Topography of the late-glacial sub-surface in the salt-marsh area at Tønder.

By N. Kingo Jacobsen.

As part of an investigation of the landscape genesis along the south-western coast of Jutland after the last glaciation, *De Danske Vade- og Marskundersøgelser* have carried out detailed mapping of soil types, levellings and topographical mapping in the western part of the Tønder area, Møgeltønder Kog (polder). The salt-marsh investigated covers about 1.600 ha. The programme comprises a net of borings to a depth of 1.25 m. at intervals of 50 m. and a system of borings in lines going down to the late-glacial sub-surface. These borings were placed at intervals of 50 m. in lines situated at a distance from each other of 2—300 m. The spot height of the borings has been determined by a detailed contouring of the whole area, with points at each 25 m. in a net with a density of four times the borings. The accuracy of the levelling is found within 1 cm. The spot heights are carried forward to the boring points with an estimated uncertainty of up to 5 cm. In a previous article *(N. Kingo Jacobsen, 1956)* this programme has been outlined, and a single profile has been published. In great parts of the area it has been possible, already with the surface drill, to reach the geest, i.e. the old surface of the outwash plains from the Würm Glaciation and the old morainic isles from the Riss.

The contour-map of the geest-surface, description and topography.

On the basis of about 7.000 borings in all, the accompanying contour-map has been drawn of the geest surface in Møgeltønder Kog (Pl. I). In this article is given partly a topographical description, partly an attempt of an interpretation based on profiles (fig. 2) and on 6 borings to a depth of about 30 m. below the surface (fig. 1). These borings have been executed by *Dr. Sigurd Hansen, Danmarks Geologiske Undersøgelse* (D.G.U.). Studies of corresponding phenomena observed in Germany and Holland will be referred to and, finally, the results will be summed up in a morphological description of the terrain in question.

In view of the distribution of heights, screens have been introduced between the contours according to a sevenpartite scale (i.e. with contour intervals of 1 m.), trying to produce an almost 3-dimensional picture with the highest lying parts dark toned. The fully drawn contours have an interval of 0.5 m., and taking the intervening dot-and-dash contours into account the contour interval is 0.25 m. In the areas where the geest is situated at such a level that it can be reached by the small drill (1.25 m. below surface) a very detailed picture of the geest surface has been established. Broadly speaking, the contours down to – ¾ to – 1 m. D.N.N. (Danish Ordnance Datum) have been established with this accuracy, considering that in this area the surface of the salt-marsh is situated at the level + 0.20 to + 0.50 m. D.N.N. Certain parts are situated at a higher level; however, they coincide with the areas where the geest too reaches a high level. An exception from this is only the region in the most south-western part of the map, where the morphology of the salt-marsh is of a quite different type. The deeper lying parts (below – 1 m. D.N.N.) have, as mentioned, been mapped on a rougher scale than the rest; however, the variations of the spot heights in these areas have had a pronounced tendency indicating the basins in question. As an example can be mentioned the spot heights on a line N/S through the north-western basin (figures in m. — D.N.N.): 0.40, 1.04, 1.20, 1.25, 1.32, 1.42, 2.09, 2.85, 2.91, 2.80, 2.88, 2.85, 2.90, 2.50, 2.13, 2.10, 1.56, 1.72, 1.50, 1.55, 1.52, 1.36, 0.68. As mentioned, the distance between the points is about 50 m.

The topographical description of the map pl. I is preceded by a classification which in broad outline results in three types of terrain situated at different levels:

1: *The high-lying geest*, old morainic island, Riss Glaciation.

This type is found to the north from Bønderby to Møgeltønder with a lowermost level at about + 1 m. D.N.N., which almost corresponds to the upper shore-line of the Post-Glacial time. The western part (about 1½ km.) shows but little of this type of geest, which at this place is steeply descending to the basin situated to the south. In the eastern half (also about 1½ km.) is partly seen the older moraine cliff facing the Vidå valley (levels above + 2 m. D.N.N.) and partly, to the south of this, a landscape, undulating on a small scale with dome-shaped hills and serrated contour lines with the first signs of funnel-shaped estuaries, which are further accentuated at the lower levels.

