Dynamics of the Norwegian Continental Margin

by A Nottvedt, B.T. Larsen, S. Olaussen, B. Torudbakken, J. Skogseid, R.H. Gabrielsen, H. Brekke, O. Birkeland, editors, 2000, Geological Society Special Publication No. 167 London, 472 pp.

This eminently worthwhile book is the latest, and most comprehensive, release of the results of an integrated study of the Norwegian margin, sponsored by the Norwegian Research Council, the European Union and the (then) three Norwegian oil companies, Statoil, Norsk Hydro, and Saga. Scientific participants represented all major Norwegian geoscience research groups, the oil companies, and scientists from several universities across Europe. The result is a truly integrated publication and, let us hope, a catalyst for other publications to come, which may present similar integrated studies of other major petroleum provinces of the world. Excellent integration between the papers is a credit to the strong impact of the senior editor, Arvid Nottvedt.

Tectonics and basin formation— The Caledonian orogen suffered gravitational collapse in the Devonian and the North Sea and NE Atlantic have been in a state of continued extension ever since. A very wide rift basin of Permo-Triassic age underlies all younger basins throughout the region. The North Sea proper underwent another major extension in the middle to late Jurassic, producing much more restricted rift zones, including the Viking Graben. Extension then shifted to the central Northeast Atlantic where it ultimately led to full continental separation in the earliest Eocene. At about 55 Ma, shortly before continental separation, the Icelandic mantle plume (then centered beneath Greenland) had reached lithospheric levels and emplaced an extensive oceanic flood basalt province, recognized by seaward-dipping reflectors beneath the Northern European margin and basalt in outcrops in northern Scotland and Greenland. The plume-head drove regional uplift, apparently most pronounced within the rift zone where the extended crust was thin. A plume 3000 km in diameter is required in order to encircle this entire North Atlantic igneous province. The emplacement of such lower crustal igneous bodies dramatically affects both timing and style of basin formation as well as subsidence history and the thermal regime. Basin modeling and hydrocarbon maturation studies must consider these factors and the central Norwegian margin now provides a quite well documented case of their effects.

The dynamics of North Sea crustal extension has been debated for years. As expected the debate was most lively in the early years when deep seismic data were limited and of poor quality. The extensive database which now exists, including 3D seismic over most producing fields and more than 10,000 km of ultradeep 2D seismic reflection profiles (to depths of 16 sec TWT) allows detailed imaging of the entire crust and upper mantle. The thinnest crust underlies the Viking graben where it is only 21 to 24 km thick, increasing to 30 to 36 km in the platform areas. Several papers address this crust itself, including the documentation of a dense, high-velocity, deep crustal block beneath the platform off western Norway. This probably represents partially eclogitized rocks that formed a crustal root during the Caledonian orogeny.

All the seismic data now clearly document extension by simple shear (low-angle detachments). There are supra-basement detachments, such as within the Gullfaks block, which truncate the base of the Permo-Triassic section and can be followed at a very low angle for more than 10 km. At the next scale and depth there are intra-basement detachments, which may extend to depths of 20 km and laterally more than 50 km. These intrabasement detachments are particularly pronounced at the very margins of the Permo-Triassic rift zone. These detachments flatten within the lower basement and are thought to follow earlier zones of intra-crustal weakness, probably reactivating Caledonian (Devonian) thrusts.

Basin filling— One major effect on Cenozoic basin filling in the region was the uplift associated with the Icelandic mantle plume. One 'transient' high created by this plume, the Shetland platform and surroundings, fed sediment into the northern North Sea from the west. Cenozoic sequences in the northern North Sea, therefore, represent a complex 'interfingering' of sequences derived from these western sources and others representing drainage off the Norwegian mainland to the east. Several excellent papers present comprehensive seismic, well log, geochemical, and petrographic data in support of this Cenozoic basin fill history. Sediments from the Eocene volcanic province to the west are easily identified, as is the arrival of coarser sediments from the east during the late Cenozoic climatic cooling and uplift of the Norwegian source areas. Several authors emphasize that a simple, post-rift thermal subsidence model cannot explain the interplay between uplifts, subsidence, and outbuilding directions in the northern North Sea during the Cenozoic. Instead, there were basin-floor movements controlled by lithospheric forces, including those induced by ridge-push from the NE Atlantic rift zone and spreading center, as well as far-field effects of the Alpine collision zone to the south. The several chapters dealing with the history of the North Sea Cenozoic provide sobering evidence for the complex interplay of tectonism and eustasy in the development of basin-fill architecture.

A wealth of subsurface data from the extensive oil fields of the northern North Sea allow detailed analysis of the stratigraphy and depositional systems of the Permo-Triassic as well as late Jurassic rift fills. The earliest rift phase was dominated by arid systems whereas Jurassic rift fills are mixed marine and non-marine, including fluvial, shallow marine and deep marine sediment gravity flows and hemi-pelagic strata. Rift basins were overfilled, balanced, or underfilled, depending on distance from source area. A study of the Snorre oil field presents an excellent case study of rift basin hydrocarbon play models, emphasizing the linkage between shallow and deep marine deposition and the evolution of the syn-rift unconformity. It provides a very useful conceptual model of great value to anyone exploring rift basins elsewhere in the world where the data may not yet be as detailed as they are in this field.

The presence of several rift episodes and also the occurrence of repeated rift phases within each episode, suggest that rift basin fills can be arranged hierarchically. Rift episodes and inter-rift episodes are 1^{st} order, and last 10's of My's. Individual rift phases are 2^{nd} order, and last a few millions of years. 3^{rd} order sequences can perhaps be related to individual faulting events in each rift segment.

Here is a book both comprehensive in scope and precise in detail. It provides new insights for the specialists in a variety of fields, from deep crustal geophysics, to oil field play concepts, to basin fill stratigraphy. It can be used as a reference; it can also be used as a regional text for a seminar. Much more importantly, however, the "Dynamics of the Norwegian Margin" will provide the greatest value to those who read it exactly because they want to understand the interplay of geodynamics and stratigraphy that lies beyond their daily concern. The data are regional; the principles, however, are global.

Dag Nummedal
Institute for Energy Research
University of Wyoming
Laramie, WY 82071