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Sedimentary and volcanic development of the East Greenland margin - implications for the hydrocarbon habitat of the Vøring and Møre Basins

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The opening of the North Atlantic Ocean marked the culmination of a 340 Ma history of extensional deformation and sediment basin formation following the Caledonian orogeny. Geological data from onshore East Greenland combined with offshore data from the NE Atlantic and northern North Sea provide a unique data base for better understanding the processes of continental rifting and onset of active seafloor spreading.

East Greenland forms the conjugate margin to one of the most promising petroleum provinces in northwestern Europe, and prior to the opening of the North Atlantic the rift basins in central East Greenland was located less than150 km northwest of the Gjallar Ridge. The Kangerlussuaq Basin in southern East Greenland forms the nearest onshore analogue to the offshore Faroe Islands (Skogseid et al. 2000). The onshore basins underwent a very similar evolution during the Cretaceous–Early Paleogene and terminate with onset of flood basalt volcanism at the Paleocene-Eocene boundary.

The East Greenland onshore succession thus provides important information to understand the late phase of continental break-up and the initial seafloor spreading of the northern North Atlantic and the evolution and hydrocarbon habitat of the Møre and Vøring volcanic basins. The East Greenland basins thus form basin-scale outcrop analogues providing information on rifting, uplift and volcanic history. Furthermore, studies of the sedimentary successions allow detailed bio- and sequence stratigraphic framework to be established, and from this to judge the importance of a western sediment source area for the profound deep-water reservoir units drilled along the Norwegian margin.

North-East Greenland

The post-rift Cretaceous succession of North-East Greenland (north of 72°N) is more than 2 km thick, and consists of siliciclastic, mainly marine sediments deposited following the latest Jurassic–earliest Cretaceous rift phase and reorganization of the basin (Surlyk, 1978). During the Barremian–Aptian, the inherited rift topography became submerged and in most areas offshore mudstones onlap Triassic and Jurassic sediments on the footwall of rotated fault blocks. Locally, however, coarse-grained deltaic and shallow marine sandstones were deposited in this overall transgressive stage (Larsen et al. 2001).

The Upper Cretaceous succession in North-East Greenland consists mainly of offshore mudstones with subordinate turbidite sandstones and fault-scarp derived conglomerates (Stemmerik et al., 1993; 1997; Surlyk and Noe-Nygaard, 2001). The palaeocurrent directions changed from mainly south parallel to the basin-controlling faults during the Early Cretaceous to offshore directed easterly flows in the Late Cretaceous (Stemmerik et al., 1997; Whitham et al., 1999). The change in basin configuration may have opened for transport of coarse-grained material into the Vøring Basin to the east.

The Cretaceous succession is unconformably overlain by fluvial and shallow marine sandstones and conglomerates of ?Late Paleocene age. Locally these coarse-grained sediments were deposited as incised valley fills. Although exposures are poor the main palaeocurrent directions are believed to be east and southeast. The sedimentary succession in Hold with Hope and Wollaston Forland is overlain by flood basalts 1–2 km thick.

Several petroleum systems have been identified in East Greenland. The most important comprise potential source rocks in marine shales of the Upper Permian Ravnefjeld Formation, the Upper Jurassic Hareelv Formation and lacustrine shales of the uppermost Triassic – lowermost Jurassic Kap Stewart Group. Potential reservoir rocks include Upper Permian carbonates and deep-water sandstone turbidites, uppermost Triassic – lowermost Jurassic lacustrine sandstones (Kap Stewart Group), Lower and Middle Jurassic shallow marine sandstones (Neill Klinter Group and Pelion Formation) and Upper Jurassic turbidite sandstones (Hareelv Formation). Lower Cretaceous sandstones form coarse-grained wedges of deltaic and shallow marine origin along older Mesozoic lineaments. Upper Cretaceous and Paleogene reservoir units are less studied, but comprises slope channel and basin floor sandstones of Late Turonian (Vega Sund Formation) and Santonian (Østersletten Member) age and fluvial conglomerates and sandstones of ?Late Paleocene age.

Southern East Greenland

The Cretaceous–Paleogene succession in the Kangerlussuaq Basin of southern East Greenland is an onshore analogue to the Faroes-Shetland region forming the conjugate margin (Larsen et al., 1999). The exposed 1 km thick sedimentary succession is dominated of mudstone and fine-grained sandstone and records a Late Aptian–Albian transgression followed by Late Cretaceous highstand. The Cretaceous succession is unconformable overlain by Paleocene sandstones.

During Paleocene time the Kangerlussuaq area experienced several episode of uplift leading to extensive erosion and supposed deposition of coarse clastic sediments in the offshore areas to the south east. Outcrops illustrate a proximal–distal facies change from an inland bedload-dominated braidplain to stacked shallow marine and deltaic successions in the most distal areas to the

southeast. Depending on the offshore basin physiography the delta may have fed sand into a wide storm dominated shelf or directly into submarine channels/submarine fans in deeper basins towards the southeast. The thick sedimentary succession allows recognition of repeated episodes of deltaic mouth-bar progradation most likely controlled by tectonic or magmatic uplift, it was shortly followed by the onset of volcanism. The sedimentary succession is overlain by Late Paleocene – Eocene volcaniclastics, pyroclastics and flood basalts reaching a thickness of 4–6 km.

So far, no organic rich shales have been identified in the succession. However, three major sandstone-dominated intervals are identified and may act as analogues for reservoir units in the offshore basins: 1) mid–Cretaceous fluvio-estuarine sandstones; 2) Paleocene submarine fan sandstones; 3) Late Paleocene fluvial and deltaic sandstones and conglomerates.

Basin evolution

Throughout East Greenland, the Late Cretaceous was a time dominated by deposition of fine-grained material. Sea-level rise appears to have culminated around the Turonian with local source rock development. Major episodes of sand deposition occurred in North East Greenland in the Late Turonian and Santonian. In the Early Paleocene regional uplift led to regional uplift and widespread erosion of Cretaceous and older rocks. The transition from sedimentary depositional systems to active volcanism was marked by subsidence, local basin formation and intense pyroclastic activity. Following the relatively localized initial volcanic activity, voluminous plateau lavas were extruded during the process of active sea-floor spreading.

The sedimentary succession is intruded by numerous dikes and sills related to the volcanism. In North-East Greenland, Early Paleogene intrusions are concentrated in the Cretaceous mudstone succession whereas in Kangerlussuaq they occur both in Cretaceous mudstones and in the largely unconsolidated Paleocene sandstones. The impact on source rock maturation and reservoir properties is locally significant.

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