2: *The terrace surface.*

To the south of the high-lying geest is found a geest surface situated at the level + 1 m. to - 1 m. D.N.N. It comprises a border-zone of a width of 2—500 m. connected with an area of about 3 sq. km. to the west of Sødam Gård. At the level 0 to - 1 m. D.N.N. it must be considered as a sort of terrace surface for the whole mapped area to the south of the old moraine island from the Riss Glaciation (Møgeltønder bakkeø) and to the north of the fluvio-glacial valley from the Würm Glaciation, which forms the bed of the Vidå. In its eastern border-zone towards the high-lying geest this surface is characterized by the above mentioned estuaries in the direction N—NE; in the middle is a ridge, NW/SE oriented. To the west it is intersected by a channel in the direction N/S and terminates abruptly to south-east at the southern deepest part of the easternmost basin. On this ridge and on the plain to the west of Sødam Gård is seen a working-out of the terrace surface with long ridges WNW/ESE, which have a striking resemblance to dune topography.

The basins.

Almost half of the map comprises levels below — 1 m. D. N. N. They group mainly around three basins or bays with adjoining channels.

a): Towards north-west is found a basin of an extent of about 2 sq.km., which has a symmetrical shape with the longitudinal axis in the direction WNW/ESE (refer the above-mentioned levels from a cut N/S through the basin). The depth is about - 3 m. D. N. N.

b): To the east is found a bay-looking basin of an asymmetrical shape; the greatest depth is about — 3 m. D.N.N. in the southernmost part. The border consists of funnel-shaped tongues towards WNW, NW, NE and N. In the central border of the basin, at Kærgård (fig. 1) is seen the northernmost of the meanders of the Vidå (depth about - 4,5 m. D.N.N.)

c): Towards south-west is found a deeper lying area of an irregular shape; in the westernmost part this area reaches a depth of about – 3 m. D.N.N. With smaller depths from – 1 m. to – 2 m. D.N.N. it covers an area of about 2 sq.km. and is connected by a channel N/S oriented with the north-western basin (a).

Geology.

At the end of the Tertiary the south-western part of Denmark was a plateau high above the sea and with deep cut valleys. At the end of the Pliocene the deterioration of climate sets in, and the ice masses extend from north to east. At the beginning of the Quaternary a general subsidence took place, the result of which was that the old tertiary land surface was lowered so as to be again below sea level. This subsidence in combination with the forces set in motion by the climatic fluctutations in the Quaternary have supremely determined the landscapes in the southern part of Jutland. The supposition of later block movements advanced by *H. L. Heck* (1936) has been refuted by *E. Dittmer* (1941), who has proved that no such movements have taken place in North Friesland in Younger Pleistocene.

It should here be mentioned that the sea level has been exposed to enormous fluctuations in the course of the changing glacial and inter-glacial times. For instance, during the Würm Glaciation, the sea level was about 100 m. lower than now; at the beginning of the Post-Glacial time the lowering of the sea level was about 55—60 m., in the transition time to Boreal about 40 m., to Atlanticum about 17 m., to Subboreal about 4 m., and at the beginning of Subatlanticum the level of the sea was only about 2 m. lower than now. There is every reason to suppose that in Late-Glacial time the sea level has been subjected to a considerable rise, a process which has taken place in stages corresponding to the retirement of the inland ice. It is supposed that in Post-Glacial time a progressing, though declining rise of the sea level has taken place, perhaps interrupted by periods with a stagnation (*N. Kingo Jacobsen,* 1956). In this connection it is the conditions of the Late-Glacial time which offer a particular interest.

