Puglia 2003 - Final Conference
Project IGCP 437

Coastal Environmental Change
During Sea-Level Highstands:
A Global Synthesis with implications
for management of future coastal change

Otranto / Taranto - Puglia (Italy) 22-28 September 2003
Quaternary coastal morphology and sea level changes

IUGS UNESCO IGCP
Project 437

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Formation of Gates in Nearshore Areas of the Southern Baltic Sea.

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Keywords: *Nearshore environment, sediment transport, cross-shore currents, large scale coastal behavoir, Baltic Sea*

Introduction

The Baltic Sea is a very young marginal sea, which was formed after the last glaciation. Along the southern Baltic Sea coast rapid sea level rise turned into relative stable sea-level conditions with minor fluctuations in the range of only a few meters some 6000 ^{14}C - years before present (Schumacher and Bayerl, 1999). Since then, along with this relative stability, other factors of external forcing, such as sediment supply by coastal erosion, climate and/or anthropogenic impact and hydrodynamic conditions have become increasingly important for coastal evolution. Under those conditions coastlines are striving for an equilibrium, determined by hydrological forcing, sediment transport and geomorphological development.

The evolution of the upper and lower shoreface of sandy coastlines is a function of highly dynamic processes acting at different scales of time and space (Cowell et al, 1999). The upper shoreface is most sensitive to forcing. Depending on the typical slope of the beach, or equivalently, the median grain size, several longshore bars may occur, as waves break and re-form on their way towards the coastline. These longshore sandy bars react with on-offshore displacement due to different energy input by breaking waves (Larson and Kraus, 1994).

Circulation cells, composed of longshore and offshore currents, and different in their spatial extension and temporal occurrence play a dominant role in sediment distribution on the upper shoreface (Short, 1999). Large-scale circulation cells link the upper and lower shoreface due to their extension and sediment transport capabilities.

Investigation area

Along the coastline of the investigation area (Fig. 1) cliff coasts alternate with lowlands encompassing an approximately 500 km long coastline.

Cliffs are composed of easy erodable material (till, melt water sands and dunes).

The average rate of retreat is approximately 30 cm/year. While in front of cliffs abrasion platforms exist and nearshore bar systems are not well evolved, extensive nearshore bar - trough system are common in front of lowlands. Here sometimes up to ten bars occur where the gradient of the slope is below 1 : 200. Sediment supply to the nearshore system is provided from the subaerial parts of the coast and as well from the nearshore area itself (Schrottke, 2001). The energy input by waves is low to moderate due to a limited fetch, which for no location exceeds 116 km.

Methods

To investigate coastal changes and the development of the morphology of the upper shoreface on longer time scales, for some areas up to 12 series of aerial photographs were analysed.

These photos cover a period of approximately 60 years. The observed nearshore bar systems were classified into three groups (Fig. 1):

? More than two continuos nearshore bars,
? one or two continuos nearshore bars,
? one discontinuous nearshore bar or no bars.

Locations of irregularities, where bars were deformed, connected, with each other, re-shaped or destroyed were identified in every series. An example of such an area is shown in Fig. 2. According to Furmanczyk and Musielak (1999) those areas of irregulateries were named "gates".

After detection of these gates further investigations included side-scan sonar blanked coverage mapping, bathymetrical surveying, sediment sampling and analysing and underwater video observations.

Results

Along the whole investigated coastline, thirteen areas were identified where a permanent destruction of the nearshore bar systems appears (Fig. 1). Besides these some locations were visible, where the destruction is only periodically. Gates appear in front of lowlands and as well in front of cliff coasts. The lateral extension of these disturbances varies between only 100 m for the periodically disturbed areas and up to 1 km for the permanently destructed areas. Seaward of the gates the seafloor is lowered by up to 1 m and some incised channels occur. Additionally elongated sedimentological structures, composed of fine sand, resting on gravel or till, can be observed. These structures are striking more or less perpendicular to theshore. Based on the sedimentological analyses it could be shown that the grain sizes of the sediment in front of the gates are coarser than in the surrounding area. The extension of changes in the surface sediment distribution and as well in the upper shoreface morphology is observed up to 2 km offshore.

Conclusion and discussion

Furmanczyk and Musielak (1999) observed similar structures along the whole Polish coastline. They assume that these gates are part of a large-scale circulation system, only active during severe storm conditions.

