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The surficial sediments of Königshafen – variations over the past 50 years

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ABSTRACT: The investigation highlights the untypical nature of the intertidal sediments of the sheltered Königshafen embayment in the north of the island of Sylt. The area is characterized by medium sand, which might be explained by aeolian input from the adjacent dunes. Mudflats and sandy mudflats build up the western part of the bay. Other sandy mudflats, all with a small spatial distribution, are associated with mussel beds. A peculiarity of the sediments in the Königshafen embayment are the gravel and cobbles along the northern shore and parts of the southern shore. These can be interpreted as residual sediments from former stages of the "Ellenbogen" spit. A comparison of the present results with earlier studies by Wohlenberg (1937) and Felix (1981) shows a decline in mudflats and an increasing consolidation of the mud in the period up to 1981. Since 1981 the sediment distribution has not changed, hence this tidal embayment can today be qualified as representing a relatively stable depositional area.

INTRODUCTION

Königshafen, a tidal embayment in the north of the island of Sylt is almost completely enclosed by the "Listland", the "Ellenbogen" and the island of Uthörn (Fig. 1). A connection to the adjacent Sylt-Rømø Wadden Sea is provided by an opening to the east. The water exchange of the embayment is achieved by a central tidal creek.

The distribution of the surficial sediments of the embayment was mapped (Austen, 1992). The survey provided information on the grain-size texture and the distribution of different sediment types within the embayment. In this study a comparison with previous surveys is conducted to estimate temporal change in sediment distribution and composition.

MATERIAL AND METHODS

A total of 250 sediment cores with an internal diameter of 4.5 cm and a penetration depth of 10 cm were taken within the Königshafen embayment (Fig. 1).

The choice of sampling stations followed the sedimentological gradients observed in the field. As a result, the distances between sampling points varied between 50 and 300 m. Samples were dry-sieved (0.25 PHI° steps in ASTM, American Society for Testing Materials) after a standardized pretreatment. Grain-size statistics were calculated with a special computer program, developed at Kiel University (Kachholz, pers. comm.).

For comparison with older maps the German DIN scale is used for the classification of

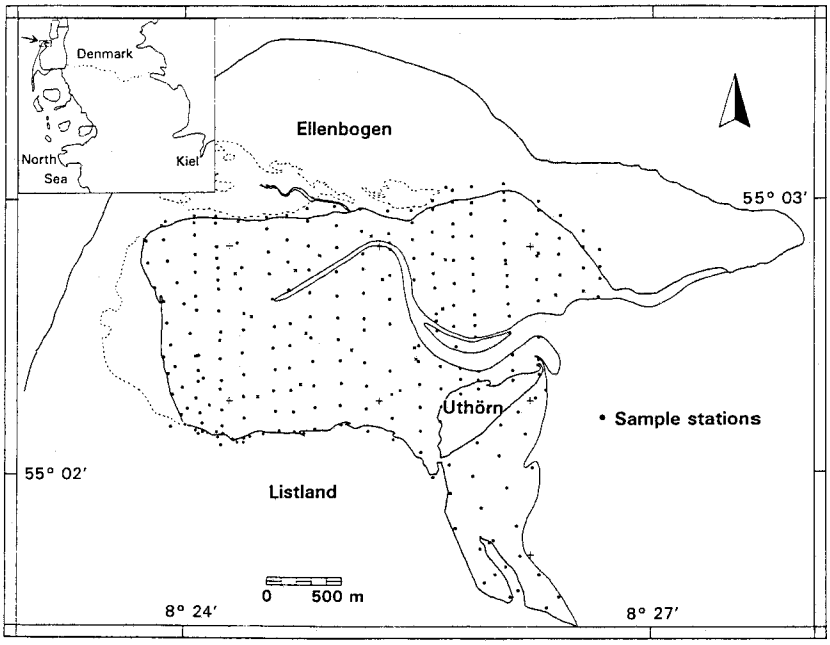

Fig. 1. Map of Königshafen, on the island of Sylt, with location of sampling stations