Superposed on the tertiary layers we find deposits from the three glaciations with intervening inter-glaciations. A brief summary of the results of the boring at Brodersmark gives a rather good impression of this even if the possibility exists, that the tertiary in question is a glacial flake, as mentioned by *L. Banke Rasmussen* (1958):

m. D. N. N.	Description D. G. U.	Interpretation
+ 0.94 to + 0.76	humus	salt-marsh deposits
+ 0.76 – + 0.29	clay of the foreland type	
+ 0.29 – + 0.04	heavy, dark clay	
+ 0.04 – – 0.06	peat	basis-peat, post-glacial
– 0.06 – – 0.21	coarse sand mixed with peat	
– 0.21 – – 3.06	sand, fine-grained varied grain-size yellow-brown	blown sand, Late Dryas time
– 3.06 – – 4.06	sand, very fine-grained uniform grain-size, yellow-brown	niveo-eolian and niveo-fluviatile sand from the time before the Allerød period
– 4.06 – – 4.56	sand, very fine-grained, light	
– 4.56 – – 5.06	do. do. with small, dark grains	
– 5.06 – – 6.36	do. do. with mica content	
– 6.36 – – 9.36	sand, very fine-grained uniform grain-size	fluvio-glacial deposits, Würm Glaciation
– 9.36 – –12.61	sand, medium size with a few pebbles, light grey	
–12.61 – –13.31	sand, stony	
–13.31 – –13.56	do. do. with a few clay lumps	
–13.56 – –14.46	boulder clay, grey, of a sandy character, with a few shell fragments in the uppermost part. Fluvio-glacial erosion, Eemian deposits on secondary locality	boulder clay, Riss Glaciation at the latest
–14.46 – –17.06	boulder clay, grey sandy, rather stony	
–17.06 – –21.46	boulder clay, crey, at – 21.31 m. D.N.N. with numerous pebbles	
–21.46 – –25.41	mica clay, brown, with a few shell fragments, among others Nucula sp.	tertiary mica clay
–25.41 – –32.06	mica clay, dark, greasy. At – 30.36 m. and – 31.16 m. D.N.N. with light, yellow-brown concretions	

Examinations of the Urstromtal of the Elbe and of the lower Ems valley have proved that these valleys, which are cut into the tertiary surface without regard to the ancient relief, have kept their appearance unchanged through all three glaciations, apart from unimportant shifts (*W. Dechend*, 1956). A similar development seems to have been the case of the Vidå valley.

At the end of the Riss Glaciation the melt-water rivers of the western Slesvig were assembled in one big Eider Urstromtal with outlet through the present Lister Dyb. Farther to the west it was a tributary to the Elbe Urstromtal. During the Second Inter-Glacial time the climate became again rather mild (temperate), and the sea level was but a few metres below the existing. A big, bifurcated inlet (the Eemian Sea) at that time stretched through the above-mentioned Urstromtal from Lister Dyb, partly to the east into the Vidå valley, partly to the south to Husum between the old land-group Sild — Føhr — Amrum and the present geest-border (*P. Woldstedt*, 1954). At that time the Eider valley was situated to the south of the land-group transgressed by the sea. The Eemian deposits start with sandy layers corresponding to the transgression phase and end with clay deposits in the regressive phase. The layers are grey-green and are characterized by a fauna from a somewhat warmer climate than the present. As reference horizon these deposits are of great value; however, in the greater part of the Vidå valley, the fluvio-glacial rivers from the Würm Glaciation have eroded into the underlying layers. According to *Dittmer* (1954) the orginal surface of the Eemian deposits is supposed to have been situated at a level of about – 5 m. D.N.N. As already mentioned, the erosion in the Vidå valley has been heavy, and Eemian deposits on primary locality are often totally lacking. The results of five borings immediately to the south of Tønder show that the Eemian deposits are found at a level of – 12 m. to – 16 m. D.N.N., at Dyrhus (2 km. east of Kærgård) – 7 m. D.N.N., at Rudbøl – 22 m. D.N.N.; three borings at Gl. Frederikskog show – 16 m., – 18 m. and – 23 m. D.N.N., *Sigurd Hansen* (1955). Thus, we have got a rather good impression of the powerful erosion which has taken place, and which in the central parts of the Vidå valley has been at least 20 m.

At the transition to Late-Glacial time the coastal line was situated at the Dogger Bank and the Jutland Bank. The changing sea level has caused new states of equilibrium for the rivers; however, in Pleni-Glacial time the sea has been situated at a distance of at least 100 km., and in this region the fall of the river terraces has been comparatively great, coinciding with a big discharge in summer.

The morphology of the late-glacial sub-surface (geest) in the Møgeltønder Kog (polder).

