Developmental history of the River Gudenå, Denmark

KAJ HANSEN

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New observations on the terrace levels in the east Jylland valley systems indicate that Ussing's (1904, 1907) view of the Falborg Stage is correct. On the other hand, his explanation of the Skalså Stage, and the retreat of the ice from Falborg Stage to Skalså Stage, requires further examination, since the explanations so far offered do not hold. Further study is needed on the development of the lake systems of the Gudenå and connecting valleys since a number of different processes appear to be responsible for these erosion forms. The present study appears to show that the last glacial advance (Baltic Phase) has not influenced the morphology of the area to any great degree. The topographic expression of the land definitely owes its origin to older glaciations, to the processes that follow with both glacial advance and retreat.

Kaj Hansen, Gammeltoftsgade 16, 1355 København K, Denmark. August 16th, 1977.

In 1896 Gerard de Geer published his book "Om Skandinaviens geografiska Utvickling efter Istiden" (On the geographical development of Scandinavia after the Ice Age), which caused strong protests both in Sweden and in Denmark, in Sweden because de Geer maintained that there had been two glacial eras in Scandinavia, in Denmark because he placed the outer limits of the last glaciation across Jutland along the bottom of the fjords from south to north ending in Mariager Fjord.

This was the reason why Ussing (1903) wrote his treatise on the outwash plains of Jutland, in which he proved that the outer limit of the last glaciation lay somewhat further to the west; and at Dollerup the limit had curved to the west continuing to the North Sea near Bovbjerg. In several treatises in the following years (1904 and 1907) Ussing offered further evidence in support of his ideas as to where the border of the ice had been and the progress of the melting; thus he divided the period of melting into three stages: The Falborg stage, the Skalså stage, and the Gudenå stage.

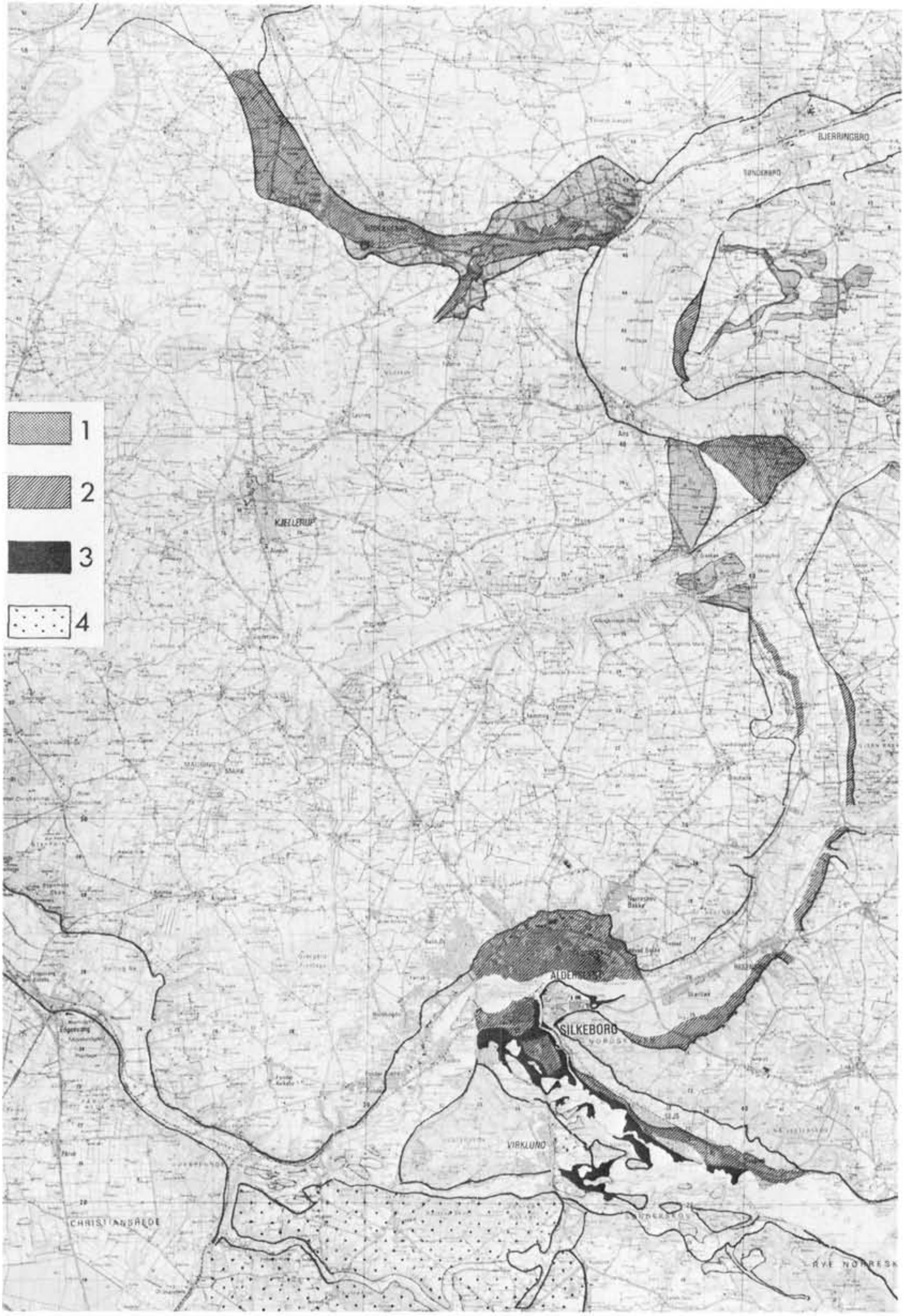
Ussing's treatises excited great interst and right up to the present they have been considered some of the safest tracts within Danish Quaternary geology. However, the more one concerns oneself with the details the more difficult it becomes to make Ussing's theories fit.

