# Linking warming, environmental changes, and volcanic ash falls from onset to recovery of the PETM: a multi-proxy study from Fur, Denmark

ELLA W. STOKKE[1]*, JESSICA H. WHITESIDE[2], LARS RIBER[3], HAFLIDI HAFLIDASON[4], JESS E. TIERNEY[5], HENRIK H. SVENSEN[1] AND MORGAN T. JONES[1]

[1]CEED, University of Oslo, PO Box 1028, 0315 Oslo, Norway (* Correspondence: e.w.stokke@geo.uio.no)
[2]National Oceanography Centre, Southampton, University of Southampton, Southampton, SO17 1BJ, UK
[3]Department of Geosciences, University of Oslo, P.O. Box 1047, Blindern, NO 0316 Oslo, Norway
[4]Department of Geology, University of Bergen, Alle´gt. 41, N-5007 Bergen, Norway
[5]The University of Arizona Department of Geosciences, 1040 E 4th St, Tucson, AZ 85701, USA

The Palaeocene-Eocene Thermal Maximum (PETM; ca. 55.8 Ma) was an extreme global warming event initiated by a substantial release of $\delta^{13}C$-depleted carbon to the ocean-atmosphere system. It coincided with the opening of the North Atlantic and emplacement of the North Atlantic Igneous Province (NAIP), causing significant carbon release that potentially contributed to the initiation of the PETM.

One of the best exposures covering the PETM interval is found on the island of Fur in northwest Denmark, where a ca. 60 m thick sedimentary succession of marine clays and diatomite with ca. 180 interbedded tephra layers of NAIP origin crops out. The section covers the onset-, body-, and recovery phase of the PETM (defined by Total Organic Carbon (TOC) $\delta^{13}C$ analyses), with exceptionally well-preserved sediments allowing for a high-resolution multi-proxy investigation of the environmental and climatic response to the large carbon release.

Results from the organic paleothermometer $TEX_{86}$, organic biomarkers, and inorganic geochemical proxies indicate significant increases in sea surface temperature and ocean anoxia directly following a sharp PETM onset and ash deposition. The PETM body is characterised by sustained high temperatures, high weathering rates (indicated by an increased influx of kaolinite), as well as steadily increasing TOC and sulphur concentrations, before all decrease during the recovery phase, coinciding with a dramatic increase in ash deposition. Our results highlight the rapid environmental response to large carbon emissions, and the possible links between the PETM and the NAIP.