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GEOMORPHOLOGY OF SUBTIDAL AND INTERTIDAL AREAS IN THE SOUTHWEST OF THE NETHERLANDS[1]

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ABSTRACT

Kooistra, M. J. 1983 Geomorphology of subtidal and intertidal areas in the southwest of The Netherlands. In: J. H. J. Terwindt & H. Van Steijn (eds.): Developments in physical geography – a tribute to J. I. S. Zonneveld - Geol. Mijnbouw 62: 637-641.

For centuries tides have played a major role in the estuaries and sea-arms in the southwest of the Netherlands. Tidal currents are responsible for deposition of subtidal and intertidal sediments in which several characteristic geomorphological units can be distinguished.

The tidal wave comes from the south of the North Sea. The tidal amplitude decreases from south to north and consequently the induced tidal currents reduce in velocity in the same direction. These changes are reflected in the deposits and their geomorphology. First an overview is given of the occurrence of different geomorphological units and their stability in estuaries from entrance landinward and the changes in the successive estuaries from south to north. Secondly an example is given of the differentiation and stability in a high silted-up intertidal area. The stability of the geomorphological pattern in these areas is not only governed by the tides. Aeration and physical ripening also become important.

INTRODUCTION

In the coastal area of the southwestern Netherlands there are several large estuaries and sea-arms, surrounding a number of islands. In these large watercourses several geomorphological units can be distinguished. Before the start of the Delta Works, after the flood disaster of 1953, these geomorphological units were mainly the result of natural processes. The tides with variations in water levels, changes in current velocities, and erosion and deposition of sediments were and in part of this area still are, the main factors determining the geomorphology. Locally, other factors can also play an important role: shape of the coastline, exposure of the coast to prevailing winds, and discharge of rivers.

The semi-diurnal tides in the southwest of The Netherlands cause a succession of accelerating and decelerating currents, resulting in increasing and decreasing transport capacities, and a reversal of transport directions. The transported material may be supplied by rivers or brought in by the sea. It may also originate from the tidal basin or from estuaries, either by erosion of older deposits in the tidal channel or by biological action (TERWINDT, 1967).

In the next paragraphs the geomorphology of tidal deposits in the different estuaries in the southwest of The Netherlands is discussed.

OVERVIEW OF THE MAIN GEOMORPHOLOGICAL UNITS IN THE SOUTHWEST NETHERLANDS

In an estuary or sea-arm the influence of the tidal currents decreases landwards. The reduced influence of the tidal currents is reflected in lower current velocities, finer-grained sediments, more stable deposits, and also in the geomorphology. In a landward direction the surface occupied by shoals and flats decreases and that of the marshes increases relatively; the relief on shoals and flats, mainly determined by ripple patterns, diminishes.

In the southwest of The Netherlands there are four main watercourses with roughly an east-west orientation (Fig. 1). The tidal wave comes from the south of the North Sea. The induced tidal currents reduce in velocity from south to north in the successive watercourses. Consequently, as they travel

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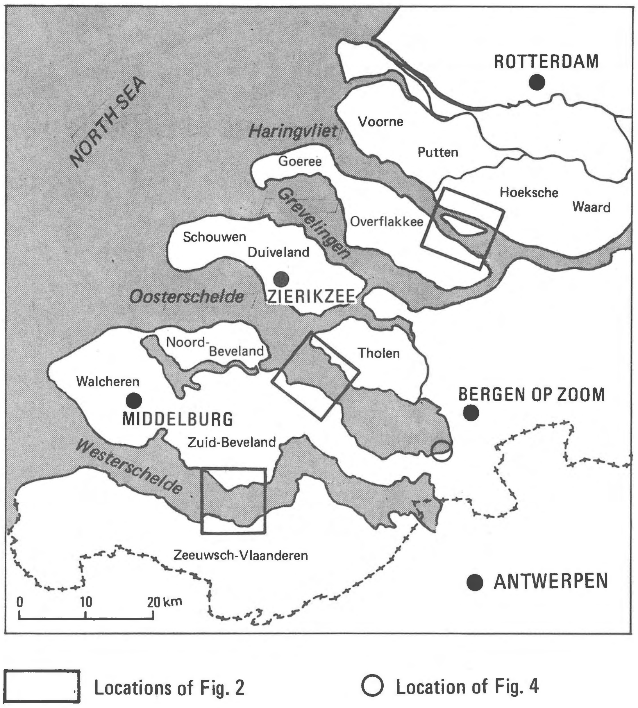

Fig. 1
The southwestern Netherlands with location of areas presented in Figs. 2 and 4.

north the tidal channels become less deep, there is less differentiation in ebb and flood channels and the position and shape of shoals and flats becomes more stable.

