New Sub-basalt Imaging Technology Reveals a Hidden Prospective Geology on the Norwegian-UK Atlantic Margin

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Rifting and continental breakup is commonly associated with voluminous magmatism, forming so-called volcanic basins. Such basins include prospective sedimentary sequences that are party intruded by magmatic sill complexes and/or covered by volcanic sequences.

The Faroe-Shetland, Møre, and Vøring volcanic basins in the NE Atlantic comprise proven hydrocarbon provinces that were influenced by Paleogene continental breakup-related magmatism. Discoveries in the Faroe-Shetland Basin prove a range of volcanic influenced regional play concepts including sub-basalt (Lochnagar), intra-basalt (Rosebank) and supra-basalt (Cambo/Tobermory) hydrocarbon accumulations. Landward of the extrusive volcanic cover, a number of additional discoveries have been made above intrusive complexes, including Laggan and Tormore in the Faroe-Shetland Basin, Tulipan in the Møre Basin, and Baldebrå in the Vøring Basin. Despite these proven plays, large areas of these prospective basins remain almost entirely unexplored to date.

Two major contributing factors to the disproportionately small number of exploration wells within the volcanic influenced regions of these basins are 1) seismic imaging challenges associated with seeing beneath and within the volcanic sequences, and 2) several high-profile exploration boreholes failing to reach sub-basalt targets due to drilling challenges associated with thicker than predicted volcanic sequences. The imaging and drilling complications result from the heterogeneous nature of the igneous deposits, which include mixed lava flows, hyaloclastites, pillow basalts, tuffs and sheet intrusions. The high density and velocity of igneous rocks causes major energy loss alongside heterogeneous property distributions causing scattering, interference and offset-dependent tuning phenomena. Many approaches to improving signal recovery from sub-basalt regions have been attempted with the greatest uplifts coming from enhanced low-frequency boosting, multi-domain noise attenuation, careful velocity picking, demultiple processing, and muting.

A major expansion in the coverage of conventional high-quality 3D seismic data along the margin is enabling rapid improvements in the mapping and understanding of volcanic influences on associated prospective basins. Highlights from mapping using the methods of seismic volcanostratigraphy and igneous seismic geomorphology from the Erlend region, south of the Norway-UK border reveal the spectacular imaging advances that are now possible within the volcanic influenced basin areas alongside their clear implications for mapping sub-basalt prospectivity.

Major 3D seismic data volumes of more than 40,000 km^2 have been acquired in the outer Møre and Vøring basins since 2017. These data have partly been processed using new pre-stack depth processing methods developed for imaging in complex terrains, such as image-guided tomography, anisotropic pre-stack depth migration, reverse time migration, and forward wave-equation modelling. The resulting depth images reveal improved continuity and detectability of intra- and sub-basalt reflections. This may partly be due to the inclusion of lateral interval velocity variations within the basalt sequences and less scattering of the low-frequency wave field.

Interpretation of the new 3D data reveals previously invisible details of a large unexplored prospective region of the NCS. Examples from the Møre Marginal High and the Kolga High in the Møre Basin highlight how improved imaging and interpretation of the break-up related volcanic rocks is revealing new exploration opportunities. Through a combination of expansive new 3D data acquisition, processing developments, and integrated regional interpretation, exploration within the volcanic influenced areas along the margin has never been more exciting.