Based on aerial photographs, they discovered a seaward extension of these systems of several kilometres (only 2 km in Kiel- and Mecklenburg Bay) and a lateral extension of up to 2 km (only 1 km in Kiel- and Mecklenburg Bay). Compared to Kiel Bay and Mecklenburg Bay, these larger dimensions of the structures along the open Polish coastline are due to a longer fetch and therefore stronger energy input by incoming waves (Schwarzer et al., 2003).Along the Polish coastline the locations of these gates are as well stable for decades. We assume that modifications in grain size distribution are evidence of cross-shore water movement. his was proofed by a tracer experiment with luminophores carried out in the area of gate no. 4 (Fig. 2) in a previous study (Schwarzer, 1994).

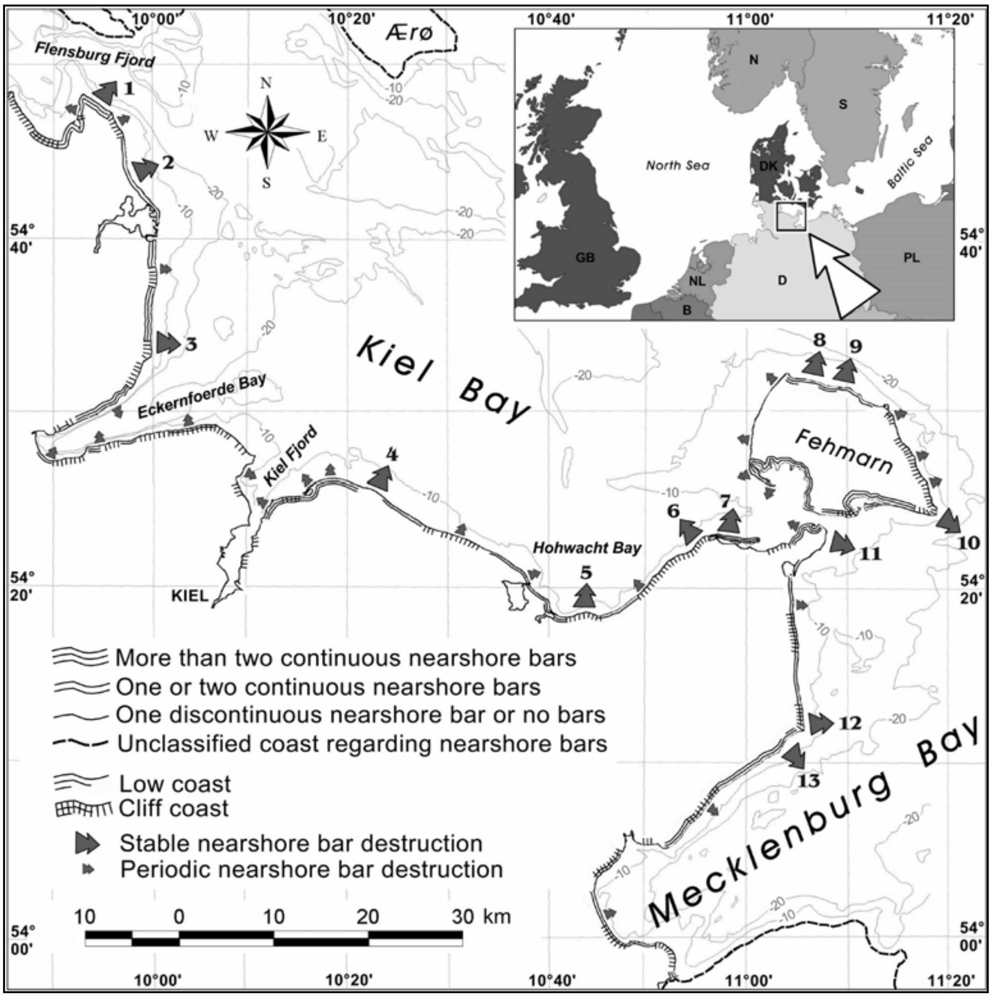

Figure 1. The coastline of the state of Schleswig-Holstein (South-western Baltic Sea). Cliff sections alternate with lowlands. Nearshore bars exist along most parts of the coastline. Large arrows indicate areas, where destruction of the bar system has been observed permanently over a period of approximately 60 years. These destructions are named "gates". Small arrows indicate destrutions, which appear only periodically.