Due to the reduction of current velocities from south to north finer-grained sediment is transported with the currents. In the southern watercourses sandier deposits are found and in the northern ones clayey deposits prevail.

Not only the tidal currents reduce in velocity but also the vertical difference in flood-tide and ebb-tide levels decreases from south to north from about four metres to less than two metres. The combination of the reduction of tidal-current speeds associated with a decrease in tidal amplitudes largely determines the presence of levees along creek courses. Well-developed natural levees occur where the amplitude of the tides is large, more than 2 metres, and current speeds are high. Most well developed natural levees are found in the marshes of the southern watercourses, the Westerschelde and Oosterschelde. From south to north they decrease in height. In the southern part they can reach 40-50 cm above basin level; north of the Oosterschelde levees that are several centimetres higher than the adjoining basin rarely occur. With the decrease in height and size of the natural levees the differentiation of granular composition of the levee and the adjoining basin becomes less distinct. In the Wester- and Oosterschelde sandy or loamy sandy natural levees occur,

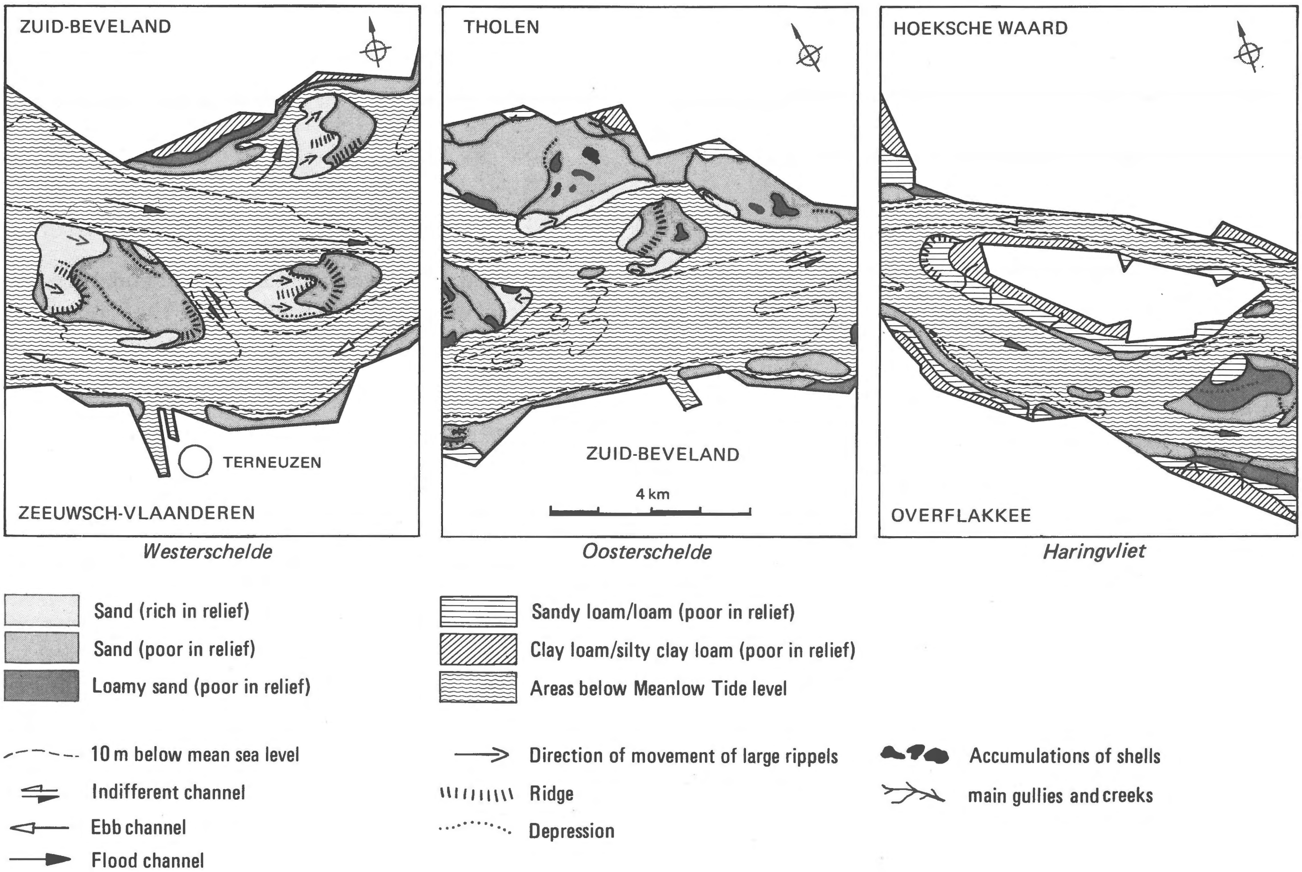

Fig. 2
Three segments of a geomorphological map (Duursma et al., 1982) from the Westerschelde, Oosterschelde, and Haringvliet.

adjoining basins with a silty clay loam texture (SOIL SURVEY STAFF SCS, 1975); while north of these inlets the low levees are rich in clay and differ hardly in composition from the adjoining basins.

This general pattern is locally obscured by tributaries of sea-arms and discharges from the Schelde, Bergse Maas, and Nieuwe Merwede and their sediment supply.

In Fig. 2 three segments of a geomorphological map of the non embanked area in the southwest of The Netherlands (DUURSMA et al., 1982) are given. They represent the situation around 1950, before the flood disaster of 1953. The segments are taken from three different watercourses: the Westerschelde, Oosterschelde, and Haringvliet at about the same distance from the entrance of the sea. The locations are indicated in Fig. 1. In the subtidal zone the depth contour of 10 m below mean sea level is given together with the dominance of ebb or flood currents. The geomorphology of the intertidal zone is repesented by the granular composition and richness in relief. Using