Eruption mechanism and volatile budget of the early Eocene Danish ash series, and implications for the emplacement of the North Atlantic Igneous Province

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The Danish ash series is a succession of more than 180 tephra layers cropping out in northwest Denmark, deposited during a ~1.2 Myr period from about 55.8 Ma to 54.6 Ma. The volcanic ashes are grouped stratigraphically in a negative and positive ash series, based on outcrop appearance and chemistry. While the negative series is a heavily altered, relatively heterogeneous mix of magma compositions, the positive series are composed largely of almost pristine tholeiitic basalts. The ashes are sourced from the North Atlantic Igneous Province (NAIP), erupted during the opening of the North Atlantic. The NAIP comprises extrusive and intrusive rocks along the east and west coast of Greenland, on plateaus and ridges in the North Atlantic, and the Faroes and British Islands. The province was emplaced 64–52 Ma, but the most voluminous activity was focused between ~56 and 54 Ma and led to the emplacement of the bulk of flood basalt volcanism and to the deposition of the Danish ash series.

The thicknesses of the ash layers and the long distances from possible source volcanoes suggests unusually large and explosive eruptions. Several studies have discussed the possibility that this explosiveness may be due to magma-water interactions, but none have attempted any quantitative or indeed qualitative investigation into the style and extent of possible hydromagmatic volcanism. Hydromagmatic activity is governed by a complex interplay of several factors, such as the relative amounts of magma and water, the depth of submarine eruptions, and the magma composition. We measured the residual sulfur concentrations in pristine matrix glasses and the variation in ash morphology and vesicularity through the ash stratigraphy. Together, these data allow us to model the changes in degassing and evaluate the degree of magma-water interaction during the fragmentation process. Our results suggests that the Danish ash series is indeed a result of hydromagmatic activity, and that there has been an overall increasing depth of eruptions through time.