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3D SOURCE ROCK MODELLING OF THE LATE JURASSIC VØRING BASIN OFF MID-NORWAY

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The greater Vøring Basin area off mid-Norway, close to the well established petroleum plays of the Dønna and Halten Terraces, has high potential for petroleum prospectivity. It remains under-explored, although several discoveries of mainly gas but also oil (Ellida prospect) were made in the last few years. One important risk-factor for the area is the presence or absence of an effective source rock. The Late Jurassic Spekk Formation, equivalent to the Kimmeridge Clay and Draupne formations of the North Sea, is the only source rock off mid-Norway proven capable of generating significant quantities of oil. However, in the central parts of the Vøring Basin the Spekk Fm. is overmature as it is covered by 9000 to 13000 m of Cretaceous and Tertiary sediments (Brekke, 2000). Higher chances for prospectivity are suggested at local highs and the western flank of the basin where the overburden is less. However, at the western flanks of the Vøring the sediments are covered by Tertiary lava drapes and distribution and quality of the Spekk Fm. are highly speculative. As part of the VØTEC project, we used geochemical data from wells off mid-Norway together with structural information, interpreted seismic sections, and paleo-water depth reconstructions as input to the organic facies modelling tool OF-Mod to approach the quantitative distribution and quality of the Late Jurassic source rock.

As direct information (well data/seismic interpretations) on the development of the Late Jurassic in the Vøring Basin is limited, we included information from the eastern and western margin of the Jurassic rift zone (Halten Terrace, Dønna Terrace, Trøndelag Platform, and East Greenland, respectively). From the available literature and well data the organic facies distribution was evaluated, and based on the structural and seismic information and general process-understanding a 3D model was developed, on which several conceptual settings were tested.

The well data from the Norwegian Sea revealed an average total organic carbon content (TOC) of 6.2 wt% and an average hydrogen index (HI) of 280 mgHC/gC for the Spekk Fm., reflecting its high potential and general oil-proneness. But bulk organic parameters, biomarkers, and maceral analyses show that the kerogen composition varies representing mixtures of type II and III from marine and terrigenous sources. In accordance with previously published studies (Langrock & Stein, 2004; Swiecicki et al., 1998) our data

analysis and modelling results suggest that the rift zone between Norway and Greenland of the Late Jurassic represented a marine basin with most probably highly restricted water circulation resulting in anoxia and deposition of organic matter rich clays.

Assuming anoxic water conditions below the storm wave base also for our model, a comparatively low marine primary production (50 to 100 $gCm^{-2}yr^{-2}$; compare Mann & Zweigel, 2002, in press) is sufficient to support high organic content (5-6 wt% TOC) and quality (HI of about 300 mgHC/gC) in the sediments down towards the basin floor because of reduced degradation of the organic matter. In areas of shallower paleo-water depth on the other hand, current and wave action allowed for better oxygenation of the water column reducing the preservation of organic matter. In addition, the mainland as well as exposed highs acted as sources for terrigenous organic matter and siliciclastica. In these areas, the source rock potential is reduced (2-4 wt% TOC, HI of 100-200 mgHC/gC). Special local patterns of sediment input (rivers) and transport close to the coast and local highs resulted in a rather strong variation of source rock quality over small lateral distances.

Our modelling results indicate that during the Late Jurassic a very good source rock was deposited in large parts of the Vøring Basin area. However, the distribution and quality of the source rock is highly dependent on paleo-water depth. Some of the structural highs that are today in the focus of the petroleum companies probably already existed before the Late Jurassic and may therefore represent areas with limited source rock potential in their surroundings.

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