symbols, additional information is given. The sand and loamy sand areas are shoals and intertidal flats; whereas the areas with higher clay contents represent marshes. Shoals and intertidal flats are rich in relief when large ripple patterns with a vertical relief of more than one decimetre occur, whereas marshes are rich in relief when natural levees occur with more than 10 cm difference in height with the adjoining basin.

From south to north the following trends can be distinguished from these segments. The depth of the tidal channels decreases northward. In the Westerschelde the largest area is occupied by shoals, in the Oosterschelde by intertidal flats and in the Haringvliet by marshes. In the same sequence the sediments become finer-grained. In the Westerschelde large ripple patterns occur extensively on the shoals, in the Oosterschelde only on edges of shoals and intertidal flats, and in the Haringvliet they are absent. All these aspects illustrate the decreasing influence of the tidal currents. One feature occurs only in the Oosterschelde segments. Large mollusc populations live in this saline sea-arm and, on the shoals and intertidal flats accumulations of their shells are present. In the Westerschelde the water, due to the discharge of the Schelde, is not saline enough for these molluscs and the Haringvliet is fresh water. The marshes represented on the segments do not have well-developed natural levees. These occur more to the east in the Westerschelde and Oosterschelde where the tidal amplitude is larger due to channelling of the current.

Fully developed intertidal areas consist of five or six different landscapes: intertidal flats, divided into low and high parts, when present a transitional zone, and marshes divided into low, middle-high, and high parts all with characteristic sediments and morphology (KOOISTRA, 1978). This order represents the successive stages of sedimentation. When not fully developed a number of the last mentioned subdivisions do not occur.

Several types of fully developed intertidal areas can be distinguished in The Netherlands (KOOISTRA, 1978). The two most common types for the southwest are given in Fig. 3. In the first type the surface level slopes gradually and in the second a distinct cliff edge marks the level at about Mean High Tide. In the first type (3A), the marshes proper start below Mean High Tide level. In the second (3B) occasionally the vegetation continues below the level of Mean High Tide (VAN