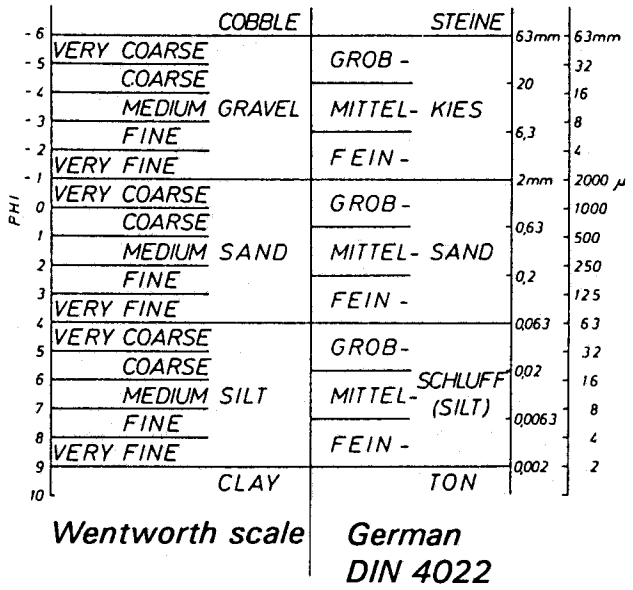

Fig. 2. Comparison of the German DIN scale with the Wentworth scale (Füchtbauer, 1988)

the sediment. Figure 2 shows the relation between German DIN scale and Wentworth scale.

A comparison of the results of this study with sediment data originating from the years 1932/33 (Wohlenberg) and 1981 (Felix) allowed an assessment of the changes within the depositional area over the past 50 years.

RESULTS

Sediment distribution

As demonstrated by Gast (1980), Nommensen (1982), Runte (1985) and Schwarzer (1983), the mud content is a useful parameter to characterize tidal sediments in the Wadden Sea. According to Figge et al. (1980), the following classification was applied: sand (< 10 % mud by weight), muddy sand (10–25 % mud), sandy mud (25–50 % mud) and mud (> 50 % mud). On the basis of this classification, the distribution pattern of the surficial sediments was established (Fig. 3).

Over large areas of the embayment the proportion of the mud fraction (< 0.063 mm) lies below 10 %. As a result, most of the area consists of sand flats (Fig. 3). Areas with sandy mud or mud only occur in the western part of the bay and south-east of the island of Uthörn. Furthermore, small areas of sandy mud are found in the vicinity of mussel beds.

A sedimentological peculiarity of the tidal flats in the Königshafen are areas in which gravel and cobbles are concentrated at the sediment surface. They are found along the