The following is an attempt to describe the morphology of the geest surface below Møgeltønder Kog. In support of this is given a schematical review of climatic conditions, soil conditions, dynamic forces (fluvio-glacial and eolian), the result of these forces (erosion and sedimentation) and an approximate indication of the changing sea level. Further is given an account of the effect of the different forces at various times. Finally, an attempt has been made of uniting these results into a total impression.

The effect of the Eemian Sea.

The most impressive feature in the terrain to the west of Møgeltønder is the rather high, marked geest cliff to the south of Bønderby; it has previously been ascribed to the sea in the Bronze Age. However, this cannot be the case, as at that time the level of the sea was situated about 3 m. below the existing. Nor can it be a question of a coastal cliff from the Late Middle Ages, considering that the upper shore line is situated at about + 1 m. D.N.N. and that the region of the whole Subatlanticum was an inner protected basin. It is more probable that the cliff has been formed by the Eemian Sea, which, it is true, did not reach higher levels than those of the Bronze Age sea. At this age, however, deposits existed from the Würm Glaciation and from Late-Glacial time which were not found at the time of the Eemian Sea. Therefore, it is probable that the cliff has continued below the present surface. However, Eemian deposits may hardly be found because of the fluvio-glacial erosion from the Würm which took place at these levels. In accordance with this, fluvio-glacial erosion may also have been contributary to the formation of the cliff mentioned. Especially in the melting phase of the Würm Glaciation, when the ice sheet retreated from the east coast of Jutland. Referring to the boring pag. 171 it is nevertheless probable that this effect is inferior to that of the Eemian Sea.

The effect of the solifluction.

In the terrain description the attention has been drawn to the extreme difference of the topography to the west and to the east along the geest cliff, a difference which is mainly due to solifluction during the Late Dryas time. Also during Pleniglacial A a strong solifluction took place. However, the effects of this have no doubt been washed away by the melt-water during the high water levels in summer-time. The fact that the solifluction has especially taken place along the eastern half of the geest border is partly due to the materials of which the old morainic island is composed, partly to its terrain forms. To the west the Bønderby peninsula consists of marl and boulder clay, and at the same time the water-divide is placed directly above the geest cliff. It means that the area is mainly drained to the north, a direction which has been followed by the solifluction. The eastern part of the morainic isle, immediately to the west of Møgeltønder, is composed of gravel and sand, and the water-divide is situated somewhat farther to the north of the cliff. Both these factors have greatly favoured a considerable solifluction to the south. Consequently, an area of about 4 sq.km. with slided material is seen at this place. The contours offer a characteristic serrated picture, and the landscapes are flattened and dome-shaped. Apparently, the slidings have filled up the terrain down to the level - 1 m. D.N.N. The greatest landslide has taken place from Møgeltønder towards south-west, where it reaches the previously mentioned central ridge, which is NW/SE oriented. In the westernmost border of the map is seen a corresponding sliding, which originates from a branch valley between Kannikhus and the farm Brink; this farm is situated on a separate, small, dome-shaped, morainic isle.

The effect of eolian action.

As appears from table II, a strong eolian action has been prevailing during three periods: Pleniglacial B — Earliest Dryas, Early Dryas and Late Dryas — Preboreal. However, it is necessary to treat the first two mentioned jointly, as it has been impossible to indicate any effect of the Bølling Interstage. There is an older period before Allerød with prevailing wind direction NW and a younger period after Allerød with prevailing wind direction WNW; the effect of the eolian action is partly blow-outs, partly formation of dunes. The grain size increases from the oldest to the youngest eolian deposits: simultaneously, the wind-blown sand from the oldest period and from the Arctic part of Late Dryas has no doubt been deposited together with sublimated snow evaporated later on (niveo-eolian deposits), *Edelman & Zandstra* (1956) and *Edelman &*

Maarleveld (1958). Thereby, the older forms have been more levelled, as the sand, after the evaporation of the snow, is deposited in thin layers.

Older blown sand.

