping and local well data. This play fairway methodology can be applied to any basin with potential hydrocarbon prospectivity.

Play fairway maps

A suite of regional maps has been produced for each North Sea play, with the aim of providing an integrated and consistent view of known and potential hydrocarbon prospectivity in the area to the north of the Mid North Sea High. Further, the stratigraphic interpretation of the wells



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A case study

Overlaying the regional distributions of reservoir, topseal and hydrocarbon charge produces play fairway maps.

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on which this mapping is based is captured in a digital database, facilitating interactive interrogation of the data and enabling updating. The technique is illustrated by using the suite of maps from the Palaeocene Heimdal/Balmoral sandstones play as an example.

In conclusion, play fairway mapping is an excellent tool for screening and ranking acreage, whether for licensing round applications, asset acquisition or disposal. It removes a significant amount of exploration risk before reaching the stage at which considerable investment of time and money is required for purchase of seismic data and detailed assessment of prospectivity leading to drilling decisions.

Integration of the 3 Ternan studies sponsored by Apache (UK Central North Sea and UK Northern North Sea) and Talisman (Norwegian North Sea) provides a comprehensive regional overview of the northern North Sea basins, and has advanced our collective understanding of important plays which straddle the under-explored median line corridor. The reports are available to the industry in general, with uptake coming from across the board - not only from new entrant companies but also from established North Sea players, from independents to super majors. With exploration firmly back on the agenda, many companies lack their own up-to-date regional work, essential to making the most of current opportunities in the UK and Norway.

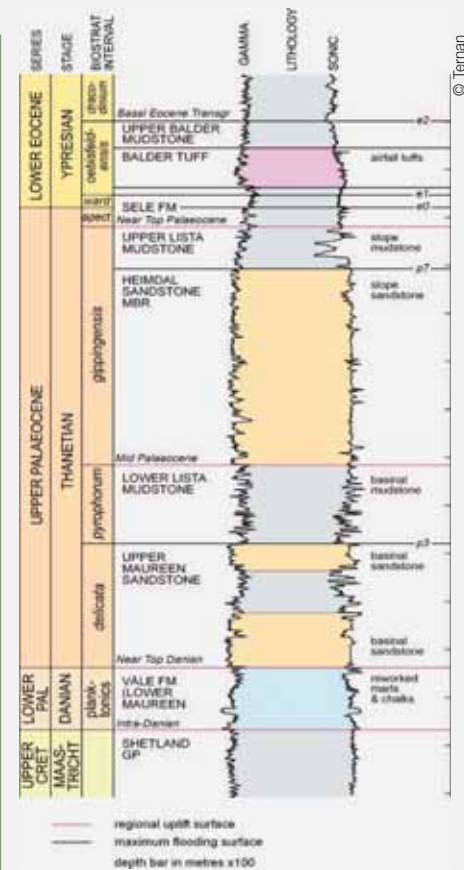
The Upper Palaeocene Balmoral/Heimdal sandstones provide a good example of how play fairway mapping can be used to evaluate remaining hydrocarbon prospectivity in the North Sea. Differing stratigraphic terminology for these widely distributed sandstones has led to the mapping of three separate plays: the Balmoral play in the UK Central Graben and Outer Moray Firth area, a Heimdal play in the Norwegian part of the South Viking Graben and a Heimdal play in the UK East Shetland Basin. However, biostratigraphic data and well correlation show that these sandstones were shed off the East Shetland and Forties platforms and laid down in slope and basinal slumps, submarine channels and fans during a single depositional event associated with thermal uplift and erosion of a Scotland-Shetland hinterland to the west.

Type well

A consistent stratigraphic framework is key to proving a solid foundation for Play Fairway mapping. Biostratigraphic data combined with wireline log correlation are used for stratigraphic interpretation, which is recorded in an extensive digital well database.

Reservoir distribution

The sandstones form excellent reservoirs up to 400 m in thickness, pinching out southwards into the Central Graben and eastwards onto structural highs. An incised east-west channel system is seen in the southern part of the Central Graben and sandstones of Heimdal age have also been drilled along the northern flank of the Ringkøbing-Fyn High. Evidence for active faulting is seen in the East Shetland Basin where over 800 m of sandstones have been drilled in the hanging wall of the platform margin fault.



