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The Holocene relative sea-level curve for the tidal basin of the barrier island Langeoog, German Bight, Southern North Sea

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ABSTRACT

During the late Holocene sea-level rise in the Southern North Sea, a wedge-like sediment body accumulated at the East Frisian coast, being characterised by intercalated peat layers.
These peat layers were used to generate a relative sea-level curve on a regional scale for the backbarrier tidal basin of the East Frisian island Langeoog, Southern North Sea. It is based on ~600 cores, 68 km of Boomer seismic profiles and 44 pollen- and radiocarbon ages 44.
The investigated core data are difficult to correlate in terms of sea-level change due to multiple small-scale facies changes that are typical for tidal flat sediments. However, the seismic profiles show that the intercalated peat beds correlate with clearly defined seismic horizons, identifying the peat layers between the cores. Therefore, the stratigraphic significance of the peat beds has been evaluated dependant on their spatial distribution before using them as sea-level indicators.
The dated samples of positively evaluated peat beds were used for the relative sea-level curve. As the intercalated peats represent phases of stillstands or slow-downs during sea-level rise, this results in a step-like sea-level curve for the last 6000 years of Holocene relative sea-level rise at the East Frisian coast in the German Bight of the Southern North Sea.

1. Introduction

1.1. Research history

The first Holocene relative sea-level curve (rsl-curve) for the East Frisian coast of the southern North Sea region was generated by Schütte (1939), who concluded that global sea-level was not rising, but that the coast was subsiding instead, as did Nilsson in 1949. However, subsequent researchers adopted the concept of an eustatic rise (e.g., Haarnagel, 1950; Louwe-Kooijmans, 1974; Roeleveld, 1974; Jelgersma, 1979; Roep and Beets, 1988; Van de Plassche and Roep, 1989; Denys and Baeteman, 1995; Behre, 2003). The German part of the southern North Sea coastline (the German Bight) was presumed to be isostatically stable and, therefore, ideal for study of eustasy. However, more recent studies (e.g., Kiden et al., 2002) show, that isostatic movements may occur along the German coast. In the northwestern part of The Netherlands, Van Balen et al. (2005) show neotectonic subsidence inferred from geodetic levelling studies of up to −0.8 mm/year. Therefore, sea-level curves derived from this region represent relative sea-level rather than eustasy.

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1.2. Two main approaches of sea-level curve interpretation

The sea-level curve for the German Bight shows several sea-level fluctuations during the late Holocene (Behre, 2003) whereas Holocene sea-level curves from The Netherlands and Belgium have a smooth shape (e.g., Jelgersma, 1979; Denys and Baeteman, 1995). This may be due to the dataset. For example, the curve of Jelgersma (1979) is based on basal peats (basal with respect to the Holocene coastal sequence). This means that possible sea-level fluctuations are not recorded. Other curves are based on a data density that is too low to allow reliable resolution of high-frequency sea-level fluctuations. Therefore, new sea-level curves must be based on a large number of observations in order to identify potential high-frequency relative sea-level oscillations superimposed on the general rising trend during the Holocene (Mauz and Bungenstock, 2007).

1.3. Global versus regional observations in East Frisia/Southern North Sea

Not all relative sea-level changes indicated by coastal sediments can be correlated with global climate changes. Many events reflect local to regional processes:

- Kiden et al. (2002) suggest for the coast of the Southern North Sea (Germany, the Netherlands, Belgium) that areas of approximately ~50 km across have their own neo-tectonic history.

- Intercalated peat beds (i.e., intercalated within the Holocene coastal sequences and often used as sea-level index points, meaning that fen peats are indicators for former sea-level as they are nourished by groundwater, which corresponds to mean sea-level, s. Behre and Streif, 1980) need to be precisely defined prior to rsl-curve construction considering the palaeogeographical situation of their regional environment. They are not necessarily directly linked to sea-level rise because of specific regional palaeogeographic conditions (Baeteman, 1999).
- Different rates of compaction, resulting from variable thicknesses of peat layers as well as the overall thickness of the underlying Holocene deposits, influence the depths of the sea-level index points for several coastal sections (e.g., Streif, 1971).
- Tides along the coast of the southern North Sea differ remarkably with respect to distance from the tidal amphidromic point in the central North Sea and the coastline morphology. Therefore, tidal ranges and high tide levels differ along the North Sea coast (e.g., tidal range at Langeoog: 2.70 m, tidal range at Wilhelmshaven: 3.80 m (BSH, 2008), distance ~65 km along the coastline, s. Fig. 1).

Because of these local effects, a separate relative sea-level curve must be provided for each tidal basin – in more precise words: "Fluctuations in sea-level rise cannot be assumed synchronous and equal in amplitude along all the coasts of the southern North Sea; moreover, it is not right to explain such fluctuations in terms of widespread regionally occurring transgressions and regressions. They should be interpreted as small-scale fluctuations of the 'Holocene transgression'….." (Weerts et al., 2005).

