The structure of the Salt Marsh Area at Ballum, SW. Jylland

by

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Abstract

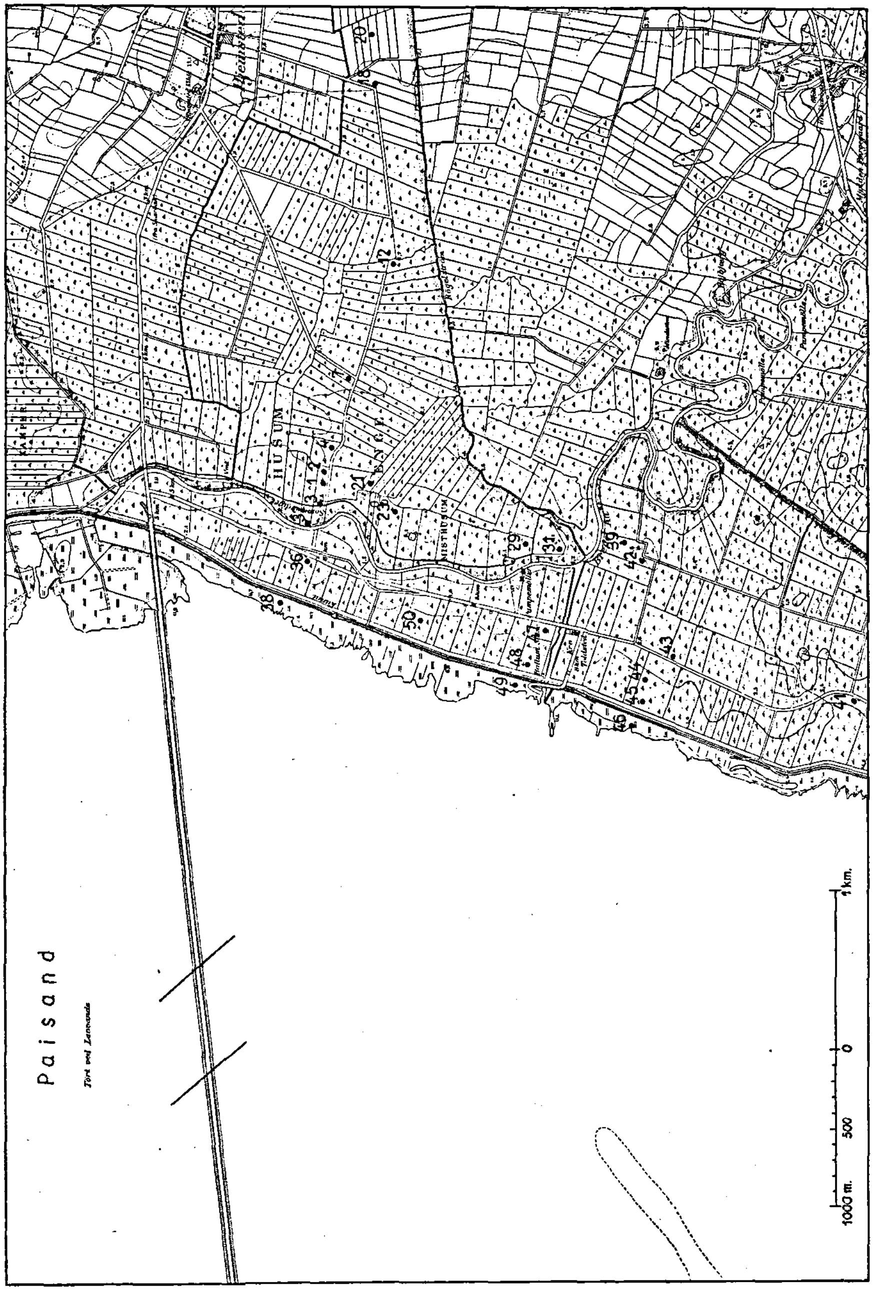
Borings through the Ballum salt marsh area indicate, that in late glacial time, and in the beginning of the postglacial time the river Bredeaa was running in a much wider and deeper valley than to day. In the shallow basins on both sides of the river bed homogeneous klei was deposited. When the transgressing North Sea entered the river by extraordinary high tides, sand was deposited in the outer part of the river bed and a sapropelitic gyttja more upstreams.