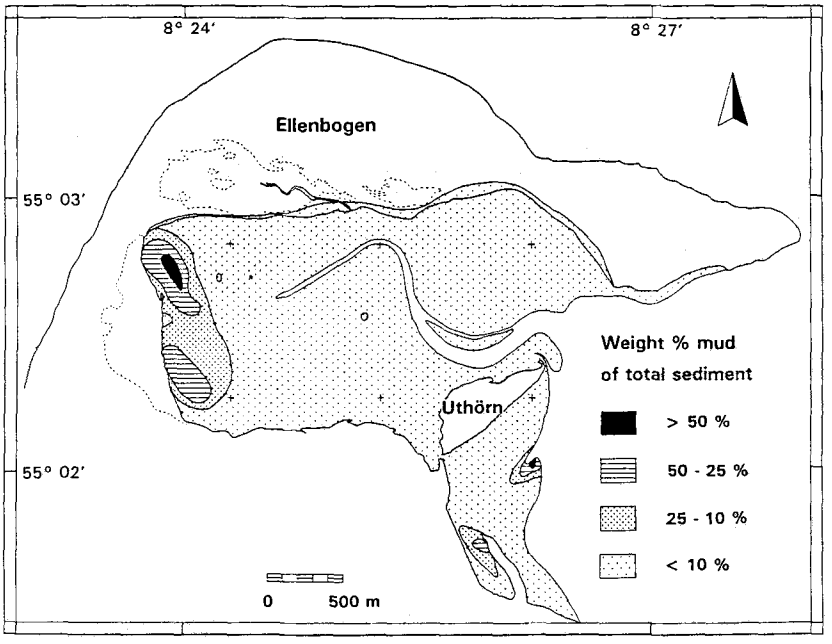

Fig. 3. Distribution pattern of the fraction <0.063 mm in the Königshafen, expressed in terms of weight percentages of total sediment (modified from Austen, 1992)

northern and parts of the southern shoreline and around the island of Uthörn. The size of the cobbles varies between 1 and 15 cm. They are mostly rounded and consist of beige-coloured flintstones. In addition, rounded magmatic and metamorphic rock fragments as well as black flintstones and quartz are found.

Grain-size texture

The greater part of the sediment samples from the Königshafen have polymodal grainsize distributions. The diameter of the dominant modal size class was used to differentiate sediment types. The dominant modal diameter represents the most frequent grain size interval of a polymodal sample and hence is a better textural description of the sediment than the mean diameter.

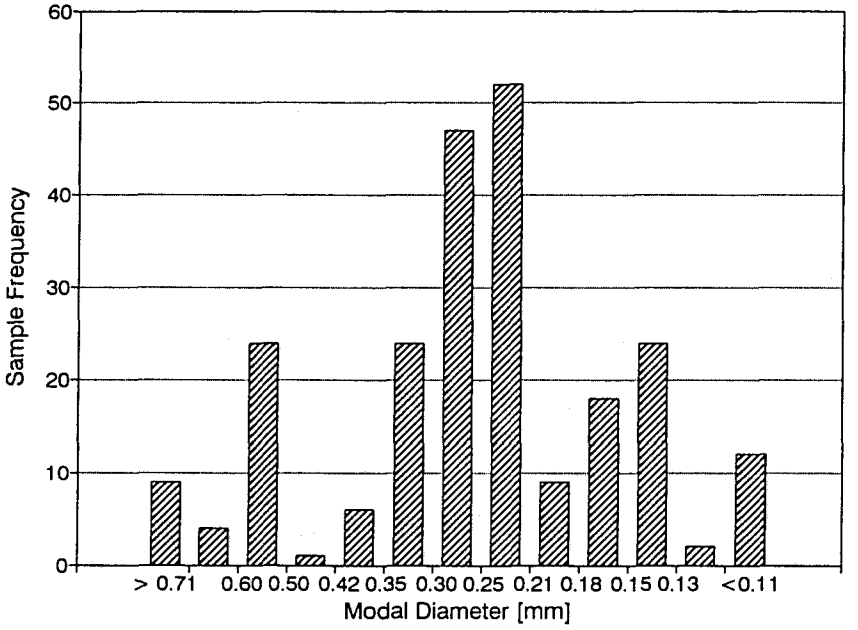

Fig. 4. Spectrum of modal grain sizes registered in sediments from Königshafen (modified from Austen, 1992)

The spectrum of the modal diameters of the sediments is shown in Figure 4. Most of the samples are characterized by modal diameters between 0.21–0.35 mm. Furthermore, peaks in the spectrum of modal diameters are observed at 0.5–0.6 mm and at 0.13–0.18 mm. In fact, 62 % of the modal diameters of all samples fall into the range of medium sand.