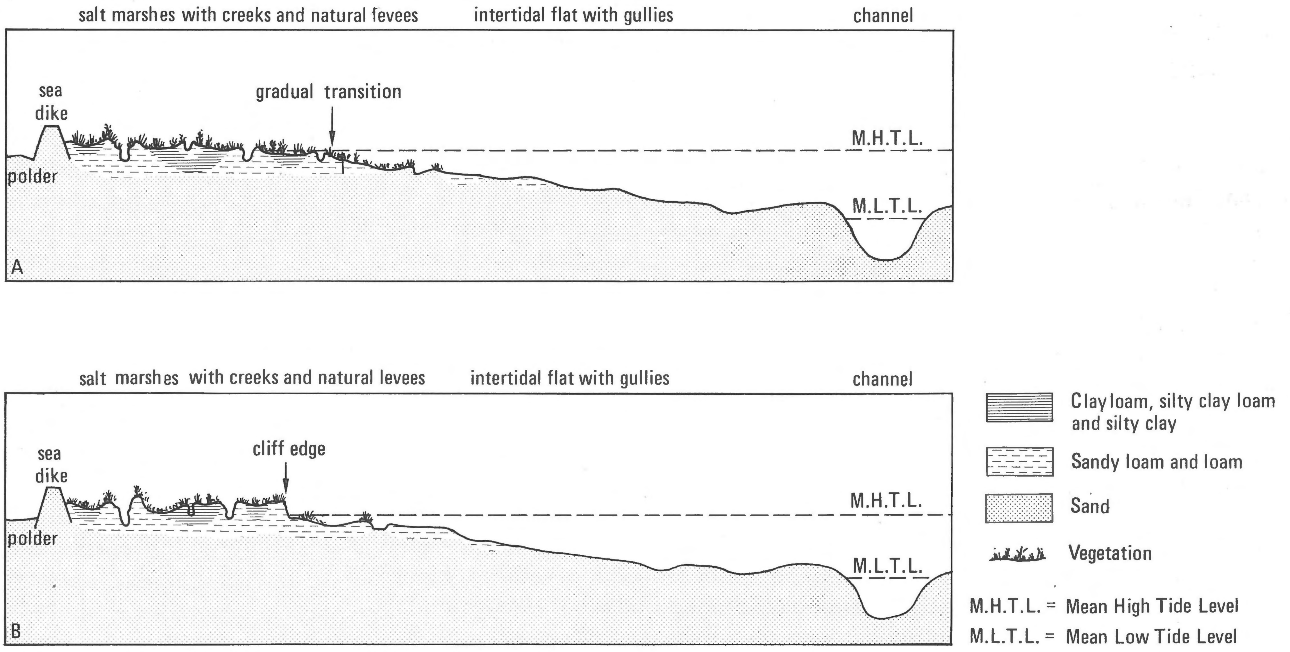

Fig. 3
Transect of the two commonmost types of intertidal areas in the southwest of The Netherlands (Kooistra, 1978).

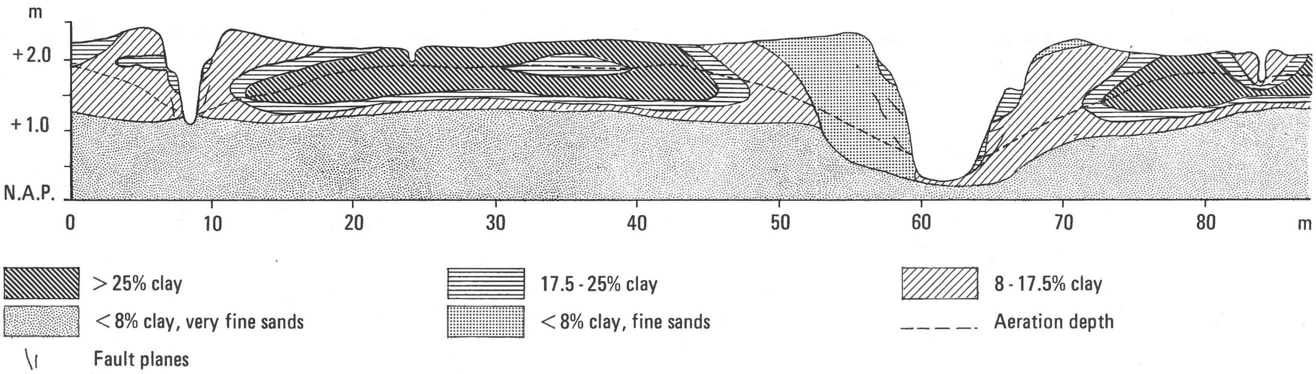

Fig. 4
Representative cross-section of a transect in a high marsh area, showing the relief and granular composition of intertidal deposits. The location is indicated in Fig. 1.