As the postglacial transgression continued the outermost part of the riverbed silted up and low ridges (klints) of stratified klei were built upon the marsh surface, in the same way as it takes place on the wadden to day.

Introduction

Whereas there exist a rather considerable number of publications dealing with the recent processes of salt marsh formation in Denmark (GRY 1942, K. HANSEN 1951, 1953, 1956, K. HANSEN og JACOBSEN 1960, JAKOBSEN 1953, 1954, NIELSEN 1935, OLSEN 1959, PETERSEN 1926, WARMING og WESENBERG LUND 1904), our knowledge of the structure of the older salt marshes in Denmark is very limited (A. JESSEN 1916, 1922, 1925, KINGO JACOBSEN 1959, 1960). Therefore, on the initiative of Mr. BØRGE JAKOBSEN, the author and the State geologist Dr. SIGURD HANSEN from the »Geological Survey of Denmark« decided in 1951 to set down borings in the Ballum Salt Marsh in two sections. No. I from east to west along a road to the north of the brook Røgelstrømmen and no. II from north to south, east of the old now abandoned part of the river Bredeaa.

The Ballum Area was chosen because it is a rather small area and could be supposed to be of a rather simple structure. To the north, east and south it is surrounded by the Riss Diluvium and it has an extent from north to south of 8.8 km and from east to west of 6.4 km. It is traversed by the river Bredeaa, which drains the Fiskbæk basin and the northern part of the Tinglev Sandur (glacial outwash plain) and enters the salt marsh area in the southwestern corner. The drainage area is 292 sq. km and


Paisand
1 km.
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the average of yearly run-off is 10.4 litres per second. Still, it may vary considerably.

The greatest part of the area is at the level +2 m D.N.N. (Danish Ordnance Datum); however, at some places it is a little lower. The highest level is that of the salt marsh ridge (Klint) running north—south immediately to the west of the river Bredeaa. This ridge reaches a height of +2.68 m D.N.N. On the eastern side of the river we find Warften (Terpen) upon which the houses of the former village Misthusum were built. Its age is not known, but at any rate the village dates further back than 1300 A.D. Several times this region, like the whole western coast of Slesvig, was inundated by floods; most houses were abandoned after the great flood in 1634, and the last inhabitants left the place after a flood in 1814 (Nordmann 1935).

The Ballum Salt Marsh was diked in the years 1914–19 (Betænkning 1955). The dike is 9.9 m long, 6.2 m high and 2.5 m broad on the top. The river Bredeaa passes the dike through a sluice and the old northern course of the river is now a dead branch.

The sections

The section I (plate I) was placed along a line at a distance of 1.6 km to the south of the road from Hjemsted to Rømø. It crosses the river Bredeaa a little north of the northernmost of the Warften of Misthusum. East of the river the salt marsh area has a rather simple structure. At the eastern end of the section (boring 20) the Pleistocene land surface consisting of late glacial sand is situated at the level +2.26 m D.N.N. and slopes very gently to the level −1.22 m in boring 32 at the eastern bank of the river. The surface is slightly undulating with shallow basins filled with peat.

The Pleistocene surface with its peat basins is overlain by a homogeneous klei with a cloddy structure. This homogeneous klei is exposed at the surface between boring 7 and 14. Farther east it is of a different character being more or less mixed with fresh water or brackish water peat and gyttja.

Westwards from boring 7 the homogeneous klei is covered by a sandy stratified klei of the same type as that deposited in the recent upgrowing salt marshes (Hansen og Jakobsen 1960).

Westwards from boring 32 the section is quite different from the eastern part. The Pleistocene was only hit in boring 38 outside the dike below peat at a level of −1.69 m D.N.N. and in the boring 33 where glacial till was hit at −4.6 m D.N.N.

