# Recent Development of the Back-barrier Tidal Basin in the East Frisian Wadden Sea (southern North Sea)


RESEARCH-INSITUTE SENCKENBERG
Dept. of Marine Sciences
Wilhelmshaven

**T.S.Chang, A.Bartholomae, E.Tilch & B.W.Flemming**

Senckenberg Institute, Division of Marine Science, Schleusenstraße 39 a, D-26382 Wilhelmshaven


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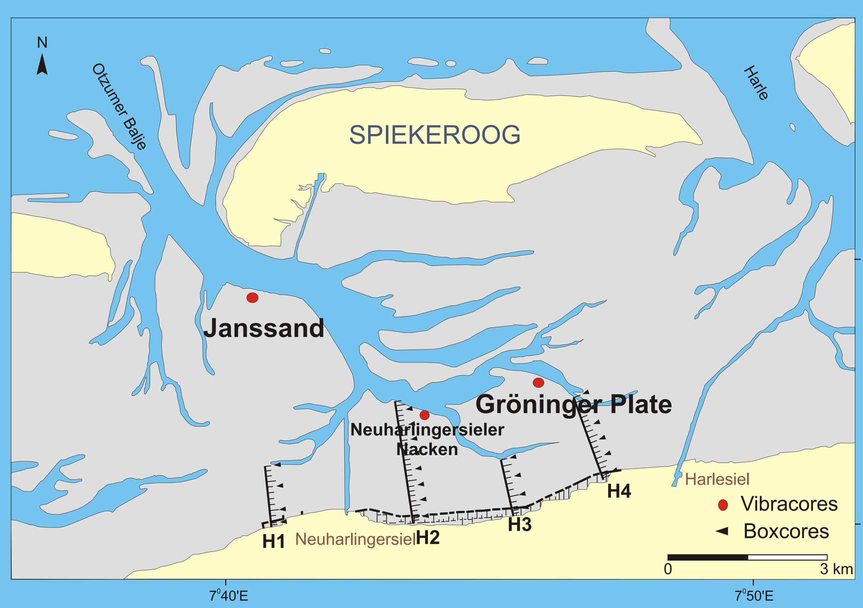



Fig. 1. Study area showing the vibracoring locations. The cores were obtained along the main channel from the inlet mouth to the end of the inner channel.

## INTRODUCTION

The combined effects of sea-level rise, land reclamation and dike construction in the past along the mainland coast of the Wadden Sea have inevitably led to substantial changes in the tidal basin morphology and biological community structures. Of these changes, the abrupt reduction of the tidal catchment area in the course of land reclamation has resulted in dramatic morphological adjustments in the back-barrier tidal basin. In order to document and understand this morphodynamic readjustment and its influence on the evolution of the tidal basin, the back-barrier tidal flats behind the island of Spiekeroog, Lower Saxony, Germany, has been surveyed in detail.

## MATERIALS and METHODS

Three long vibracores were taken along the main channel margins, Janssand Nord, Neuharlingersieler Nacken, and Groeninger Plate, respectively (Fig. 1). Recovered core lengths range from 3 to 6 m. In the laboratory, the vibracores were conserved in sediment peels using epoxy and were then described in terms of lithology, grain size, colour and sedimentary structures. Sediments were sampled for grain size analysis. In addition, box-cores were collected along landward intertidal transects and historical charts were evaluated.