Considering the topography with blow-outs and ridges, longitudinal or irregular, in the direction NW/SE, and leaving out of account the solifluction from Late Dryas, just described, the existence appears partly of a big blow-out, partly of a characteristic ridge. The blow-out has been situated along the total border of the morainic isle and has a width of about 1½ km. The bottom of the blow-out must have been situated at the level about – 3,50 m. D.N.N. In this big U-shaped valley there has no doubt occasionally existed a dune topography in minor scale, which, however, for the above-mentioned reasons, has later on been smoothed out. To the south of the described blow-out is seen the above-mentioned ridge (the central ridge, direction NW/SE). It can be followed beyond the map up to and including the mound Husum at a distance of 2 km. south-east of Højer. Here it consists of comparatively coarse sand. It is therefore possible that the ridge has been formed in the latter part of the first eolian period (Older Dryas), in which the sand became coarser and the tendency to formation of ridges more pronounced. Only the boring at Pokkenbøl: II,70 is situated on this ridge. It should further be mentioned that the Pokkenbøl boring is one of the few places where the ground moraine from the Riss Glaciation has been met with (– 9,05 m. to – 14,30 m. D.N.N.)

Younger blown sand.

In Late Dryas and Preboreal another period arrives with big sand-drift, blow-out and formation of dunes. The wind-direction is WNW; the material is coarser and of varied grain size; often we find thin layers of fine, small-grained gravel *(Edelman & Maarleveld,* 1958). In the upper part are found distinct cryoturbations, refer fig. 2 and fig. 3 and the following description of the profile at Sødam: II, 8. Surface level: + 1,23 m. D.N.N. (p. 176).

The whole of this profile must be taken as younger blown sand; according to the profile p. 156, the Allerød horizon is found at – 1,07 m. D.N.N., below which we meet the older blown sand.

The younger blown sand has completely dominated the working-out of the landscape in details on the central ridge and on the plateau to the south of this. The result is a smalldomed terrain,

m. below surface	Description
0.00 to 0.23	clay
0.23 – 0.25	A_0, dark-grey humus layer
0.25 – 0.38	A_1, bleached sand
0.38 – 0.81	B-horizon, partly stratified, cryoturbations. Dark »chimneys« 1 to 3 cm. thick, a single one is 20 cm. broad, filled with black illuvation of humus.
0.61	A stripe ½ cm. broad with small-grained gravel. It is characteristic of the whole upper part of the profile to 0.81 m. below surface that small-grained gravel of a size of about 1 mm. are found in big quantities.
0.81 – 1.24	Purer sand, fine to medium-grained, light yellow-brown with horizontal deposits of coarser grained sand. In two horizons: 1.10 m. and 1.23 m. to 1.24 m. below surface were found dark-brown ferrugineous illuvation layers.
1.24 – 1.60	Grey-green sand, medium-grained with a few horizontal layers, for instance in 1.33 m. below surface.

which on the plateau forms a small parabolic dune with a height of about 1,5 m. Further, the wind has caused blow-outs in the remainders of the big blow-out before Allerød along the geest-border, remainders which had not been filled up by solifluction in Late Dryas. This has led to the formation of the north-western symmetrical basin and the south-eastern basin asymmetrically shaped by the solifluction. The central part of the latter and the tongue towards WNW must be of eolian origin in the same period.

Post-Glacial erosion.

In Subboreal the western part of the area was transgressed by the sea (the Cardium transgression about 2.000 B.C.); at that time the sea level was about – 3.50 D.N.N. The N/S oriented gully to the north-western basin may have its origin in that time. At the transition to Sutatlanticum about 700 B.C. the sea level has risen to about – 2,25 m. D.N.N.; consequently, the gullies and creeks created by the sea in connection with the tidal streams in the south-western basin were then active and drained off the north-western basin. However, this basin has been well protected by the central ridge (NW/SE) and is mainly filled up with peat formations.

When the sea covered the area in the Middle Ages, before the diking took place in 1556, the peat has been superposed by a clay layer of 20—50 cm. The south-eastern basin has been in connection with the sea through the northern meandering channel of the Vidå, seen on the map, and which has functioned as tidal stream at the end of Post-Glacial time. Therefore, in this basin exclusively fine-grained sand has been deposited, starting with fine-sand at the bottom and ending with fat basin clay apart from the ridge (fine-grained sand) which closes the basin and which is at the same time a sort of levee from the Vidå channel.

Genesis of the region.