In the borings 36, 37 and 38 the homogeneous klei is lacking or only developed in very thin layers and the stratified sandy klei is resting upon fine sand which again covers very coarse sand in which the borings came to a standstill.

In the borings 33 and 34 a clayey or sandy bluishblack gyttja or sapropel was found below the homogeneous klei with a sandy layer between −2 and −2.7 m D.N.N.

The section II (plate I) along the eastern side of the former course of the river Bredeaa has, between boring 3 and 29, the same simple structure as that of the eastern part of section I. The late glacial Sandur surface is gently undulating with shallow basins with peat in the bottom, covered by homogeneous klei and stratified sandy klei.

Between the borings 29 and 42 the section crosses the river Bredeaa, and also here the late glacial river bed is much wider and deeper than to day. Boring 31 stopped in peat at −6.5 m D.N.N. and in the boring 39, 500 m southwards, the surface of the peat was hit at −3 m D.N.N.

The peat is covered with 6 m gyttja with two sandy layers and uppermost follows homogeneous klei and sandy stratified klei.

The sediments

The Pleistocene, glaciofluvial sand below the peat (fig. 2) is a rather poorly sorted quartz sand with Md. varying between 180–300 μ, Q_{D_φ} varying between 0.4–0.7 (So. 1.50–1.70) and a content of grains larger than 250 μ which is rather constant about 50 %.

The grains larger than 0.3 mm are usually strongly worn and rolled; the grains between 0.3–0.15 mm are more subangular, and only the grains smaller than 0.15 mm have sharp angular edges. Quartz is the dominating mineral, however in the coarser fractions several grains of limestone are found, and the finer fractions contain some heavy minerals.

The coarse sand in the river valley (fig. 3) is evidently essentially different from the glaciofluvial sand. Md. varies from 340–460 μ and with a few exceptions the sorting is much better. Q_{D_φ} is varying between 0.3–0.4.

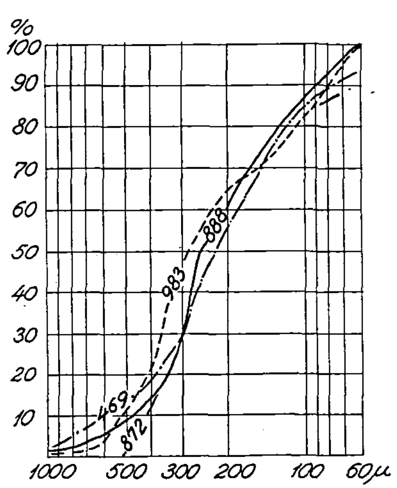

Fig. 2. Pleistocene glaciofluvial sand.

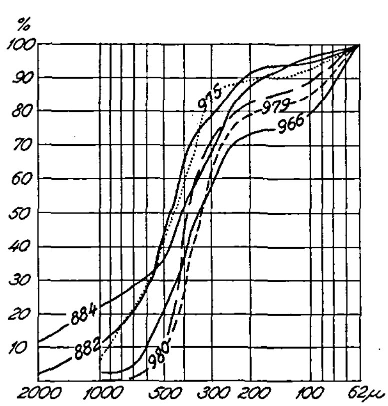

Fig. 3. The coarse sand in the river valley.

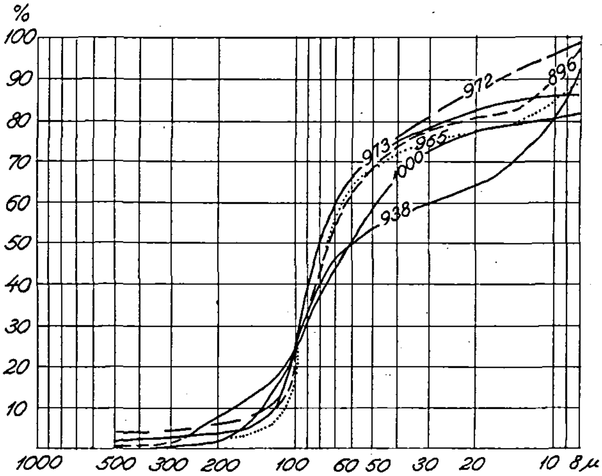

Fig. 4. The fine sand in the river valley.