## FACIES ANALYSIS

From the analysis of the vibracores, ten sedimentary facies were recognized on the basis of grain size and sedimentary structures. Three general grain-size classes are defined by the sand to mud ratio: Class S (sand), Class SM (sandy mud and muddy sand), and Class M (mud). Each class is further subdivided into individual sedimentary facies using primary sedimentary structures (Table 1).

| Facies Types | | Characteristic Feature | Interpretation |
|---|---|---|---|
| Facies Sm | | massive sand, scattered shell fragment and organic debris included, rare mud chips and lumps included, partly bioturbated | storm |
| Sp | | parallel (subparallel) laminated sand, partly organic debris included | bar migration |
| Sx | Sxd | large-scale cross-laminated sand | dune migration |
| | Sxr | small-scale cross-laminated sand, flaser bedded sand common, climbing ripples found | ripples migration |
| Sd | | deformed sand, cross-laminated sand highly deformed and convoluted | deformation by differential loading |
| Ssh | | shelly sand, shell densely concentrated and aligned, sharp erosional base, small gastropods included | channel lag |
| Facies SMp | | parallel inter-laminated sand and mud, sand/mud laminae alternations, wavy bedded | tidal bedding |
| SMx | | cross-laminated sand and mud, mud drapes | tidal bundle |
| Facies Mm | | homogeneous mud, plant stems and leaves, shell fragment included | supratidal flat, salt marsh |
| Mp | | parallel laminated mud, thin sand streaks, lenticular bedded, greenish gray color | upper tidal flat |

Table 1. Ten sedimentary facies types and their characteristics as observed and classified from the vibracores.

## FACIES ASSOCIATION

On the basis of this facies analysis, the back-barrier tidal deposits can be divided into four facies assemblages (Fig. 2).

### Facies Association I: Salt Marsh/ Mud flat

The mud-dominated facies association I was detected only in the lowermost parts of the core from Neuharlingersieler Nacken. This association is characterized by greenish gray or pale olive mud with plant remains. It consists mainly of homogeneous mud (Facies Mm) and parallel-laminated mud (Facies Mp).
Plant stems and leaves, and shell fragments are also present in some layers. The presence of sand streaks, shell debris and plant remains in the lower part of this association indicate that the muddy sediments were formed in a salt marsh/mud flat environment intermittently exposed to inundation during storms (Fig. 3a). The dominance of lenticular bedding in the upper part of the column is considered to represent deposition in a high mud flat rather than in a salt marsh.

### Facies Association II: Shell Lags

This association unconformably overlies succession I and is conformably overlain by sand sequences of association III. The succession is characterized by coarse shelly sand with a sharp erosional base (Facies Ssh) (Fig. 3b). This also contains massive sand beds with scattered shells (Facies Sm).
These are considered to be transgressive lags formed during sea-level rise. A similar succession was also found in boxcores of transect I (Fig. 3e).

### Facies Association III: Intertidal Flats

This association represents tide- and wave-dominated sand sequences. The association consists of large-scale cross-laminated sand (Facies Sxd), rippled sand (Facies Sxr), and parallel-laminated and cross-laminated muddy sand (Facies SMp and SMx). It also contains massive snads and shelly sands (Facies Sm and Ssh), and deformed sands (Facies Sd). Horizontal tidal bedding and cross-bedding with tidal bundles and mud drapes dominate the upper part (Fig. 3c). This suggests deposition in sand to mixed flat environments. Some small-scale fining-upward successions were also found. These are considered to have been deposited by small migrating tidal creeks. The presence of deformed thick sand layers

