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Characterizing lava flows in offshore North Atlantic boreholes: a review with implications for basalt carbon storage

John Millett[1,2], Sverre Planke[1,3], David Jolley[2], Christian Berndt[4], Peter Betlem[5], Marija Rosenqvist[3], Dmitrii Zastrozhnov[3], Simona Pierdominici[6], and Reidun Myklebust[7]

[1]Volcanic Basin Energy Research AS, Oslo, Norway (john.millett@vber.no)
[2]Department of Geology and Geophysics, University of Aberdeen, UK
[3]University of Oslo, Oslo, Norway
[4]GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany
[5]Department of Arctic Geology, the University Centre in Svalbard, Svalbard
[6]German Research Centre for Geosciences, GFZ, Germany
[7]TGS, Askekroken 11, Norway

Widespread and large-scale volcanism associated with the North Atlantic Igneous Province (NAIP) erupted during the Paleocene and Early Eocene and covers vast regions of the conjugate North Atlantic rifted margins. The majority of the preserved volume occurs in the offshore sequences of the continental shelves of Greenland, the Faroe Islands, UK, and Norway. These vast mafic igneous rock volumes in the offshore NAIP have been proposed as a potential area for permanent CO_2 storage. However, a wide range of factors influence the suitability of mafic rock masses to act as fluid reservoirs including perhaps most importantly the volcanic facies (and associated pore structure, permeability, and distribution), along with alteration state, fracturing, and reactivity. In this contribution we focus on assessing the nature, distribution, and reservoir potential of sub-aerial lava flows from available borehole data across the NAIP. Lava flows are chosen for focus as they represent the most favorable reservoir target identified to date whilst also often constituting the dominant facies within much of the accessible NAIP offshore sequences.

Over 50 offshore boreholes have penetrated the lava sequences of the NAIP including both industry and scientific boreholes drilled from the 1970's onwards. Boreholes have encountered anything from a single lava flow through to several 10's of lava flows in volcanic sequences reaching over 2 km in cumulative thickness in the deepest industry wells such as Brugdan (6104/21-1) and Lagavulin (217/15-1z) in the Faroese and UK sectors respectively.

A summary of the lava flow nature (simple, compound, thickness, core-crust ratios) and physical property ranges (P-wave velocity, density, resistivity) of the penetrated lava flow sequences is presented utilizing available core, sidewall core, wireline and drill cuttings data to support the facies appraisal.

Borehole data and the level of possible interpretation vary significantly depending on the age, purpose, and importantly the drilling operations of the individual boreholes. Some of the most

robust and complete datasets are represented by modern hydrocarbon industry boreholes, for example those from the Rosebank Field in the UK sector, and cored boreholes from recent IODP Expedition 396 drilling Mid-Norway. Results from Expedition 396 are presented to highlight formation evaluation approaches for NAIP lava flow sequences including assessing the effects of different lava flow facies on Net to Gross calculations and the impact of alteration and secondary alteration on wireline log responses.

This study presents important new constraints on the nature, variability, and distribution of NAIP lava flows from extensive available borehole ground truth data forming a foundational study for the development of reservoir appraisal techniques in the province going forward.