(So. 1.27–1.39), which is nearly the same as to the sand on the wadden. (K. HANSEN 1951). Another characteristic is, that the content of grains larger than 250 μ is 70–80 %.

Grains larger than 1 mm are angular, those from 1–0.5 mm are strongly

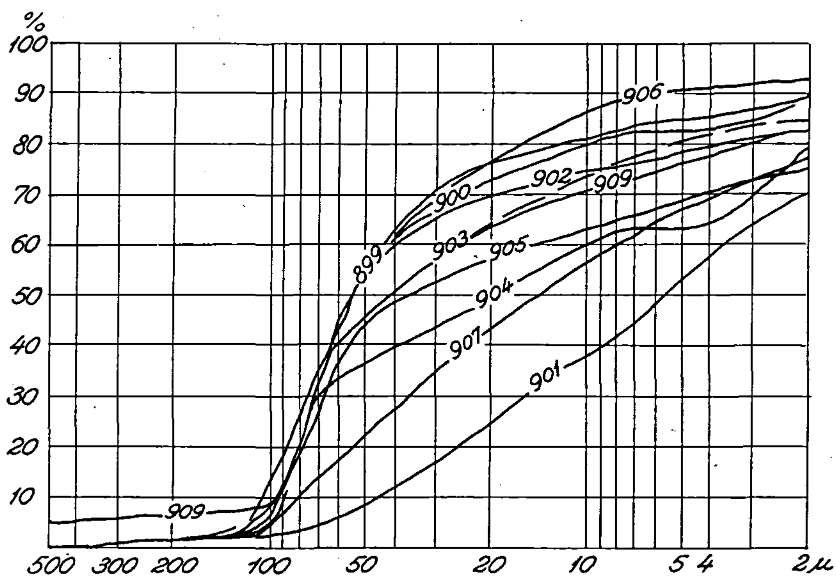

Fig. 5. The stratified sandy kleı.

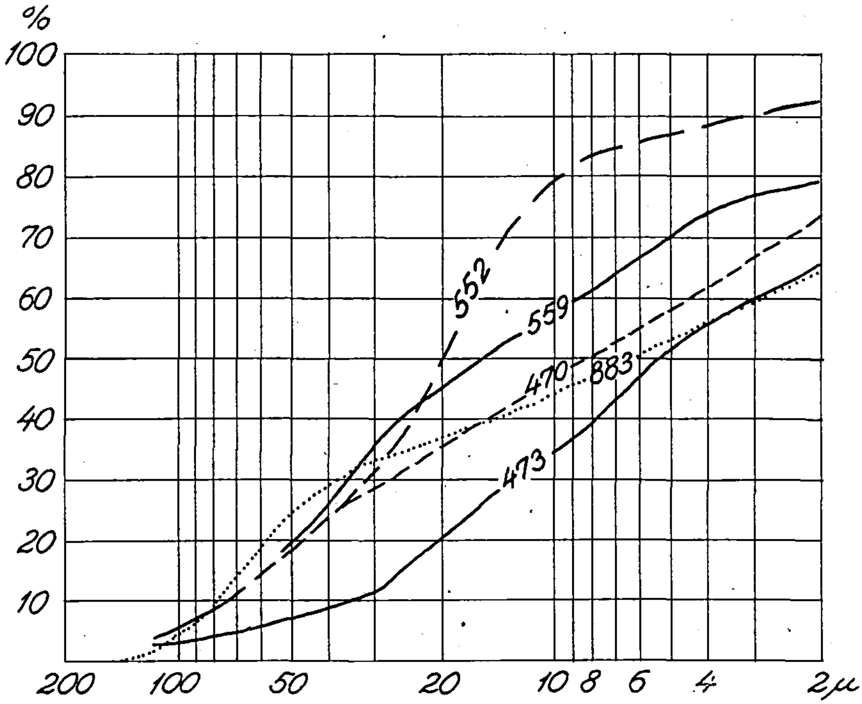

Fig. 6. The homogenous klei.

rolled; in the fractions 0.5–0.15 mm the grains are subangular, and the grains less than 0.15 mm have all sharp edges.