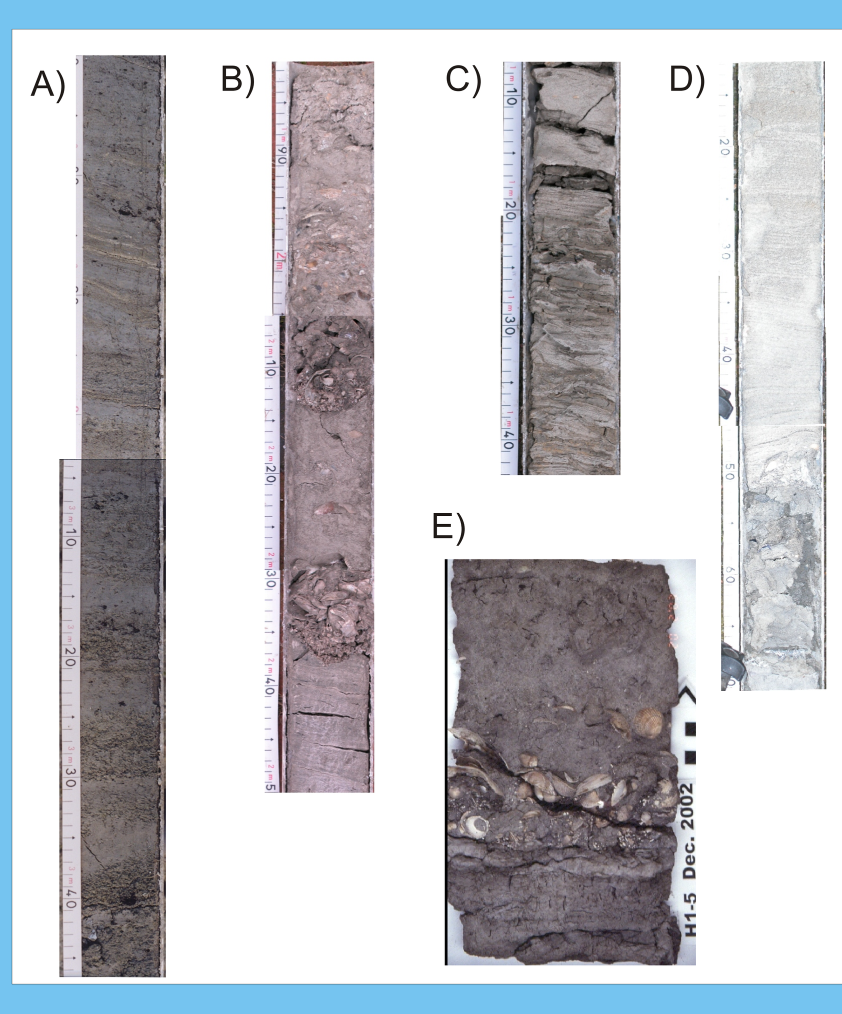



Fig. 3. Representative sections. A) salt marsh deposits showing thin sand streaks and intermittently supplied shell fragments . B) transgressive lags sharply overlain by muds. C) tide-generated structures. D) near-horizontal laminated sand suggestive of a swash bar. E) boxcore peel of transect I showing trangressive shell lag deposit.

### Facies Association IV: Swash Bar

The sand-dominated association IV was only found in the Janssand core. This is characterized by parallel-laminated and low-angle cross-laminated medium sand (Fig. 3e). Less bioturbation and well-developed near-horizontal lamination of this association are suggestive of a swash bar environment under high-energy conditions.

