1 Organic facies and hydrocarbon distributions in the Norwegian North Sea

B. M. Thomas, P. Møller-Pedersen, M. F. Whitaker and N. D. Shaw
A/S Norske Shell, Stavanger, Norway

Significant hydrocarbon accumulations have been found in North Sea reservoirs ranging in age from Devonian (Buchan Field) to Eocene (Frigg area). In Norwegian waters, the oldest reservoirs are at present Rhaeto-Liassic Statfjord Formation sands. Source rock development in the northern North Sea is restricted almost entirely to the Jurassic. Rich oil-prone source rocks occur mainly in the Humber Group, and particularly within the Kimmeridge Clay Equivalent (Upper Jurassic ‘Hot Shale’). In basinal settings within the Viking and Central Grabens, Kimmeridge source rock sections may be over 1000 m thick. Net source rock thicknesses exceeding 400 m are documented in several wells.

North Sea oils appear to be sourced from these Humber Group anoxic shales, although the Liassic Dunlin Group may also contribute in parts of the northern Viking Graben. Biodegraded oils are found in fields where reservoir temperatures are less than 75 °C, and some possible low maturity crude oils occur in the Egersund Sub-basin. Mature Jurassic ‘kitchen’ areas coincide closely with the Viking and Central Grabens and deeper parts of the East Shetland Basin, although a small oil kitchen also occurs in the Egersund Sub-basin.

Rock Eval pyrolysis and solvent extract studies of core material from the Kimmeridge Clay Equivalent suggest that the principal zone of oil generation for ‘Type II’ source rocks lies between VR/E = 0.7 and 1.0*, with the peak possibly at VR/E = 0.8.

Organic facies variations occur within the Kimmeridge Clay Equivalent. In thick basinal sections source rocks are rich and oil-prone, although the inertinite content may be locally high in turbidite sequences. The Kimmeridge Clay Equivalent on the basin margins and over some structural highs was deposited under predominantly dyseraerobic conditions, often with some terrestrial influx. Source rocks from these settings are leaner and of mixed organic type. However, such facies variations are thought to be, at best, only a secondary influence on the distribution of apparent oil- and gas-prone areas in the North Sea. Other factors, such as thermal maturity of kitchen areas, timing relationships, migration paths and charge competition are considered to be more significant.

Hydrocarbon distributions and migration paths in the North Sea are complex. In some areas, e.g. Central Graben, hydrocarbon migration patterns seem to be dominantly vertical, whilst in other areas significant lateral migration is apparent, e.g. in Troll Field. On many occasions migration has occurred to a stratigraphically lower level. Geochemical data from deep, mature kitchen areas suggest that hydrocarbon charge vastly exceeds the available volume in adjacent traps. Many structures appear to be filled to spill-point, and in some areas long chains of fields are related to each other and a common ‘kitchen’ as a continuous fill-and-overspill sequence.

INTRODUCTION

Since the mid-1960s, the development of the North Sea as one of the world’s major hydrocarbon-producing provinces has been paralleled by the emergence of applied organic geochemistry (and allied basin evaluation techniques) as new and effective tools in modern petroleum exploration. The concept of the ‘generative basin’ has rapidly come into widespread use in the exploration industry (Demaison, 1984). Hydrocarbons are known to originate from distinctive source beds where they are thermally mature within mappable ‘kitchen’ areas. Their subsequent migration paths are largely determined by the stratigraphic framework and basin geometry, which defines the ‘drainage area’ of the trapping structure.

The North Sea, with its large data base, rich and distinctive source horizons, and numerous hydrocarbon accumulations, provides an ideal calibration area for such methods, which may then be applied to the
appraisal of remaining prospects or be used as an analogue for the evaluation of other basins.

The following is a summary of some recent investigations of the hydrocarbon habitat of the Norwegian sector of the North Sea, with particular emphasis on the northern part of the Central Graben and the Viking Graben.

**TECTONIC FRAMEWORK**

The tectonic framework of the northern North Sea (Fig. 1) is dominated by the north-trending Viking Graben, which intersects in the south with the southeasterly-oriented Central Graben and the westerly Witch Ground Graben. The thick, mainly-