In the sample from boring 35, 5.5 m below the surface the fraction larger than 1 mm solely consists of small iron-concretions and in the sample from 3.5 m below surface in boring 37, a few spots of blue Vivianite were seen.

The fine sand (fig. 4) has Md. varying from 60–80 μ and only 3 to 5 % of the grains are larger than 250 μ. The samples are a little silty, but the silt contents may probably be impurities from the stratified sandy klei above. The sandy components are identical with the fine sand continuously moving on the wadden. (K. HANSEN 1951).

The stratified sandy klei (fig. 5) varies in the granulometric composition from nearly pure silt (no. 901) to fine sand and coarse silt (no. 899). Most of it is sandy silt, however thin layers or lenses of fine sand occur in several horizons. It corresponds very well with the sediments in the upgrowing initial islands (klints) and other Kwelder deposits. (K. HANSEN og JAKOBSEN 1960). The pelitic fraction is very much like the homogeneous klei.

The homogeneous klei (fig. 6) is a poorly sorted silt and clay deposit with Md. varying between 5–16 μ and with Q_{D_φ} about 2. (So: 1.7–7.7). The clay content less than 2 μ varies from 20–36 %. When fresh, the klei is soft and fat with a markedly cloddy structure. The clods reach a size of 1 cm. The colour is blue-grey. When dry it is light yellow-grey and hard.

The gyttja is generally a silty sediment. The contents of fine sand can be as high as 32 % and the clay contents are lower than 13 %. When fresh the gyttja is black or bluishblack, very soft and sapropelitic. Several times during the borings a strong liberation of gas took place. Set in fire it burned for about 20 minutes.

Dried the gyttja is light grey and very hard. Some samples are a little sandy, other more clayey with black spots of organic matter. Two samples, no 36 from 6.56–6.95 m below the surface in boring 31, and no 38 from about 2 m below surface in boring 33 were analysed about $CaCO_3$ and organic matter.

	36	38
$CaCO_3$	2.2 %	9.75 %
Loss of ignition	13.3 %	10.60 %
Organic carbon	5.03 %	5.45 %
– nitrogen	0.3 %	0.4 %

This gives a C/N rate of 16.9 and 13.6 which is higher than usual in marine sediments and freshwater gyttjas (K. Hansen 1959), and must be due to the strongly sapropelitic conditions. (Smith 1954, Trask and Hammer 1934).

The development of the Ballum Salt Marsh

As will appear from the sections, three series of sediments must be held apart.

1. The sandy stratified klei.
2. The homogeneous klei.
3. The sediments in the Bredeaa valley.

The sandy stratified klei is a Kwelder or Schor deposit formed under building of initial islands (klints) as described by Jakobsen (1954, K. Hansen og Jakobsen 1960). In the section I such a klint is seen with its top at boring 35. Another more loomely seen has its top at the boring 6 and is probably an initial stage of the large one. The frontside of the large klint is also seen at the boring 47 of the section III and at the boring 43 of the section IV (fig. 7). In the field the klint is appreciably visible as a ridge running NNE–SSW.