The spatial distribution of modal diameters in the Königshafen resembles the pattern of sediment types (Figs 4, 5). Modal diameters < 0.11 mm occur in the western part of the bay and south-east of the island of Uthörn. These areas correlate well with the occurrence of mudflats (Fig. 3). A zone with modal values of 0.11–0.21 mm surrounds these regions as

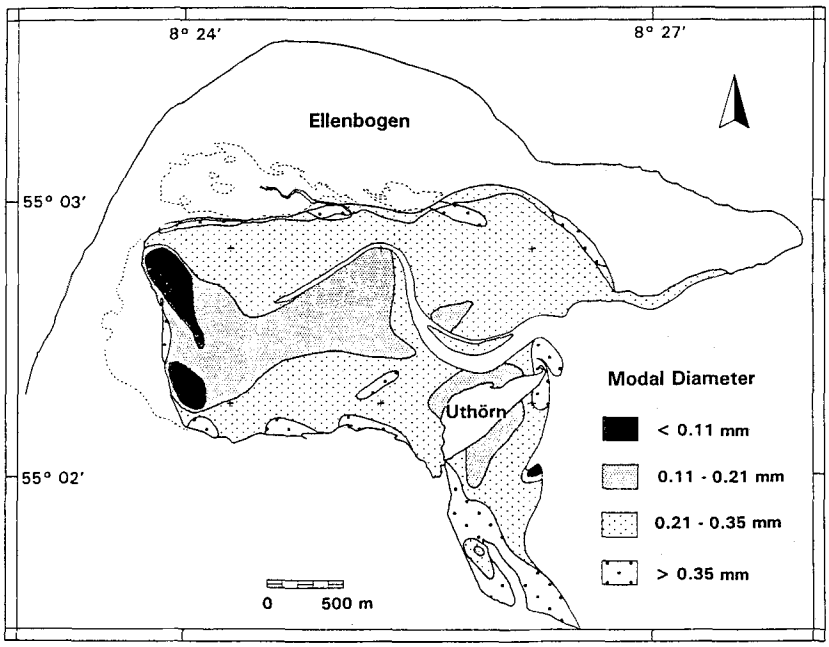

Fig. 5. Distribution pattern of modal diameters in Königshafen (modified from Austen, 1992)

well as the island of Uthörn and occupies in particular the central parts of the bay. Modal values > 0.35 mm characterize much of the shoreline of the Königshafen.

The results of the textural analysis show a clear spatial trend in the distribution of sandy sediments. Grain sizes generally decrease from the periphery to the centre of the Königshafen. The distribution of mud, on the other hand, does not fit into this pattern.

DISCUSSION

Sediment composition

The sediments of the Königshafen are characterized by a broad grain-size spectrum that covers all sizes from mud to cobbles. Within this wide grain-size spectrum the most typical sediment type is medium sand. Thus, the deposits of the Königshafen are coarser than those of other sheltered regions in the Schleswig-Holstein Wadden Sea, which are dominated by muds and fine-grained sandy sediments (Gast, 1980; Nommensen, 1982; Schwarzer, 1983; Runte, 1985).

The accumulation of fine-grained sediments (< 0.063 mm) in the western part of the Königshafen can be explained by its sheltered position in the inner part of the bay. Furthermore, this relatively low-lying tidal flat is situated at the head of the central tidal creek. This results in extended submersion times, thus promoting the sedimentation of fine material from the water column. Pejrup (pers. comm.) found a small net deposition in this area. By contrast to this accumulation, the southern and western shores are subject to erosion.

One of the two muddy areas south-east of the island of Uthörn is situated between the shoreline and a sandy hook (Fig. 3), which creates a sheltered pocket in which fine-grained sediments are protected from erosion. The other muddy area is associated with mussel beds, where fine material is produced in form of fecal pellets by the filtering activity of the mussels (Rhoads, 1974).

The occurrence of coarse sediments is a unique feature of the tidal flats in Königshafen. The energy levels in the sheltered bay are at present not high enough to transport gravel. The pebbles and cobbles must therefore represent lag deposits, produced by the displacement of the "Ellenbogen" spit towards the North (Priesmeier, 1970). To the extent that earlier stages of the "Ellenbogen" became exposed to tidal scouring, the erosion of fine material resulted in the accumulation of gravel. However, the pebbles found along the island of Uthörn are associated with the sand replacement activities carried out during the artificial enlargement of the island which was completed in 1945.

