Understanding Volcanic Rifted Margins and Paleoenvironment by Scientific Drilling in the NE Atlantic

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Large igneous provinces (LIPs) are frequently associated with the breakup of continents, leading to the formation of magma-rich rifted continental margins, or so-called volcanic rifted margins. The concept of volcanic rifted margins has primarily developed from studies of the NE Atlantic margins during the past fifty years by integrated interpretation of seismic reflection, wide-angle, and scientific borehole data. Initially, the presence of breakup basalt was proven by coring shallowly buried basement on the Vøring and Rockall plateaus during DSDP Legs 38 and 81 in the 1970's. Subsequently, ODP Legs 104, 152 and 163 in the 1980's and 1990's documented the presence of kilometer-thick subaerially emplaced basalt flows on the Vøring Plateau and offshore SE Greenland by drilling the feather edge of seaward-dipping reflectors (SDRs). These research results from the NE Atlantic have had global implications, as 2D industry and academic seismic surveys now reveal that similar SDRs are present globally. However, most breakup volcanic sequences are buried below kilometer-thick post-breakup sedimentary deposits, making them inaccessible for open-hole scientific drilling. The NE Atlantic therefore remains the premier choice for research and drilling of magma-rich margins, leading to the submission of several IODP drilling proposals in the Norwegian-Greenland Sea. These proposals have benefited from a large database of industry 2D and 3D seismic data and the development of new interpretational methods, such as seismic volcanostratigraphy and igneous seismic geomorphology. Since 2000, we have also developed and used new technologies for acquisition of high-resolution 3D seismic data, the P-Cable system, which is particularly well-suited for core-log-seismic integration. In the late summer of 2021 IODP Expedition 396 ("Mid-Norwegian Margin Magmatism and Paleoclimate Implications") successfully drilled 21 boreholes on the Vøring Margin, with more than 2 km of core recovery (Planke et al., 2023). Some of the highlights of Expedition 396 include the recovery of sub-basalt granite (c. 15 m) on the Kolga High at the boundary from the Møre to the Vøring Basin, intra-basalt sandstones at the Kolga High, expanded sequences of Paleocene-Eocene Thermal Maximum (PETM) deposits (c. 240 m) along the Vøring Transform Margin, pillow basalts and hyaloclastites at the Eldhø outer high, and basalt lava flows emplaced in subaerial and swampy environments on the Skoll High (c. 150 m). The drilling data furthermore ties shallow-water venting of large volumes of greenhouse gases to the PETM (Berndt et al., 2023). These results will be combined with geodynamic modeling to reconstruct the evolution of the margin, the origin of the break-up volcanic successions and their role in the rapidly changing environment throughout the Paleogene. Our research confirm that scientific drilling is an essential tool for developing fundamental new understanding of deep-time links between solid earth processes and paleo-environments, and that the NE Atlantic holds an invaluable geologic archive for future drilling expeditions and research.

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