The homogeneous klei must have been deposited under rather tranquil conditions either in a salt marsh area protected from the sea by a beach ridge system as recently found at the eastern side of the islands Fanø and Rømø and at the peninsula Skallingen, or it may have been deposited in shallow basins in a delta or estuary as described by Duboul Razavez 1956,

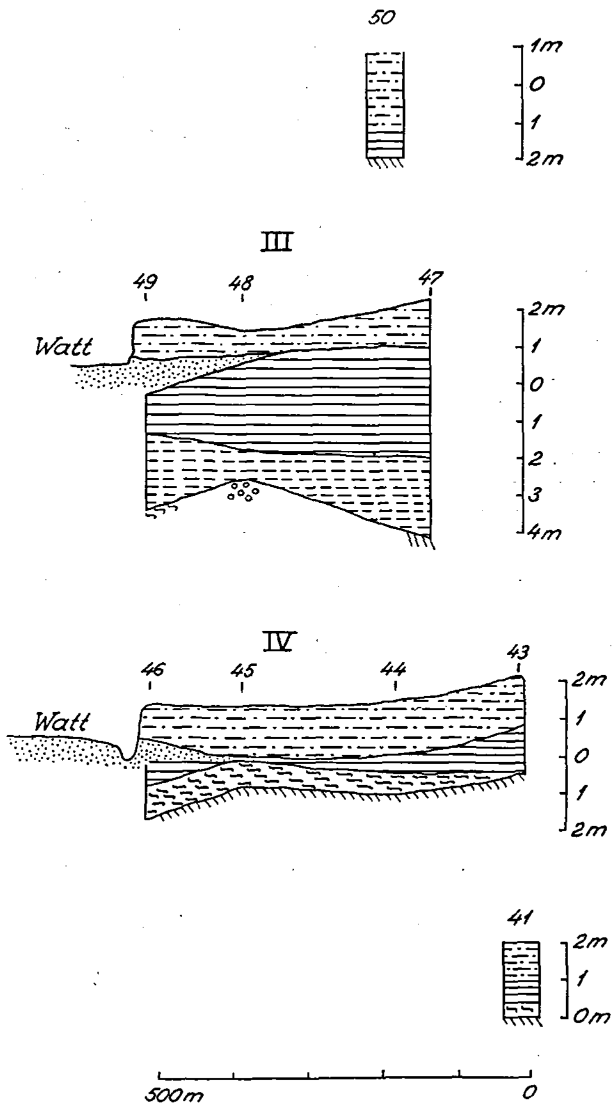

Fig. 6.

EDELMAN (1950), KRUIT (1955), SHEPARD and MOORE (1955), SHEPARD and RUSNAK (1955). As no protecting beach ridge systems have been found in the sections it seems most likely that in any case the lower part of the homogeneous klei east of the river valley is deposited in shallow basins in a previous Bredeaa delta. However the uppermost part of the homogeneous klei in the borings 7–14 is deposited at the lee side of the upgrowing klint and is of the same age as this one.

The late-glacial river Bredeaa

The sections show, that the late-glacial valley of the river Bredeaa was deeper and especially much wider than to day. In both sections it is 650 m wide. In section I the bottom is only reached in the boring 33 where glacial till was found at a depth of 5.85 m. In section II the bottom was reached in the boring 42, where sand below peat was found at a depth of 5.40 m and in the boring 31 where the peat was found at 8.65 m below surface.

The development of the Ballum Salt Marsh area must probably be as follows. Gradually, as the post-glacial transgression (Litorina-transgression) approached the recent Ballum area, the groundwater level was rising and a stagnation with the formation of peat took place.

Later the highest tides penetrated the river valley and a stewing up of the water took place causing a flooding of the plaines along the river. In this case the homogenous klei was deposited on the plains or basins, and sand was deposited in the river bed. (Bourcart, Francis Bæuf et Rajcevic 1941, Guilcher 1959, Rajcevic 1957, Tavernier 1947). As such exceptional high tides often are connected with stormy weather the sand in the river bed will be rather coarse. Farther up the river the gyttja has been deposited at the same time.

Gradually the river valley in section I is filled with coarse sand and the sea crosses it and builds a wadd of fine sand or a low beach ridge and sheltered by this a slikke of homogeneous klei.