Furthermore, most of the investigated sediments exhibit polymodal grain-size distributions. According to Tiniakos (1978), the polymodality of the distribution can be explained by a mixture of sediments originating from different sources. The occurrence of specific modal size classes in the sediments of Königshafen (Fig. 4) favour such an explanation. Potential sediment sources are the subsurface layers in Königshafen, and adjacent tidal flats, as well as the salt marshes and the surrounding dunes. An investigation of grain sizes below the surface revealed modal diameters between 0.21–0.3 mm, which corresponds to the most frequent modal values in the surficial sediments. The modal diameters of the dune sediments range between 0.5 and 0.6 mm, again corresponding to one of the modal classes observed in the Königshafen sediments. These results provide strong evidence for the contribution of subsurface sediments and dune sands into Königshafen and would explain the dominance of medium sand (grain-size spectrum 0.2–0.63 mm).

On tidal flats near the island of Sylt the occurrence of medium sand is restricted to the vicinity of dunes which originate from a regressive high-energy beach (Goldschmidt et al., 1993). Tidal sediments further away from these dune areas generally have grain diameters of < 0.15 mm (Bayerl, 1992).

The occurrence of dune sediments in the tidal flat deposits of Königshafen, as demonstrated by the granulometric evidence, could not be confirmed by specific aeolian grain surface textures. Presumably the exposure time of dune sands to aeolian transport was of insufficient duration to produce conspicuous aeolian textures.

Comparison with previous surveys

Changes that occurred in the Königshafen area in the course of the past 50 years may be illustrated by comparing the results obtained in this study with historical, sediment data (Wohlenberg, 1937; Felix, 1981). The data of Felix (1981) show that hardly any change has taken place since 1981 (Fig. 6). The location and extension of the mud flats and the sandy mud flats coincide, as can be observed in Figures 5 and 6. In addition, the decrease in grain size from the shore to the centre of the bay already existed in 1981.

In contrast, the comparison of the present situation with that of 1932/33 reveals changes on a larger scale. The present situation shows a decrease in number and extent of mud flats compared with 1932/33 (Fig. 7). Wohlenberg (1937) mapped large areas

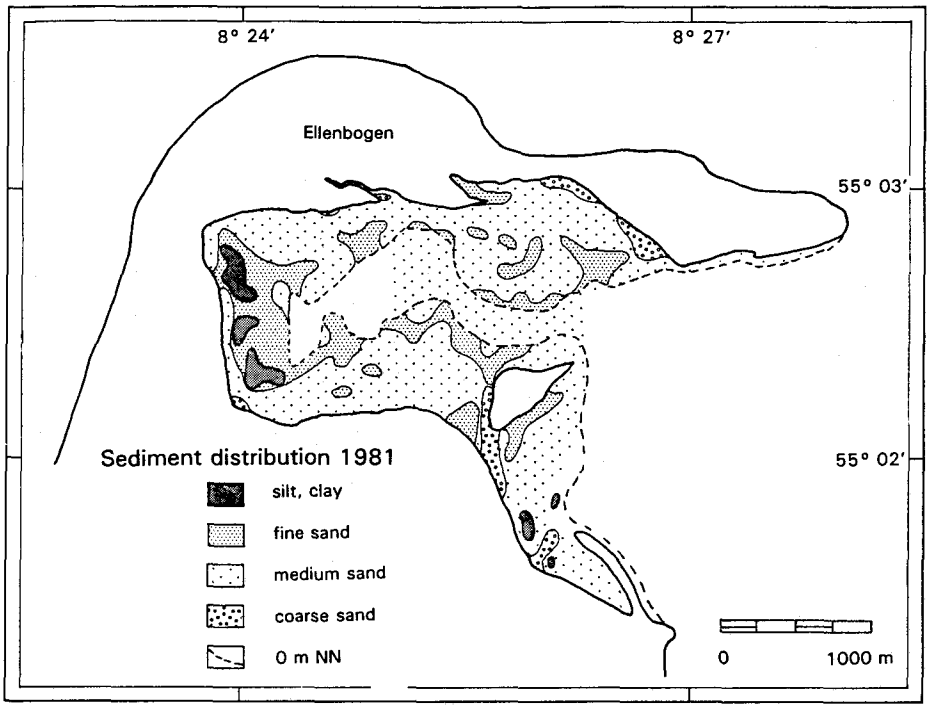

Fig. 6. Distribution of sediment types in Königshafen according to Felix (1981). Sediment classification based on German DIN scale