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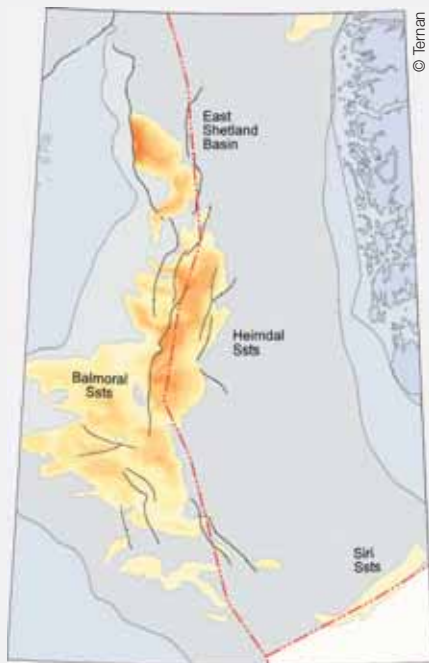
Type Well.

Topseal

The presence of regional topseal is a critical risk for Palaeocene plays in the North Sea, as with very few exceptions hydrocarbons only occur in the highest reservoir interval in any well, implying that intra-formational mudstones are not reliable seals for light oil and gas. So viable topseal for the Balmoral/Heimdal play is limited to areas shown in green, outside the limits of overlying Forties, Sele and Balder sandstones (shown in brown).

Hydrocarbon charge and biodegradation

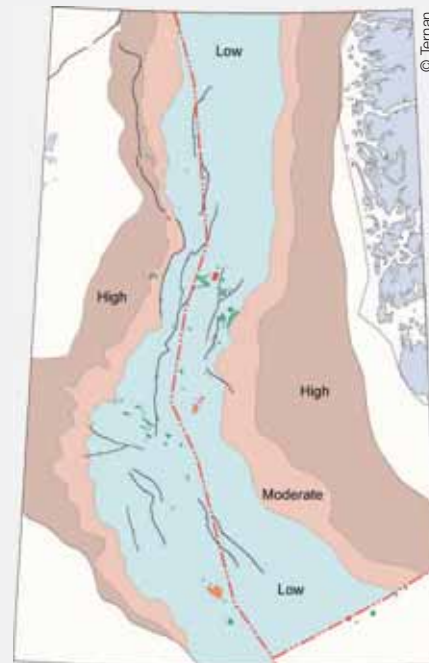
Mature Upper Jurassic source rocks are widely distributed beneath most of the



Reservoir Distribution.



Topseal.



Hydrocarbon Charge and Biodegradation.

Palaeocene reservoir sandstones and sufficient hydrocarbons have been generated to fill any traps present. The presence of oil-bearing Heimdal sandstones in the Siri fairway along the Norway/Denmark median line demonstrates the potential for long-distance migration within the Palaeocene in the North Sea. The major charge risk is associated with biodegradation which is related to depth of burial. A straight-line relationship between oil gravity and depth shows that biodegradation risk is significant above depths of 1675 m (light brown) where gravities of about 20°API are encountered and becomes critical above 1200 m (dark brown) where oils of 14°API or less are predicted. Biodegradation is only a risk for the Heimdal-Balmoral play at shallow depths on the East Shetland Platform.

Play fairway

The Heimdal-Balmoral play fairway is produced by overlaying the regional distributions of reservoir, topseal and hydrocarbon charge. The area in yellow is the play fairway, where regional risk is low or zero. Areas of moderate to very high regional risk are shown in deepening shades of blue. By definition, oil and gas fields are concentrated in the play fairway, but

a few hydrocarbon accumulations are found outside the fairway, e.g. in the Mariner and Emerald fields where an intra-formational mudstone provides local topseal.



Play Fairway.

A successful play

The main areas of the play fairway are highly prospective and productive in the South Viking Graben, on the Fladen Ground Spur and in the eastern part of the Moray Firth Basin. The success of the play can be related directly to the absence of younger Forties sandstones in these areas. The most significant Balmoral accumulations are simple anticlinal closures with an element of stratigraphic trapping that occur on the flanks of the Fladen Ground Spur.

In the South Viking Graben the Heimdal has proved to be the most successful Palaeocene play in the Norwegian sector, with hydrocarbon production in Sleipner East, Heimdal, Glitne and other fields. These fields are located along the margin of the Utsira High close to the eastern pinch-out line of the sandstones. Trapping is provided by drape or mounding with lateral shale-out providing stratigraphic closure in Jotun.

This stratigraphic play can be mapped southwards close to the UK/Norway median line. To the south and east of the main reservoir development, isolated channel sandstones contain hydrocarbons in the Joanne, Flyndre and Orion fields, and in the Siri field complex.