It is not quit obvious how the gyttja in section I has been deposited. Probably it has been deposited in a creec (Priel) silting up, but the very high stagnation and the sapropelitic sediments point to a dead or abandoned river branch.

When the transgression has advanced so far that the plain is lying at a level about the mean high tide, the formation of the klints and the sedimentation of the stratified sandy klei begins (Jakobsen 1954, Hansen og Jakobsen 1960). In the borings from the preparations of the Rømø Dam (Betænkning 1938) a valley is found below Paisand with the same dimensions as the late-glacial Bredeaa valley in section II and with the bottom at a level of −8.8 and −9.6 m D.N.N. and with a direction NW–SE pointing towards the Ballum sluice.

To get some more informations about the dimensions and the sedimentation in the Bredeaa valley the boring 41 took place in 1957 as far south as where the road from Forballum is crossing the road from the Rømø Dam to Ballum, and in 1958 the two sections III and IV together with the boring 50 (fig. 7) were bored.

It is evident that the section IV and the borings 40 and 50 do not go down in the late-glacial Bredeaa valley. They have all the same stratification as the borings east of the river and with a similar thickness. Contrasting with this, the section III with its gyttja and coarse sand must go down in the slope of a valley running NW–SE as a a continuation of the valley below Paisand.

It is not quite obvious why this valley has been filled up with sand and the valley in section I has been closed. The homogenous klei of the section

III and in the borings 33 and 36 in section I and the borings 31, 39 and 42 in section II are not of quite the same nature as the homogeneous basin klei. It is mostly more sandy, but essentially different from the sandy stratified klei. It has probably been deposited in a silting up creec or on a slikke. (K. HANSEN 1951).

The deposition of the stratified sandy klei and the growing up of the klints is the last phases of the development of the Ballum Salt Marsh, and they changed the drainage conditions in the marsh area totally by blocking the directwestward drainage. Therefore new creecs were developed from the eastern side of the klint meandering out to the main river. The main river was also blocked and had to find a new course to the north along the eastern side of the klint. Later on, when the marsh area was diked and drained by ditching, these creecs were silted up, but are still visible in many of the older salt marshes.

The structure and the development of the Ballum Salt Marsh may be considered as a pattern for all older salt marshes in Denmark. A. JESSEN (1916) states, that the salt marsh by Ribe, Sneum Aa and Novrup Bæk outwardly are bound by a beach ridge (Ovret). At Ribe this ridge is evidently a klint build up of sandy stratified klei and resting upon homogenous klei. Ribe Holme more eastwards is also a klint build up of stratified sandy klei. At Sneum Aa and Novrup Bæk real beach ridges of sand and gravel are lying upon the marsh klei, and are therefore younger than this. Further inwards in these marsh areas klints of stratified sandy klei are found.

The age of the Ballum Salt Marsh

The holocene transgression (Litorina-transgression) is in the Northsea area divided into two phases, The Flandrian Transgression at the atlantic period and The Dunkerque Transgression at the subatlantic period (BENNEMA 1954, COPPEZ 1958, DITTMER 1952, EDELMAN 1953, TAVERNIER 1947, TAVERNIER and MOORMAN 1954, ZAGWIN, DE JONG and TER WEE 1956).

A. JESSEN (1916) stated that the Danish salt marshes were rather young of age, at any case younger than the subboreal period (bronce-age) and in the Ballum Salt Marsh too, the lower marine serie is lacking. That means, that the Ballum Salt Marsh like the other Danish salt marshes is build up by the Dunkerque Transgression.

However, the sea cannot have been far away in the atlantic period, because further north along the westcoast of Jutland it is known to have entered Filsø (JONASSEN 1957) and to the south the older klei in the area between Eiderstedt and the island of Sylt is also deposited in the atlantic period at the level −10 m. This is nearly the same level as the bottom of the valley below Paisand.

In the latest part of the atlantic period a large bay was formed to the north of the island of Sylt. Its southern coast runs from Kampen southeastwards to Rodenæs and to the river Videaa at Aventoft. (DITTMER 1952).

