Impact of Paleogene Magmatism on the Hydrocarbon Prospectivity of the Conjugate Mid-Norway – Northeast Greenland Margins

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Basaltic igneous deposits and processes may have a major impact on the petroleum prospectivity of volcanic rifted margins and basins as they influence source rock maturation, fluid migration, hydrocarbon trap formation, and sub-basalt seismic imaging. The Paleogene continental breakup between NW Europe and Greenland was associated with massive igneous activity. Large parts of the Norwegian margin are influenced by voluminous igneous complexes that are deeply buried below the seafloor. Their distribution is well defined by geophysical data, and igneous rocks have been sampled by both scientific and petroleum wells during the past three decades. Breakup-related igneous rocks are also abundant both onshore and offshore the conjugate Greenland margin, and offshore on the Jan Mayen micro-continent.

New and reprocessed seismic reflection data allow for detailed seismic volcanostratigraphic interpretation of the breakup complex and sub-basalt sequences. Five main volcanic seismic facies units have been mapped on the new data: Inner Flows, Lava Delta, Landward Flows, Seaward Dipping Reflections (SDRs), and Outer Highs. These units are well-defined and extensive on the mid-Norway margin, and are locally also present on the Jan Mayen micro-continent and the northeast Greenland Margin. Two distinct levels of Inner Flows have been identified in the Møre and southern Vøring basins, the uppermost correlating with the Top Paleocene horizon whereas the lowermost is at a late Paleocene level. The base of the Inner Flows is difficult to identify, and few sub-basalt reflections are present, but the interpretation suggests that the flows are thin (10's to 100's of meters). The Inner Flows continue underneath both the Vøring and Møre marginal highs. Here, the base of the volcanic complex is easier to interpret, and well-defined sub-basalt reflections are sometimes present. On the marginal highs, the volcanic complex is typically 1-5 km thick on the central part of the Vøring and Møre margins. However, the complex is substantially thinner, and locally absent, within the Jan Mayen Corridor and on the northern Vøring Margin. The sub-basalt sequences have not been drilled, but most likely represent Cretaceous and older Mesozoic and Paleozoic sedimentary rocks locally intruded by magmatic sills. This interpretation is supported by VBPR/TGS seabed sampling of the Jan Mayen Ridge in 2011 recovering sub-basalt Mesozoic sequences and sampling on the easternmost northeast Greenland margin in 2012/2012. Our observations support the possibility of a Jurassic sub-basalt petroleum play below the Vøring and Møre marginal highs.

Extensive, multi-layered sheet intrusions and associated hydrothermal vent complexes are present both in the Vøring and Møre basins offshore Norway and in the Thetis and Danmarkshavn basins offshore northeast Greenland. Deep sills are dominantly layer parallel, whereas saucer-shaped sills dominate at shallower levels. In contrast, magma emplaced in very shallow, unconsolidated sediments display flow-like morphologies. Thousands of kilometer-sized hydrothermal vent complexes are associated with the sills. Basin modeling, constrained by well data, suggests that several hundred gigatons of carbon gas were formed in the aureoles around the sills during the

intrusive event. The gas migrated out of the aureoles by two mechanisms: (1) The major gas release that occurred immediately after the gas was generated through thousands of hydrothermal vent complexes, and may have caused disruption in the global carbon cycle triggering the Paleocene-Eocene thermal maximum (PETM); and (2) The second mechanism involves slow gas seepage, occasionally to the seafloor, in the Eocene to the Paleogene forming seep carbonates and hydrocarbon accumulations. In addition, significant volumes of aureole gas (dry gas and CO_2-rich gas) are still likely trapped in the source rocks as shale gas. Our results are important for understanding petroleum systems in volcanic basins and the cause of rapid climate changes and mass extinctions in Earth history.