Atlantic margin exploration: Cretaceous–Tertiary evolution, basin development and petroleum geology

Introduction and review

A. M. SPENCER¹ and O. ELDHOLM²

¹Statoil, Postboks 300, 4001 Stavanger, Norway
²Department of Geology, University of Oslo, Postboks 1047, 0316 Oslo, Norway

The predominantly rifted continental margin of NW Europe stretches c. 3000 km from Ireland to the Barents Sea and comprises sectors off Ireland (c. 800 km), off the UK and the Faeroe Islands (c. 1000 km) and off Norway (c. 1200 km). The conjugate margin east of Greenland is of similar total length and that southwest of Greenland measures c. 1500 km. Further north, the predominantly sheared margin along the Barents Sea–Svalbard and northeast Greenland sectors extends for c. 1000 km. These Atlantic margins lie in waters as deep as c. 2500 m. In total area the margins cover c. 1.5 x 10⁹ km², which is almost five times the area of the prospective part of the North Sea basin. The largest sectors are those off Norway, off northeast Greenland and off Ireland, each of which exceeds the area of the prospective North Sea basin. The margins are extensively underlain by sedimentary basins. The hydrocarbon exploration of these basins has been greatest in the Norwegian sector where a total area of 35 000 km² has been licensed, 142 exploration wells drilled and 25 hydrocarbon finds made. The comparable statistics for the other sectors are: UK—35 000 km², 97 wells and about seven finds; Ireland—30 000 km², 29 wells and about three finds; Southwest Greenland—18 000 km², 5 wells, no finds. Off East Greenland there has been neither licensing nor drilling.

The geological events of most importance to the occurrence of the hydrocarbons so far discovered on the Atlantic margins are those which took place in Jurassic to Tertiary times. All of the hydrocarbon finds to date have been generated from Jurassic source rocks, principally oil-prone late Jurassic marine shales which are developed from the Porcupine Basin to the Barents Sea. The most important tectonic event with respect to the known hydrocarbon finds was the late Jurassic to early Cretaceous rifting. This led to restricted marine circulation, allowing source rock accumulation, and created the fault block traps which have proved the most successful exploration targets. Major subsidence occurred in Cretaceous times with sequences 5 km or more in thickness accumulating in the Faeroe–Shetland, Møre, Vøring and Tromsø basins. Late Cretaceous to early Eocene times saw the major events connected with the break-up of the continents: first North America and Greenland separated, followed by the separation of Greenland and Eurasia near the Paleocene–Eocene transition. The rifted margins underwent extension and syn-rift uplift prior to continental break-up and the start of sea floor spreading between Europe and Greenland. The actual break-up and initial phase of sea floor spreading was accompanied by voluminous and extensive subaerial volcanic activity. The last event to have an important effect on the hydrocarbon finds is the late Tertiary, intra-plate uplift of the Scandinavian landmass.

The main proven hydrocarbon plays can be classified with respect to the late Jurassic to early Cretaceous rifting into pre-, syn- and post-rift plays. From the UK sector to north Norway, the pre-rift play is the most successful, with its tilted fault block traps, Jurassic and older reservoirs and adjacent late Jurassic source rocks. One major oil field occurs in syn-rift sandstones off mid-Norway. Significant post-rift gas finds occur in Paleogene reservoirs in the UK sector but off mid-Norway only one exploration well has been targeted at a post-rift, Cretaceous, objective. The discovered, recoverable, hydrocarbon resources, measured in units of 10⁹ Sm³ oil-equivalent, are of the order of 1000 off Norway, 100 off UK and perhaps 10 off Ireland. Current official estimates of the yet-to-find hydrocarbon resources, expressed in the same units, amount to 1500–4000 off Norway and (oil only) 20–1000 off UK.

The most important tectonic event of Cretaceous–Tertiary evolution of the margin to be highlighted. Subsidence then has been responsible for creating and sometimes destroying the maturity of the Jurassic source rocks. Early Tertiary volcanic events have also acted to restrict the areal extent of the prospective hydrocarbon basins and the Tertiary sea floor spreading has placed an absolute, oceanward limit on the extent of the prospective basins. On the other hand, the late Cretaceous–Paleocene regional uplift, erosion and re-deposition, the early Eocene greenhouse, and the thermal pulse leading to continental break-up, present new, hitherto largely unrecognized, challenges for the explorationist. The theme was also chosen to allow a wide participation in the symposium, for these Cretaceous to Tertiary events have been much studied by geoscientists from academic and government institutions.

The thirteen papers published here include an overview of the Mesozoic to Cenozoic plate reconstructions, and reviews containing new information on the Southwest Greenland, Northeast Greenland, Southwest Barents Sea and offshore west Ireland regions. The main group of articles deals with the region to the northwest of the UK, the Faeroe–Shetland Channel, with accounts of the subsidence patterns there, of the Solan Basin, of structuring and transfer zones, of Paleocene sequence stratigraphy, of Paleocene to Miocene compression and of Neogene to Quaternary seismic stratigraphy. A detailed paper describes the seismic structure of the Hatton–Rockall area. A final paper outlines apatite fission track data which suggest kilometre-scale uplift of broad areas of the UK in Tertiary times.

Some of the important implications of the papers included here for future hydrocarbon exploration are these. Although the pre-rift play has been the target of most exploration to date, further finds will be made but will demand the best possible understanding of Mesozoic tectonic history and deposition. As exploration proceeds into still greater water depths only the post-rift plays will normally be within reach of the drill: the requirement is to predict the presence of reservoirs and traps at Cretaceous and Tertiary levels. In one area, off Northeast Greenland, because of the sea ice cover, large areas are still poorly known geologically: Jurassic faults blocks may be present and a Permo-Carboniferous rift basin may contain older hydrocarbon plays. Off Southwest Greenland rift structures of late Cretaceous to Paleogene age have not so far been drilled.