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Shoreline displacement and salinity changes: The development of two shallow freshwater lakes at the Karelian White Sea coast (Northwest Russia) as reflected in sedimentary diatoms

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INTRODUCTION

The postglacial land uplift of Fennoscandia and the resulting environmental changes are important factors for changes in coastline ecosystems. In this context, shoreline displacements caused by isostatic land uplift and eustatic sea level fluctuations during the last 10 000 years were adequately described for the Baltic (Klemann & Wolf 2005, Påsse & Andersson 2005). According to Pan & Sjöberg (1999) the Fennoscandian shield shows uplift rates from 1 to 11 $mm \cdot y^{-1}$.

While the land uplift-based Holocene coastline development and the resulting environmental changes in the Baltic region are well investigated (e.g. Berglund et al. 2005), the eastern part of the Fennoscandian shield bordering the White Sea remains less studied, in particular its development during the last centuries.

Diatoms occur in both marine and freshwater sediments and have proven to be a helpful tool for environmental reconstructions. Since they are very sensitive to changes in salinity (Ryves et al. 2004), trophic conditions (Bennion et al. 2004) and pH (Birks et al. 1990) diatoms are used for defining shoreline displacement and sea level fluctuations in costal areas (Kjemperud 1980). Dated marine to freshwater transitions, preserved in sediment cores from costal basins, have been frequently used for reconstructing relative sea level changes and isostatic uplift (Pienitz et al. 1991). In the present study, analysis of sedimentary diatoms was used to investigate the development of two shallow freshwater lakes close to the Karelian White Sea coastline during the past centuries. The following questions have been asked:

1) Are salinity changes in the study lakes detectable by means of diatoms? 2) Are the investigated lakes and their sediments sensitive paleo-systems for studying land uplift processes at the White Sea coastline?

INVESTIGATION AREA

The investigated lakes, unofficially named ESW and ESO, are located directly at the Karelian White Sea coast, Northwest Russia, on the Fennoscandian shield (Fig. 1). Geological data (Natalia Tschewtschenko; pers. comm.) reveal that the two lakes (Fig. 1) had been part of the White Sea from 9 000 to 500 years ago, however they are freshwater systems today. The small and shallow lakes (ca. 0.2 km^2 surface area, max. 2 m depth) are connected via a small stream, which is draining into the Kislaya Guba bay. The tidal range in this bay is 1.3 to 1.8 m (in average 1.6 m). Compared to this the ESW is located 2.3 m a.s.l. and the ESO only 1.6 m a.s.l. The catchment area, predominantly coniferous forest, is about 6 km^2 wide.

MATERIAL & METHODS

In August 2004 two short sediment cores (ESW: 47 cm, ESO: 51 cm) were taken from the deepest part of each lake with a Mondsee corer. In every second sediment centimetre of the $^{210}Pb/^{137}Cs$ dated cores 300 to 400 diatom

valves per slide were counted. Diatoms were divided into groups according to their salinity optima based on Simonsen (1962) and Pankow (1990). The halobous index (Ziemann 1971) was used to detect salinity changes. In addition, cluster analysis (CONISS) and multivariate statistics (CANOCO 4.5) were used for this study.