As a result of these examinations, the following landscape genesis can be summarized: Already in the Riss Glaciation the Vidå valley acted as a fluvio-glacial valley. In the higher lying parts is sporadically found ground moraine from the same glaciation with underlying fluvio-glacial deposits, perhaps Tertiary. During the subsequent inter-glacial time the Vidå valley is exposed to a transgression by the Eemian Sea, which has extended far to the east and to the south, and which has originally formed the characteristic geest cliffs along the morainic isles. These cliffs have further been exposed to fluvio-glacial erosion at the melting phase of the land-ice from East Jutland. The gradient of the cliffs depends on the solifluction, especially during the Late-Glacial time (Late Dryas). During the Würm Glaciation the Vidå valley has functioned as a fluvio-glacial valley for big parts of the outwash-plain of Tinglev. At Tønder there has been a narrows; the discharge has been big, and at the same time the fall of the fluviatile terraces has been comparatively great, as at that time the sea level was 100 m. lower than now. Consequently, the fluvio-glacial river has cut down to a great depth (at least 20 m.), which appears from borings to Eemian deposits on primary locality. During the first part of the Würm Glaciation (Pleniglacial A) the climate has been cold and oceanic with violent snow-storms prevailing; during the second part (Pleniglacial B) somewhat more continental, cold and dry with prevailing eolian action and wind-direction from NW. The fluvio-glacial rivers have formed a braided system with sand and gravel deposits, which in the dry winter-time have supplied material to the sand-drift. At the beginning of the Late-Glacial time the conditions are unchanged; however, at the transition to the warmer Allerød period the character of the landscape changes. Permafrost and solifluction disappear, which means greater regularity of flow in the Vidå; simultaneously, the supply of the material is lesser and more fine-grained. At first, the Vidå formed a meandering pattern, main channel with high levees, as a transitional stage to the cutting-down of a trunk-stream, where the rest of the former system is left back empty. This development was caused by the fact, among others, that the river adapted itself to a new state of equilibrium and, therefore, was cutting down into the former fluviatile terrace. This was partly due to a reduced distance to the sea caused by the considerable retreat of the inland-ice. The previous system was completely put out of action, and the abandoned channels were filled with peat. At the same time the vegetation has spread, and the forest has immigrated (birch and pine). At that time a big, U-shaped blow-out valley with a longitudinal ridge was situated to the south of the Bønderby peninsula; the ridge was running almost parallel to the cliff of the morainic isle. The existence of this ridge is proved by the presence of podsolic profiles at the level – 1 m. to – 2,9 m. D.N.N., refer table II. Besides, it makes itself distinctly known in the central ridge (NW/SE).

The terrace surface, mentioned in the topographical description, has been formed by fluvio-glacial deposits superposed by niveo-eolian sand along the rivers of the braided system in Pleniglacial B. However, the presence of the terrace surface was predetermined by high-lying morainic deposits from the Riss Glaciation, which had the effect that this part of the fluvio-glacial valley only has functioned at extraordinarily high water levels in the Vidå. In addition, the surface has been further raised and worked out by eolian action in Earliest, Early and Late Dryas time and by solifluction especially in Late Dryas time.