Only sea-level fluctuations recognised in multiple tidal basins can potentially be linked to climatic influence; other fluctuations are due to local effects. However, understanding the reasons for such local fluctuations would yield important benefits for coastal protection management.

1.4. Southern North Sea

Different approaches to construct Holocene relative sea-level curves for the Southern North Sea have been adopted. For example, in the western Netherlands Van de Plassche and Roep (1989) used the sedimentological interpretation of beach sediments with respect to palaeotide levels. Jelgersma (1979) worked with basal peats from the entire southern North Sea region, Denys and Baeteman (1995) used data from basal and intercalated peats collected from the Belgian coast, whereas Behre (2003) worked with basal as well as intercalated peats and also used archaeological data from the entire German coast. Jelgersma (1979), Van de Plassche and Roep (1989) and Denys and

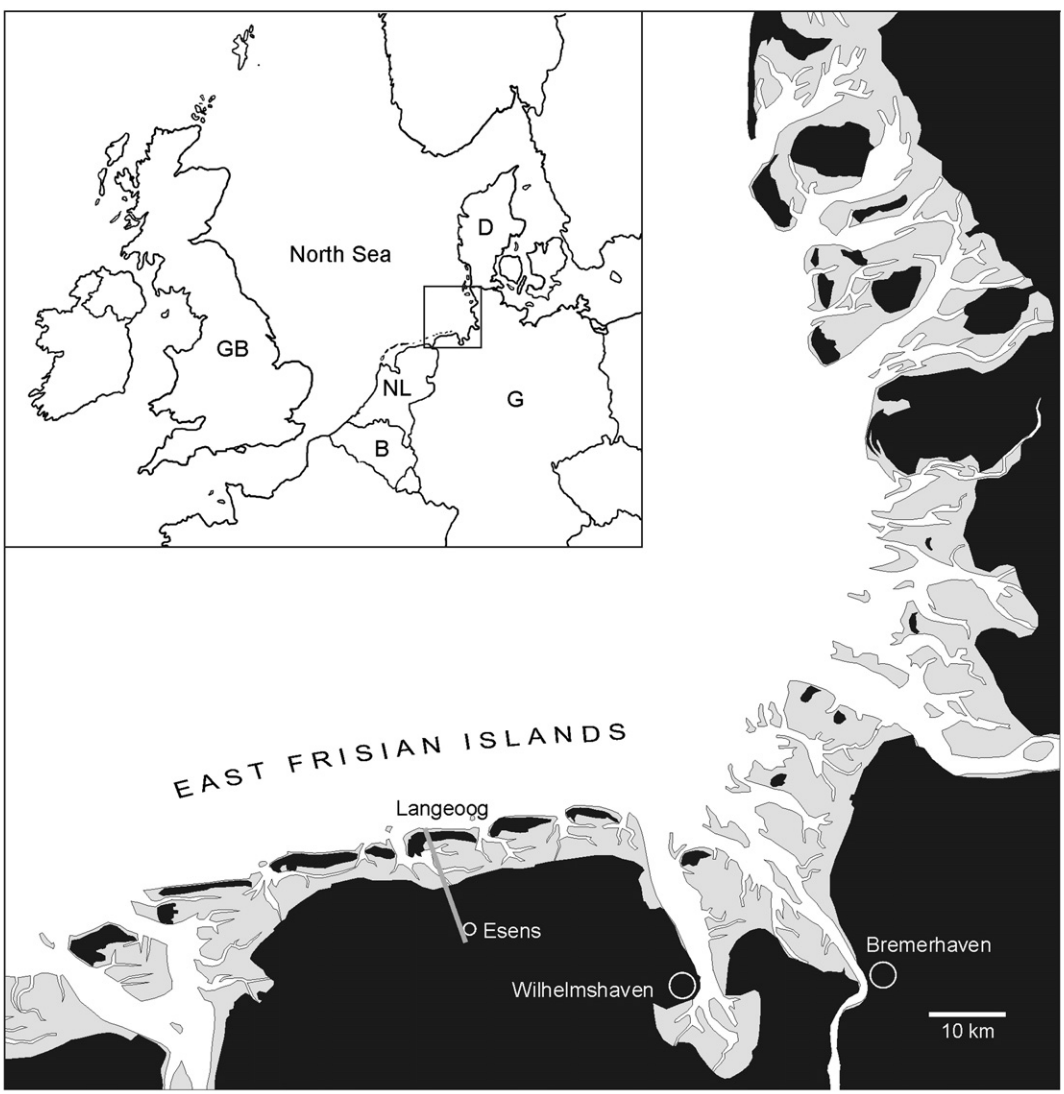

Fig. 1. The German part of the Southern North Sea. The study area includes the backbarrier of the East Frisian island of Langeoog and the adjacent coast. The transect from Langeoog to Esens (grey line) is shown in Fig. 2.