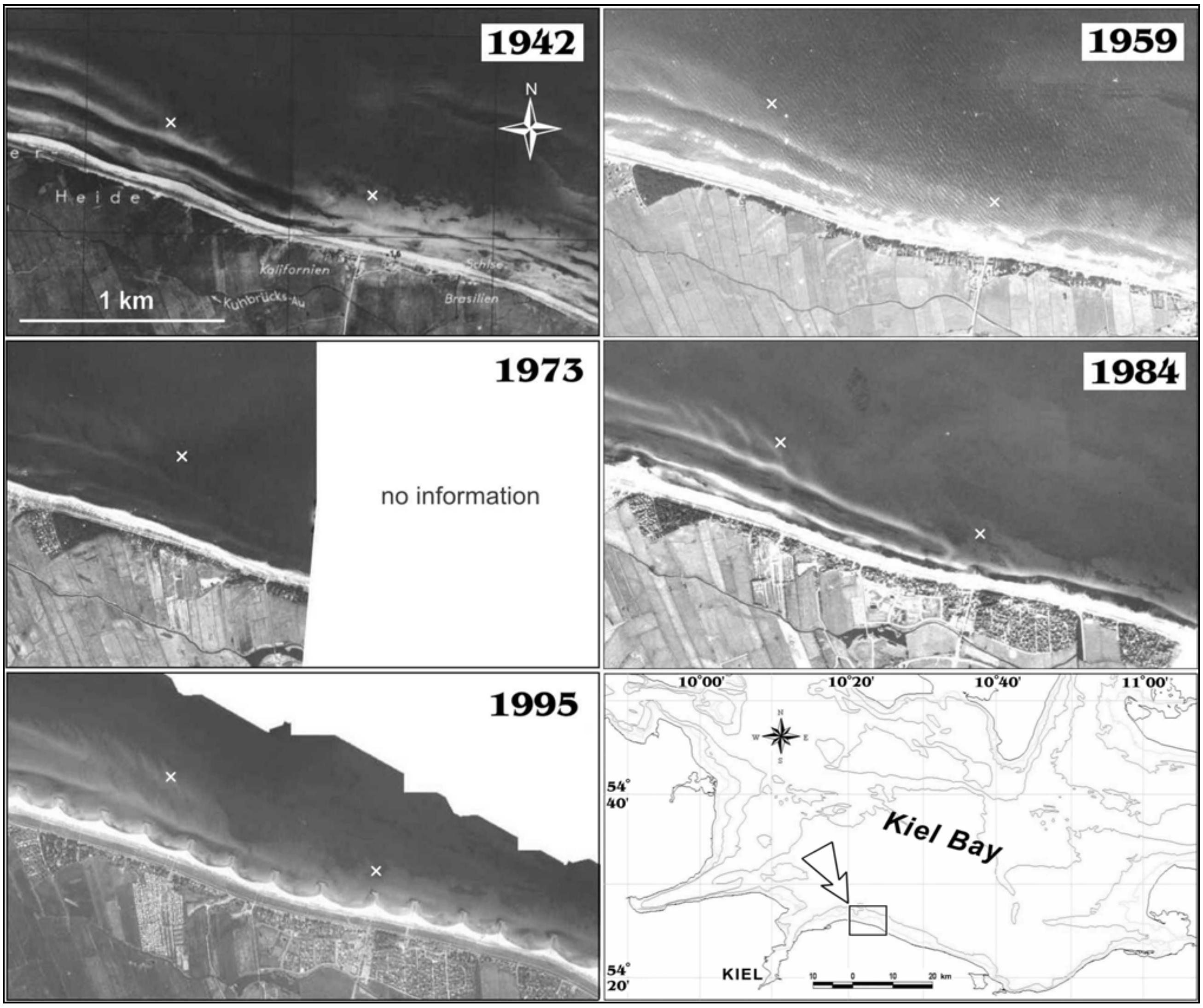

Figure 2. Gate no. 4 in front of a lowland at Outer Kiel Fjord. White crosses mark the same position in every picture. The permanently destructed bar system, located between the white crosses, can be observed in all aerial photographs.

The measurements revealed that beach sediments were transported seaward through gaps in the nearshore bar system during storm conditions.

Tracer material was eroded from the beach and deposited outside the break point during storm conditions. By decreasing energy conditions an onshore movement of tracers into the nearshore bar system was observed. Gates account for large circulation systems of water and sediment between the upper and lower shoreface and influence the coastal mechanism significantly. They evolved during stable sea level conditions and are persistent at least for decades.

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