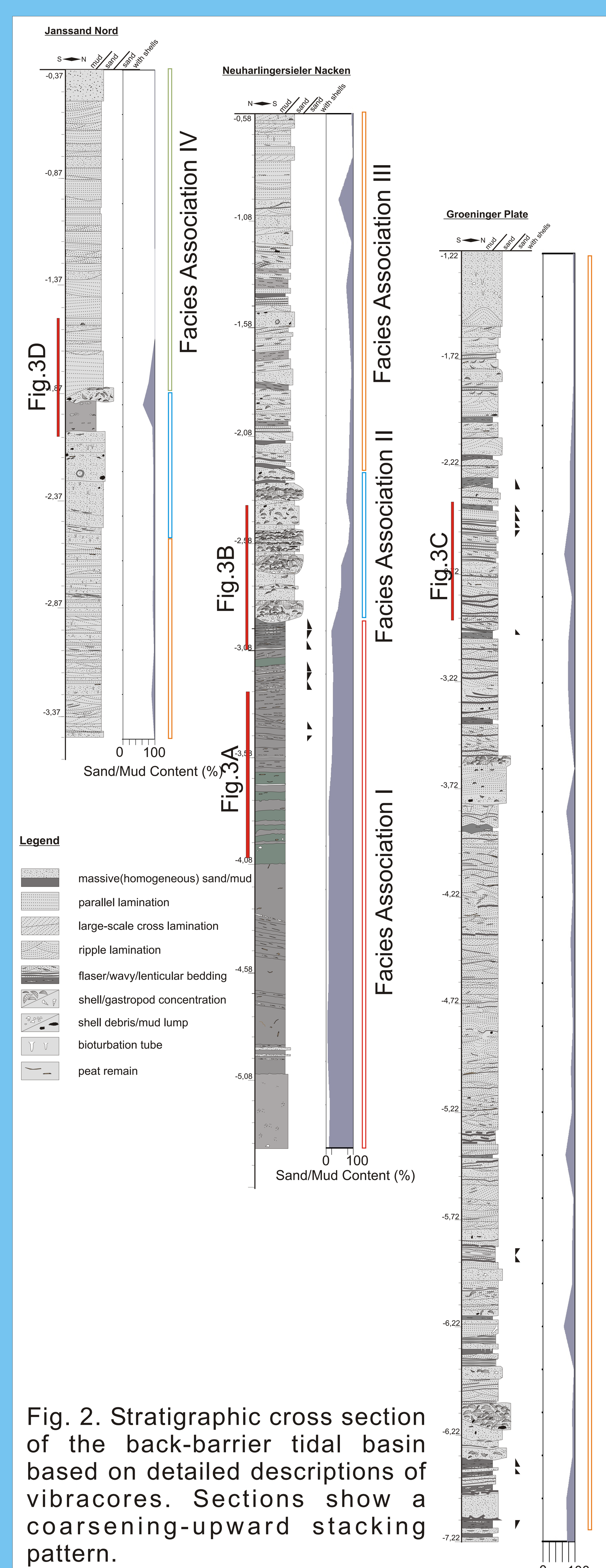
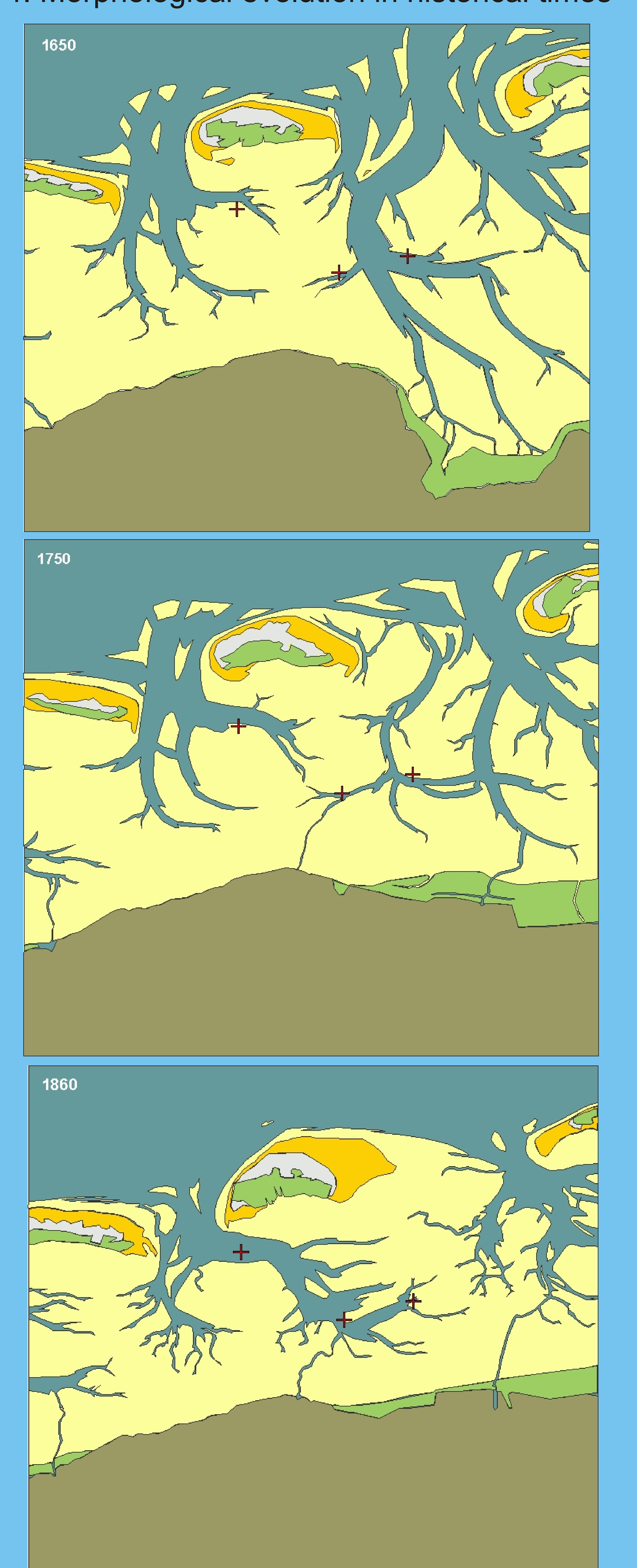