GRIPP and SIMON (1946) state, that the litorinakliff eroded by the holocene Northsea on the northern side of the diluvial part of the island of Sylt reaches from −23 to −15 m. The peninsula Listland and Ellebogen are build up by holocene deposits to a depth of 20 m, and also on the Danish islands Rømø, Manø and Fanø holocene marine sand and klei is found to similar depths. The borings from the Rømø Dam (Betænkning 1938) indicate, that the eastern coast of this bay has run just westward-of Paisand. Probably very high tides in this period may have entered the estuaries of the Bredeaa Delta, deposited the coarse sand in them, and the lowermost part of the homogenous klei in the basins between the delta branches.

In the northern and eastern Denmark, the Litorina Transgression is succeded by a regression. A. JESSEN (1916) also stated, that this was the case in the southwestern marsh areas of Denmark, and that the level to which the salt marsh surface is situated, is considerably higher than that to which the high tide to day may deposit marsh klei, and he stated, that an elevation of about 1.2–1.4 m must have taken place later on. However the very exact mapping and investigations of JAKOBSEN (1954) disprove this and show that very young klints are build up to about 2 m D.N.N.

By investigations in the southernmost of the Warften at Misthusum NORDMANN (1935) found that the base of the Warft was situated 2 m below the surrounding salt marsh surface, and he believed that this indicated a sinking succeded by an elevation at the time after 1400 A.D. However the Warft is situated between the borings 30 and 31 in section II, that means above the late-glacial river valley with its rather soft gyttja in which the Warft has settled by its weight.

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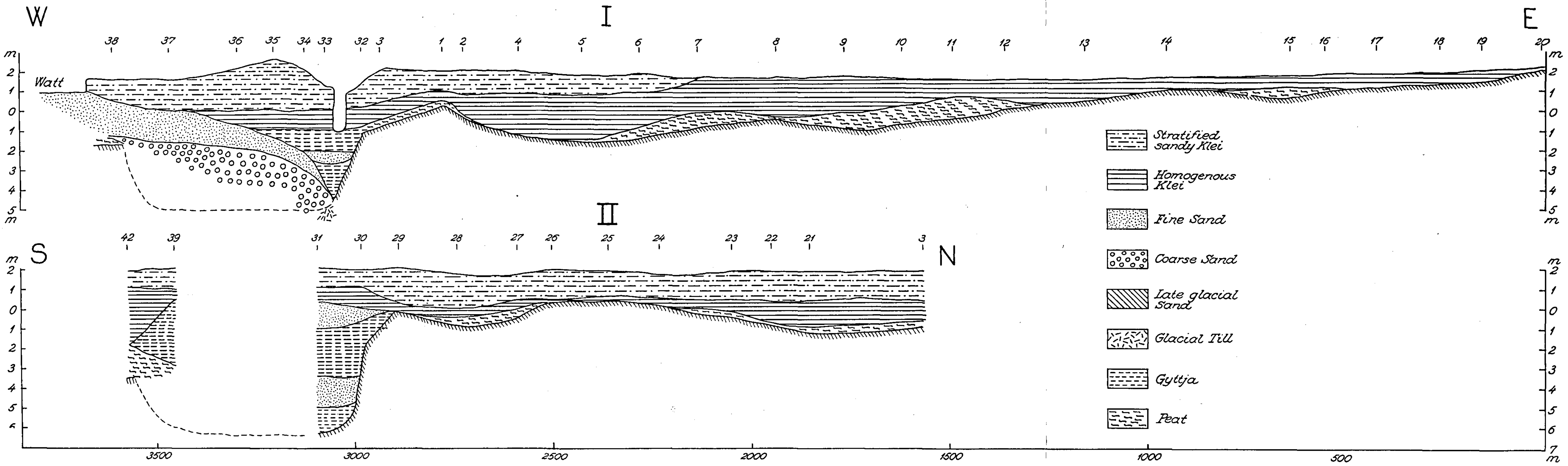
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