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Surface-water freshening and high-latitude river discharge in the Eocene North Sea

ANNE ZACKE[1], SILKE VOIGT[2]*, MICHAEL M. JOACHIMSKI[3], ANDREW S. GALE[4], DAVID J. WARD[5] & THOMAS TÜTKEN[6]

[1]*Department of Applied Geoscience, German University of Technology Oman GUtech, PO Box 1816, Athaibah PC 130, Muscat, Sultanate of Oman*

[2]*Leibniz Institute of Marine Sciences, Wischhofstr. 1–3, 24148 Kiel, Germany*

[3]*University of Erlangen, Schloßgarten 5, 91054 Erlangen, Germany*

[4]*Department of Earth and Environmental Sciences, University of Portsmouth, Burnaby Road, Portsmouth PO1 3QL, UK*

[5]*81 Crofton Lane, Petts Wood, Orpington BR5 1HB, UK*

[6]*Steinmann Institute for Geology, Mineralogy and Palaeontology, University of Bonn, Poppelsdorfer Schloss, 53115 Bonn, Germany*

**Corresponding author (e-mail: svoigt@ifm-geomar.de)*

Abstract: A shark-tooth apatite $\delta^{18}O$ record of the early Palaeogene North Sea reflects changes in regional hydrography by showing variable temperatures and salinities. A 2–4 Ma period in the early Eocene was particularly influenced by substantial surface-water freshening, indicated by a 3–4‰ reduction of $\delta^{18}O$ values. The magnitude of the $\delta^{18}O$ decrease indicates a depletion in ^{18}O of surface waters by 2–3‰ relative to Eocene mean ocean water. This value is lower than that of coeval lakes reconstructed from freshwater gastropod $\delta^{18}O$ values from the Paris Basin, suggesting that large rivers with high-latitude catchment areas drained into the North Sea. The period of surface-water freshening began close to the Palaeocene – Eocene thermal maximum, when relative sea-level fall, tectonic uplift and basaltic volcanism caused a temporary isolation of the North Sea. North Atlantic and North Sea surface waters became reconnected during a series of early Eocene transgressions.

The early Palaeogene period (60–40 Ma) was characterized by greenhouse conditions, probably induced by an intensified hydrological cycle and increased poleward heat transport (Zachos *et al*. 2001; Jahren & Sternberg 2003). Superimposed on this warm climate state, the Palaeocene–Eocene thermal maximum (PETM) represents a brief episode of global warming (Kennett & Stott 1991; Zachos *et al*. 2003; Sluijs *et al*. 2006). The high-latitude Arctic Ocean and adjacent shelf seas were repeatedly influenced by large amounts of freshwater discharge (Brinkhuis *et al*. 2006). An increased poleward moisture transport is indicated by hydrogen isotopes of land-plant derived *n*-alkanes from the Arctic (Pagani *et al*. 2006). Whereas the Palaeogene climate is well documented in the open-marine and continental record, little information currently exists about the climatic evolution in marginal seas, which linked low- and high-latitude oceans in the Northern Hemisphere. Quantitative palaeotemperature estimates derived from oxygen-isotope ratios of foraminifers and other calcitic shells are not well suited in this depositional setting because of the potentially prominent influence of meteoric diagenesis and/or the absence of carbonates.

This study presents oxygen isotope data of shark tooth apatite from the Palaeogene North Sea (Fig. 1). Modern sharks precipitate their enameloid in isotopic equilibrium with ambient seawater (Vennemann *et al*. 2001) and may be used as a reliable recorder of palaeo-temperatures. The $\delta^{18}O$ signal preserved in the PO_4-group of fish-tooth apatite ($\delta^{18}O_P$) is less prone to diagenetic alteration than carbonates, and is relative insensitive to dissolution–reprecipitation processes because of the strong chemical bond between oxygen and phosphorus (Kolodny *et al*. 1983; Lécuyer *et al*. 1999). The shark-teeth derived $\delta^{18}O_p$ data are interpreted with respect to changes in temperature and salinity of surface waters and compared with $\delta^{18}O$ data from marine-, fresh- and brackish-water gastropods (Schmitz & Andreasson 2001) to reconstruct regional changes in North Sea hydrography.

Material

The analysed shark teeth derive from a variety of Palaeocene–Eocene onshore localities in the London and Hampshire basins (UK) and from sites in Denmark, Belgium, the Netherlands and Sweden, covering a time span of 33 Ma (65–32 Ma; Fig. 1). Whereas the sedimentary facies in the Hampshire and London basins represents a nearshore environment with neritic and fluvial sediments, the Danish successions were deposited at a considerable distance from shore (300–400 km) in bathyal water depths of 600–1000 m (Schmitz *et al*. 1996). All teeth were collected from distinct beds, which have been biostratigraphically dated by calcareous nannofossils (Table 1). The dataset also covers the PETM, with one tooth (P69) taken from an interval within which the negative carbon isotope excursion of the PETM has been recorded (Schmitz *et al*. 2004). The preservation of the analysed tooth apatite has been constrained by visual screening of the enameloid and a comparison of REE analyses of enameloid and dentine (see below).

Teeth of modern selachians grow within several days to several months depending on species and age of the individuals. As a consequence, selachian teeth of the same species, age and