STRAATEN, 1954). In the southwest of The Netherlands type 3B is most common. Cliff edges are mainly formed during storms by wave action and often occur when the coastline changes frequently in direction and tidal channels occur near the mainland. Frequent changes in direction of coastline are characteristic of coastal polders, to which most of the area in the southwest Netherlands belong (DE BAKKER & KOOISTRA, 1982).

Going landinward into estuaries one finds marshes that have cliff edges, more inland, in quiet areas out of prevailing wind and wave directions, also gradual transitions occur. In the four main watercourses from south to north marshes with a gradual transition occur more often as a result of reduction in tidal current velocities and deposition of more clayey sediments which are less erosive, when not ripened.

AN EXAMPLE OF THE GEOMORPHOLOGY OF A HIGH SILTED-UP INTERTIDAL AREA

Three landscape elements can be distinguished in a high silted-up marsh: creeks, natural levees, and basins. In marshes there are intricate patterns of creeks. In contrast to a river basin, here the flood enters the marshes via the main creeks. At ebb tide, the same water system drains the marsh. The function of a watercourse need not be identical during flood and ebb tide. Creeks with a main function at flood tide, when most sediment is transported, are bordered by natural levees distinctly elevated above the adjacent basin. These levees are often covered with a specific vegetation.

In high marshes the most stable deposits occur. The stability is mainly determined by the function and shifting of position of the creeks. In Fig. 4 representative parts of a cross-section of the deposits along a traverse measured with an Abney-level are presented. The location of the marsh is indicated in Fig. 1. The levees of the main creeks are distinctly elevated and asymmetrical. Asymmetry is a common feature related to meandering of creeks. The largest creek (right off centre) is shifting to the right and erodes that side. The presence of coarser sediment on the left indicates an increase in function at flood tide that correlates with higher current velocities which are able to transport coarser sediment.

Meandering of creeks is often initiated by local slumping or slipping of parts of the creek wall. Undercutting of creek walls by ebb or flood currents is one cause of a bank slipping. In other cases more aerated sediment near the surface has slipped on oversaturated layers deeper in the sediment. The extent of the slumped material is generally controlled by the distance between desiccation cracks in the partly aerated upper sediment and rarely extends fore more than a few metres along the wall. The slumped material forms terraces on the slip-off slope which usually is tilted backwards. In Fig. 4 these terraces occur along the two main creeks.

The effect of slipping and slumping of creek walls is not restricted to meander formation. It also leads to stream capture and headward erosion. Creeks can also be put out of order by damming up of tributary creeks e.g. with clumps of seaweed, peat pebbles or large quantities of shells, pushed into the mouth by strong floods. The closed off part of the creek becomes filled, often with clay-rich sediment, which buries the former course. In the basin in the centre of Fig. 4, there is a buried natural levee. In a studied catchment area of a main creek system in an intertidal zone, surface about 125 000 m^2, there were four stream captures caused by natural processes within a period of five years and several tributary creeks were blocked off.

High silted-up areas are rare in The Netherlands. When marshes, situated above Mean High Tide level are large enough, they are reclaimed.

The execution of the Delta Works caused considerable changes in the occurrence of naturally developed subtidal and interdital deposits and their geomorphology. Large areas are cut off from the sea and tide and the former tidal deposits are now present in a stagnant lake (Grevelingen) or have a regulated discharge of rivers (Haringvliet). When the Oosterschelde storm-surge barrier is finished a reduced tide will be present there and only in the Westerschelde the full influence of the tide will be maintained.

CONCLUSIONS

In each of the four main watercourses in the southwest of The Netherlands a specific pattern of geomorphological units was developed. The distribution of the different units, area occupied, relief, and composition of deposits differed. They were all due to the decrease in tidal amplitude and consequently reducing velocities of tidal currents from south to north.

There are two types of fully developed intertidal areas in the southwest of The Netherlands: one with a gradual transition between flats and marshes and one with a marked cliff edge between these units. The occurrence and distribution of both types is not only governed by the tides. Weather factors, wave action generated by storms, and the impact of man by reclamation which causes frequent changes in the direction of the coastline, also play a role.

In high silted-up intertidal areas the influence of the tides becomes less dominant. The stability of the deposits, expressed by creek patterns, is for a large part determined by the effects of aeration and physical ripening of the deposits.

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