From the boring at Rudbøl it appears that the melt-water has eroded as far down as to at least the level – 22 m. D.N.N.; to the south of Møgeltønder the erosion has reached the level – 13 m. to – 17 m. D.N.N. and to the south of Tønder – 12 m. to – 16 m. D.N.N. Against erosion at these levels the terrace surface, as just mentioned, has been protected by deposits from the Riss Glaciation, the surface levels of which are as follows: Pokkenbøl: – 8,50 m. D.N.N.; Herredsvejen: – 9,81 m. D.N.N. and Brodersmark: – 13,56 m. D.N.N. The levels of the uppermost layers of the fluvio-glacial, fine-grained deposits in the valley to the south of the terrace surface are, to the south of Møgeltønder: – 8,72 m.; at Sødam: – 9,27 m. and at Brodersmark & Rudbøl: – 9,36 m. D.N.N. On the terrace the uppermost fluvio-glacial fine-grained deposits are situated at about level – 5 m. to – 6 m. D.N.N. Consequently, the fluvio-glacial deposits from the Würm Glaciation have here only a thickness of 2½ to 4 m., and they are found at a higher level than those situated along the southern border of the terrace. The fluvio-glacial deposits here must have their origin in the melting-phase of the land-ice in eastern Jutland, where the water level in the Vidå must have been highest. In evidence of this but one clay layer of fluvio-glacial origin is met with on the terrace, whereas two layers are found in some places along the southern border of the terrace. Borings in the abandoned meandering channels show that the borders of these are very steep, and that the bottom is situated at about – 7 m. to – 7½ m. D.N.N. These channels are filled with peat up to a level of about – 3,75 m. D.N.N.; on top of this are found fine-grained sediments. It is probable that these channels have been meandering main channels in the latter part of Early Dryas, abandoned in the Allerød time and filled with about 3½ m. of peat. The trunk-stream from this time has at Ny Frederikskog cut at least down to – 13 m. D.N.N., which appears from the above-mentioned boring-line published in 1956. The establishment of these sparse facts leads to the conclusion that in Early Dryas the Vidå valley was in this region situated at the level – 9 m. D.N.N. On account of the ground-moraine, which at Brodersmark was deposited on a high, protruding knot of tertiary mica clay, a terrace surface was situated to the north of this. To a level of about – 5 m. D.N.N. fluvio-glacial deposits from the end of the Würm Glaciation were found superposed by (niveo-fluviatile and) niveo-eolian deposits with a feebly domed relief, dominated by the central ridge and by a big blow-out valley along the cliff of the geest. The levels of this surface have ranged from – 3,75 m. (the topmost part of the peat from Allerød in the abandoned channels) to –1.07 m. D.N.N. (the lowermost podsoled horizon, Sødam, II,8). In Late Dryas the big slidings from the morainic isle to the west of Møgeltønder first took place, followed by the blow-out, described above, of the north-western basin and the south-eastern basin as well as the formation of the dune topography on the terrace surface to the south of the central ridge and upon this ridge, i. e. the final working-out of the surface which on account of vegetation is rather stable until the formation of the Post-Glacial basis-peat. The erosion of the south-western part of the terrace surface during the Post-Glacial transgression has already been described in outline.