Fig. 2. Stratigraphic cross section of the back-barrier tidal basin based on detailed descriptions of vibracores. Sections show a coarsening-upward stacking pattern.

## MORPHOLOGICAL CHANGES

Based on the analysis of historical charts, the size reduction of the ebb-tidal sand bodies, partial fills of the main back-barrier channels, and a landward shift of the barrier island have been observed (Fig. 4). In addition, an eastward shift of watersheds and associated channel fills followed. These fills reflect the sudden decrease in tidal prism and were deposited under relatively quiet conditions when compared with the western part of the basin which is erosional.

Fig. 4. Morphological evolution in historical times




## Discussion and Conclusion

Massive facies changes are recognized in the Janssand core which are characterized by well-sorted medium sands with parallel and cross-laminations. It can be divided into two significantly different parts. Common ripples and the presence of flacer bedded layers in the lower part of the core are suggestive of deposition in a sand-flat environment. In the upper succession , parallel laminated and cross-laminated sands are dominant, suggesting deposition in a swash bar environment. Between both successions coarse-grained massive sand layers with mud balls and scattered shells are intermingled, these being interpreted as a transition facies. The occurrence of these layers and the abrupt change in the depositional environment suggest that this area has experienced dramatic changes in the hydrodynamic regime. It might have been formed by an abrupt rise of the local sea level. Alternatively, dike construction and land reclamation could have been responsible for these severe morphological changes in the back-barrier area, e.g. the shifting of the watershed and main channel due to the reduction of the tidal prism (Oost, 1995).
This sudden facies transition was also observed in the core from the Neuharlingersieler Nacken. Muddy sediments were suddenly terminated by shelly coarse sand with an erosive base, grading upwardly into rippled sands. The lower mud-dominant succession can be assigned to upper mud flat and salt marsh environments. Channel lag deposits directly overlie this lower mud deposit and pass gradually upward into mixed to sand flat environments. Although both explanations are plausible, the former argument is a more likely explanation in this case because there were no transitional facies and the presence of a sharp erosional base. Indeed, the upper succession shows a small-scale fining-upward succession showing different directions of migration of small channels directly above the channel lags. A sand flat facies occurs in the uppermost part. This change seems to be related to a decrease in the tidal prism.
The core from the Gröninger Plate is characterized by an alternation between tide-dominated and wave-dominated sand deposition in a sand-flat environment. This core only shows channel fill successions controlled by channel migration. No abrupt change of the depositional environment is found in this core. Storm deposits are rare.
The vibracore data from the back-barrier tidal basin show that the intertidal deposits overlie muddy salt marsh deposits and form a coarsening-upward succession. More core data are required to fully understand and reconstruct the stratigraphic evolution. Age dating of shells and wood fragments can give further information about human intervention.