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

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**Abstract:** A shark-tooth apatite δ¹⁸O 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 δ¹⁸O values. The magnitude of the δ¹⁸O decrease indicates a depletion in δ¹⁸O 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 δ¹⁸O 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 δ¹⁸O signal preserved in the PO₄-group of fish-tooth apatite (δ¹⁸OP) 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 (Kolody et al. 1983; Lécuyer et al. 1999). The shark-teeth derived δ¹⁸Oₚ data are interpreted with respect to changes in temperature and salinity of surface waters and compared with δ¹⁸O data from marine-, fresh- and brackish-water gastropods (Schmitz & Andrèasson 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 nanofossils (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