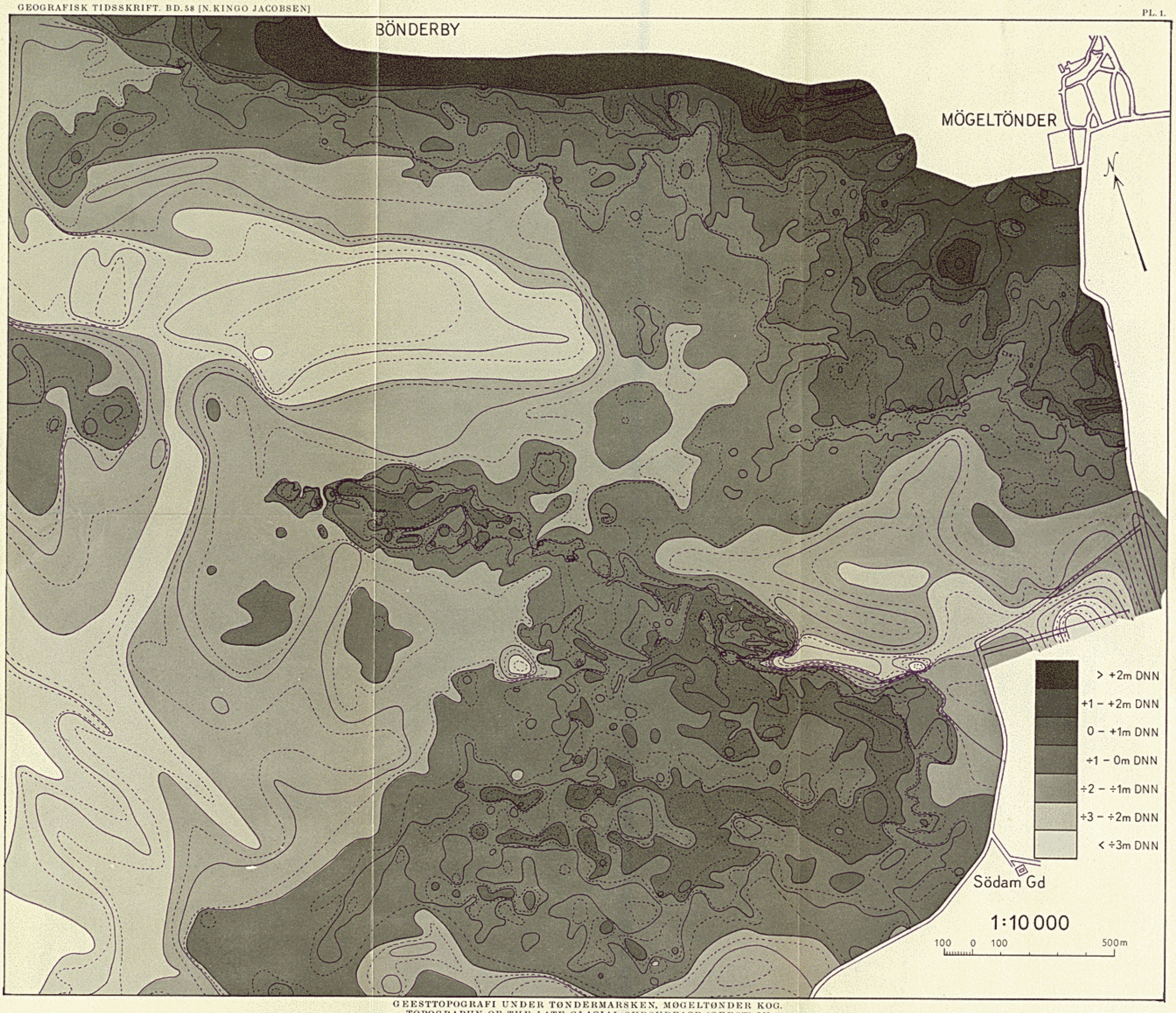
Table II.

	Würm Glaciation		Late-Glacial time					Post-Glacial time continued ⟶	
	Pleni-glacial A.	Pleni-glacial B.	Old Dryas time			Allerød time	Late Dryas time	Pre-boreal	Boreal
			Earliest Dryas time	Bolling time	Early Dryas time				
Temperature ° C.	<0	<0	— 3	+ 2	— 1	+ 5	+ 1	+ 4	+ 6
Precipitation	+	—	—	(—)	—	+	+	—	+
Permafrost	+	+	+	+	+	—	+	—	—
Solifluction	+	(+)	(+)	(+)	(+)	—	+	—	—
Fluvio-glacial erosion	F	LE	(LE)	(F)		F	LE	(LE)	F
Fluvio-glacial deposits	Gravel + niveo-fluviatile sed.	Sand and gravel + niveo-fluviatile sed.	Sand	Fine-grained sand	sand→clay	Peat and fine-grained sediments	Gravel	Fine-grained sand→clay	Fine-grained sediments
Eolian erosion		B	B		B		B	B (local)	
Eolian deposits		Blown sand and loess, niveo-eolian sed.	Older blown sand		Older blown sand		Younger blown sand	Younger blown sand	
River phases	1	1	2	3	3	4	1—2	3	4
Sea-level ab.		— 100 m					— 55 m. to ab. — 60 m.	— 40 m.	— 17 m.

F = Formation of erosion valleys.
LE = Cutting-in of the rivers, lateral erosion.
B = Blow-out depressions.
O = Older blown sand.
Y = Younger blown sand.

1 = Braided river system.
2 = Braided river system with various kinds of channels in a fixed system.
3 = Strongly meandering main channel with high levees.
4 = Cutting-down of a trunk stream; the rest of the former system is left back empty.

Compiled after
P. Woldstedt, L. J. Pons, J. Iversen, C. H. Edelman and *G. C. Maarleveld*



GEESTTOPOGRAFI UNDER TØNDERMARSKEN, MØGELTØNDER KOG.
TOPOGRAPHY OF THE LATE-GLACIAL SUBSURFACE [GEEST] IN THE SALT-MARSH AREA OF TØNDER, DENMARK.

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