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Volcano-climate interactions during the PETM and U-Pb dating from the Fur Formation, Denmark

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The Palaeocene-Eocene Thermal Maximum (PETM) at ∼56 Ma is one of the most extreme global warming events in Earth's history. Vast quantities of CO_2 and CH4 were released to the atmosphere, causing a rapid (within 20,000 years) 5-6 °C warming that persisted for ∼170,000 years. The PETM occurred during an abnormally warm period in Earth history, and was followed by other hyperthermal events later in the Eocene. The PETM also coincided with the second and major pulse of magmatism from the North Atlantic Igneous Province (NAIP) during the break-up of Laurentia and Eurasia at 54-56 Ma. Evidence of explosive volcanism is prevalent at Fur, an island in northern Denmark, where over 180 distinct >1 cm thick ash horizons are preserved in a shallow marine succession (numbered from #-39 to #+140). These ash layers are believed to have originated from volcanic centres in east Greenland and western UK, which indicates that that they were formed during very large volcanic eruptions. Here we present the results of two key sections of the Fur Formation: a beach section at Stolleklint that includes sediment deposited syn-PETM, and a quarry section at Jenshøj that encompasses post-PETM sediments. A detailed chemostratigraphic log of δ13C (TOC) and δ15N values through the section suggests that there may be part of sequence missing, either through glaciotectonism or a depositional hiatus. The δ13C values around ash #-33 are typical of the PETM negative carbon isotope excursion (-31 to -32 ‰, yet are back to background values of ∼-26 ‰ just four metres up section. The quarry section around ash #+19 displays further variations in δ13C values, suggesting a coincidence with one of the later Eocene hyperthermal events. High precision U-Pb dating of magmatic zircons from ash layer #+19 conforms to a post-PETM depositional age, giving a mean deposition rate of approximately ∼5 cm kyr-1. The correlation between the largest ash layers (#-33 and #+19) and the largest perturbations to carbon isotopes is noteworthy, although there may be a depositional effect to consider. These results indicate that the Fur Formation is of key importance for furthering our understanding of the causes and repercussions of PETM.