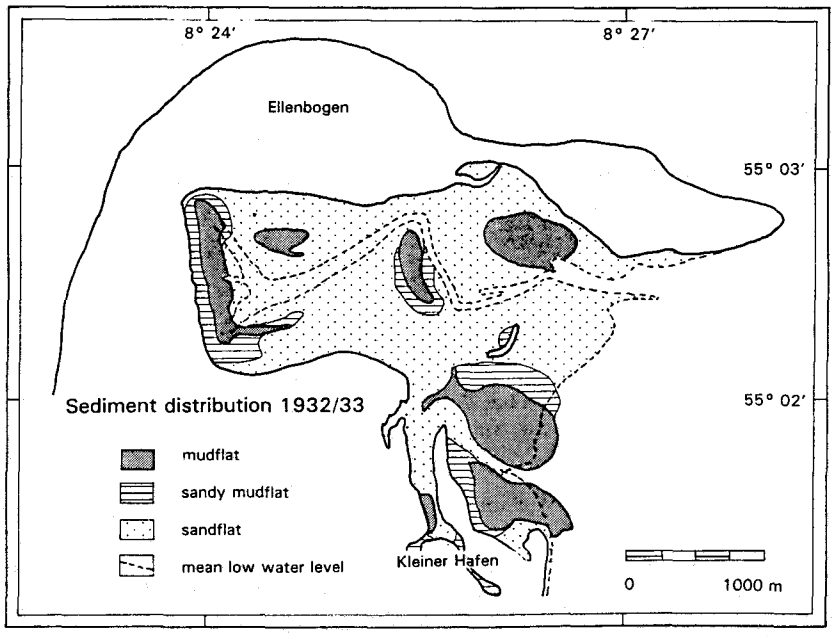

Fig. 7. Distribution of sediment types in Königshafen in 1932/33 according to Wohlenberg (1937)

north of the tidal creek as mud flats. Today, these areas are characterized by sand flats or small sandy mud flats associated with mussel beds. The mud flats in the western part of Königshafen have remained in place, although now reduced in area. This is also valid for the muddy area south-east of the island of Uthörn, which today occurs in the form of two small areas.

Apart from the diminution of the mud flats over the past 50 years, a pronounced compaction of sediment appears to have taken place. Wohlenberg mentions a depression of up to 1.3 m in the mud flats and describes the periphery of them as being of semi-fluid consistence. At present, the depression is only 0.3 m deep at a maximum, and the consistency of the mud is soft but not semi-fluid any more. Similarly, the sand flats appear to have become more compact over the years: loosely packed sands which were oversaturated with water are now densely packed.

The spatial reduction of the mud areas can be explained by variations in local erosion and sedimentation rates and hydrodynamic conditions. Changes of the energy budget, e.g. a rising mean tidal range (Führböter, 1989), can cause an increasing sedimentation of sandy material in the Königshafen, which covers parts of the mudflat areas. Mud erosion, usually caused by a rising energy budget, is unlikely in Königshafen because of the latter's sheltered position.

One reason for the compaction of sand flats and the decrease in the depression could be increased drainage in the course of time and sedimentation.

An important factor which must be considered is the artificial enlargement of the island of Uthörn. Sand replacement has enlarged the island of Uthörn about tenfold. The construction of the dike along the southern shoreline of Königshafen has cut off part of the bay.

Comparisons of the surveys conducted in 1981 and 1989 revealed no further changes. This may suggest that this tidal embayment can today be qualified as representing a relatively stable depositional area.

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