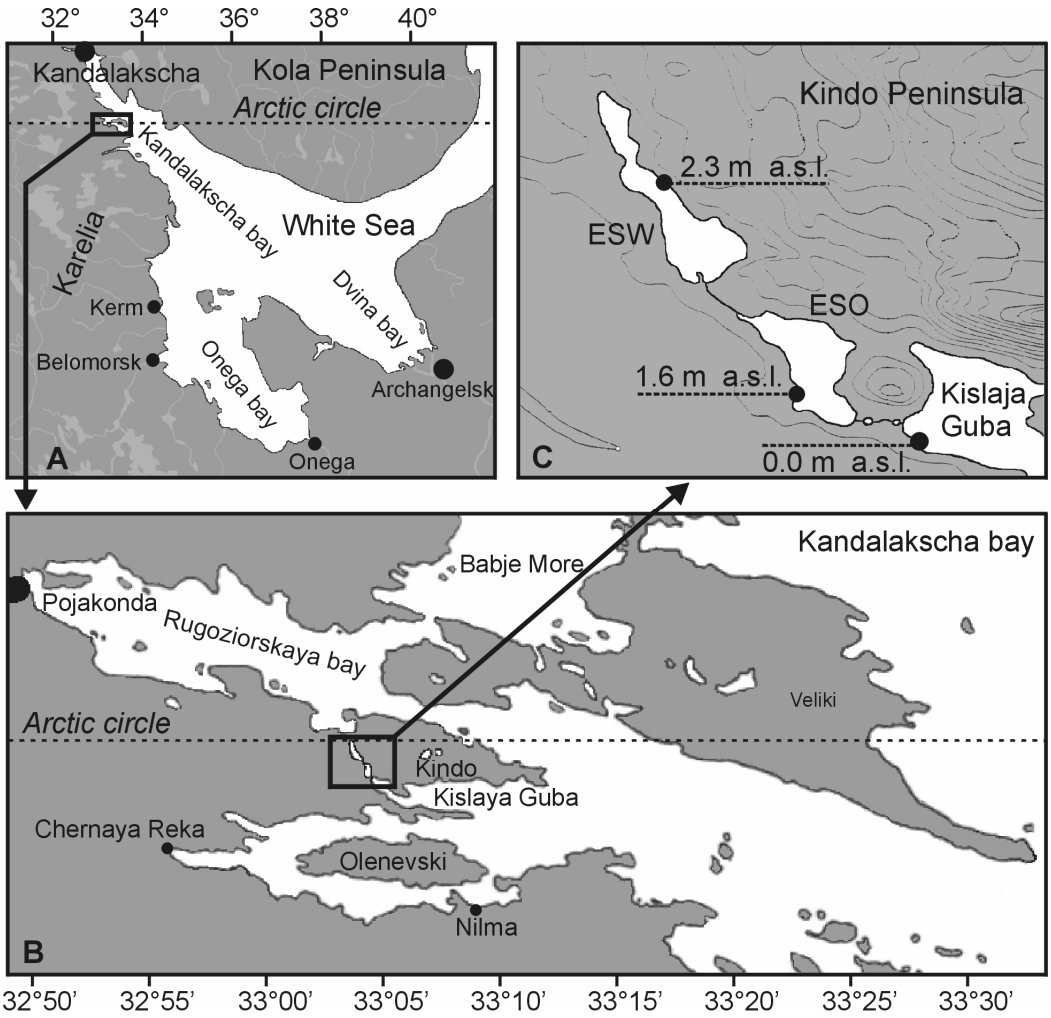

Fig. 1. A–C Investigation area and location of the study lakes ESW and ESO on the Kindo peninsula.

RESULTS AND DISCUSSION

157 diatom taxa were found in the 47 cm long sediment core of lake ESW, whereas the 51 cm long sediment core of lake ESO revealed 132 diatom taxa. Fig. 2 shows the vertical distribution of the most important diatom taxa of lake ESW and the calculated halobous index (Ziemann 1971). The zonation is based on stratigraphically constrained cluster analysis.

Diatom zone 1 (47–35 cm) contains mainly polyhalobous taxa (e.g. *Paralia sulcata* (Ehrenb.) Cleve) preferring salinity ranges between 35 and 17 down to 8 PSU. Furthermore, small oligohalobous *Fragilaria*-species were detected (Fig. 2). The transitional zone 2 (33–17 cm) is characterized by a decrease of polyhalobous taxa and the dominance of the opportunistic *Fragilaria construens* f. *venter* (Ehrenb.) Hust. The uppermost zone 3 (15–1 cm) is dominated by halophobous taxa (e.g. *Tabellaria flocculosa* (Roth) Kütz., *Eunotia sudetica* O.Müll.) indicating weakly acid conditions. The halobous index ranges between 35 and 55 in zone 1. The index declines from 55 to -7 along the transition zone 2 and ranges between -7 and -39 in zone 3, indicating calcium poor, weakly buffered freshwater. Based on the ^{210}Pb-dating the transition from brackish-marine to freshwater conditions took place about 100 years ago.

Similarly to the cluster analyses (Fig. 2), also the PCA (Fig. 3) shows significantly different zones (p-value 0.0001) in the ESW sediment core. Furthermore, a development from former brackish-marine conditions via a transition zone to a freshwater system is recognizable. The

salinity gradient might be represented by axis 2, declining from the older to the youngest sediments. Axis 1 shows probably the dynamic changes within the diatom flora caused by changing environmental conditions. Lake ESO (1.6 m a.s.l.) follows a similar development as shown for lake ESW. However, today the lake ESO still remains in the transition phase. The step from a brackish-marine to a declining and fluctuating salinity (transition zone) took place about 100 years ago in lake ESO.

