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The Northeast Atlantic breakup (IODP Exp. 396): A case study for modeling the evolution of mantle source mineralogy during continental rifting

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International Ocean Discovery Program (IODP) Expedition 396 sampled the continent-ocean transition of the Mid-Norwegian Margin, an area known to have produced voluminous magmatism during the last break-up phase of Pangea. A highly fertile mantle source is one of the leading hypotheses to explain the large volume of magma that erupted in the region throughout the rifting process [1]. Over the past decade, first-row transition elements (FRTEs) have gained popularity as tracers of mantle sources mineralogy [e.g., 2,3], as their partition coefficients between melt and mantle assemblages are close to 1. This behavior effectively preserves FRTE ratios (e.g., Mn/Fe, Mn/Zn, Zn/Fe, and Co/Fe) of the source during melting and fractionation processes [3].

We developed a new model to constrain mantle source mineralogy. The main input parameters are (1) basalt FRTE concentrations and their standard deviations, the FRTE ratios of the source provided in Lang & Lambart [3], and (2) randomly produced mineral assemblages assuming, the mantle source is composed of five main phases (olivine, clinopyroxene, orthopyroxene, garnet, and spinel). Using a Monte Carlo-inspired approach, we determine which assemblages can produce the observed combined FRTE ratios of the basalts.

When applied to samples of basaltic basement collected during Expedition 396, our model shows the bulk mineralogy of the source changes during the rifting process. Sites interpreted as representative of the onset (U1566) and the end (U1573) of rifting both present a source dominated by olivine that must also contain spinel, while the mantle source during the peak of magmatism (sites U1571 & U1572) is characterized by enrichment in garnet and pyroxenes. Our results demonstrate that modal variations played a role in the magmatic activity that occurred during Northern Atlantic rifting. The extent to which these variations might reflect lithological heterogeneities will be explored in future work. This model can be applied to basalts globally as a valuable tool across the mantle petrology community to better quantify mantle heterogeneity.

[1] Planke et al., 2022, doi: 10.14379/iodp.pr.396.2021
[2] Le Roux et al. 2015, doi: 10.2138/am-2015-5215
[3] Lang & Lambart, 2022, doi: 10.1016/j.chemgeo.2022.121137