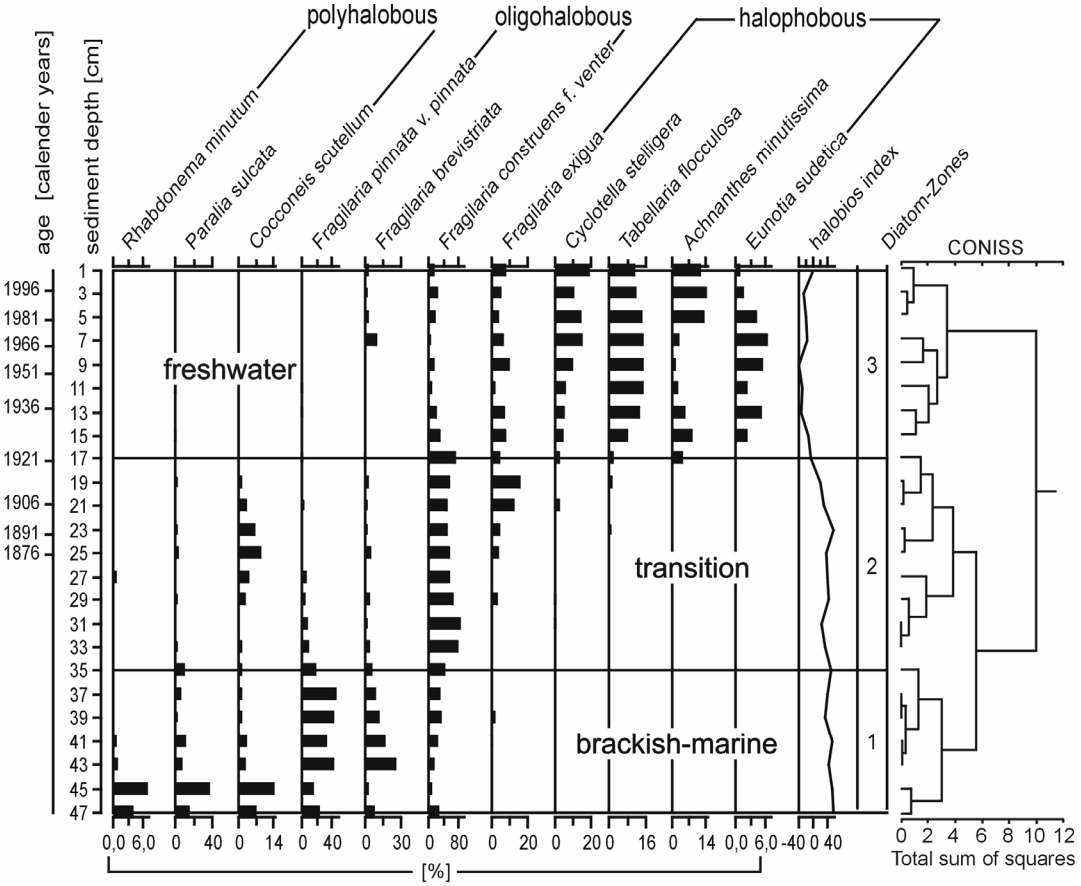

Fig. 2. Dominant diatom taxa, ecological diatom groups based on salinity and the diatom-based halobous index for lake ESW. The zonation is based on stratigraphically constrained cluster analysis (p-value 0.0001).

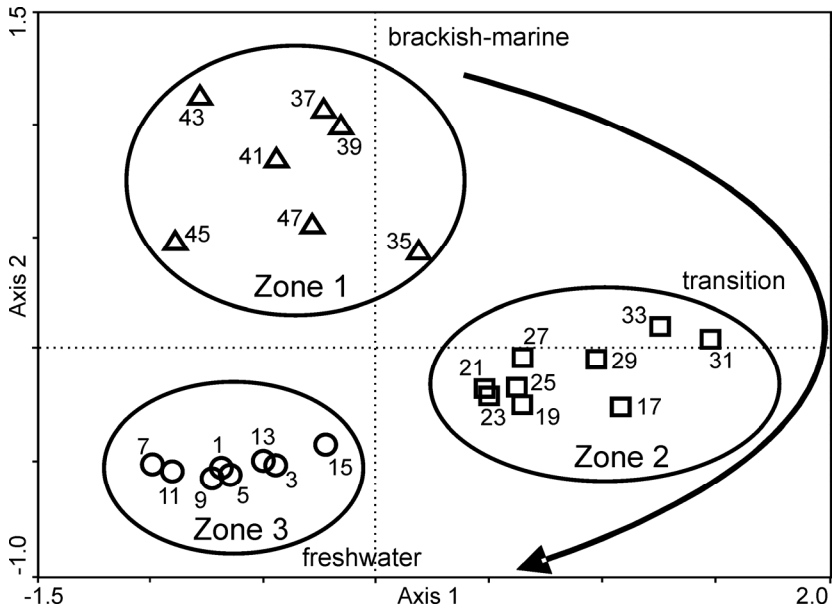

Fig. 3. PCA plot (axis 1 and 2) based on diatom data (relative abundance) from sediment samples of lake ESW. Axis 1: eigenvalues 0.559, length of gradient 3.723 SD. Axis 2: eigenvalues 0.298, length of gradient 1.613 SD.

CONCLUSION

The present study shows that the lakes ESW and ESO, located on the Kindo peninsula at the Karelian White Sea coast, had been subject to fluctuating saltwater influences during the last 150 to 200 years and partly even today. The questions of this investigation can be answered as follows: 1) Salinity changes are detectable through diatoms for both lakes. The lakes ESW and ESO show a trend from brackish-marine to freshwater conditions during the last centuries. 2) Both lakes are sensitive systems to investigate land uplift activities. Based on salinity changes detected by diatoms and ^{210}Pb dating the hypothetical uplift velocity of the investigation area is 1.0–1.8 mm·y^{-1}. This result is in good agreement with the data acquired by GPS and empirical data shown in recent literature (Pan & Sjöberg 1999, Påsse & Andersson 2005).

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