In the present paper the Gudenå valley between Silkeborg and Randers will be treated first, and after that the valley containing Julsø, Borresø, and Torsø together with the Silkeborg area (fig. 1).

The Falborg Stage

Ussing wrote (1907) that the upper end of the Falborg plain is only incompletely preserved. The direction of the plain here is west-east, only the northern part – without any slope of erosion – continues into a somewhat higher moraine landscape (at Vindum), where it is most likely that the border of the ice lay, at least during part of the formation of the Falborg plain. The southern part of the Falborg plain ends to the east in a slope down to the river Gudenå, where it was apparently eroded away by the glacial predecessor of the Gudenå.

In the Falborg valley there are terraces on two levels, 38 m and 30 m. At the northern side of the Falborg valley the 38 m level is seen in one piece from south of Vindum to Rødkjærsbro, but very much cut up by the erosion of the eastern parts. Furthest to the east the width of the terrace is 1600 m, but to the west it narrows down, and at Rødkjærsbro the terrace quite disappears. At the southern side the terrace is narrower and con-


1
2
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BJERRINGBRO
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tinues into Levring Bæk valley in order to disappear completely at the Østervandet.

Ussing (1907) wrote furthermore that it seems as if the Falborg valley originally continued to the south for a rather long distance, as at several places in the Gudenå valley he found terraces at levels just as high or higher than the 38 m stage in the Falborg valley.

To this phase of the Falborg stage the 1.5 km wide dry valley also belongs; from the Allingå valley at Grønbæk it stretches northwards to the Gudenå valley south-east of Ans. The northern part of the valley stands with a 27 m high slope towards the lake Tange Sø, and its bottom is 40–45 m above sea level.

Ussing regarded the valley as part of the Gudenå valley, but it was also an outlet for the lake Hinge Sø of that time and for the whole area between Gudenåen and Karup outwash plain.

NW and SE of Grønbæk there are terraces at the same level, and further southwards at the western side of the Gudenå opposite Tvilum Kirke there is a terrace 42 m above sea level. The 38 m stage can further be traced into some of the rivulets at the eastern side of the Gudenå (Hansen 1971).

The 30 m phase forms the bottom and the watershed in the Falborg valley. At the southern side of the valley it forms a terrace from Tange to Levring Bæk. From here and further on to the west the bottom of the valley itself lies at this level, which can also be traced through the Gudenå valley to the south.

Along the east side of Tange Sø, beneath an 11 m high straight slope there is a terrace (surface), the innermost edge of which is 30 m above sea level.

NE of the dry valley on the ridge that reaches into the meander bow of the Gudenå there is also a plain at 30–32 m above sea level, and from the point where Allingå flows into the Gudenå valley and southwards this level is found as wider or narrower terraces as far as the lake Silkeborg Langsø. Both the wide terrace north of Silkeborg

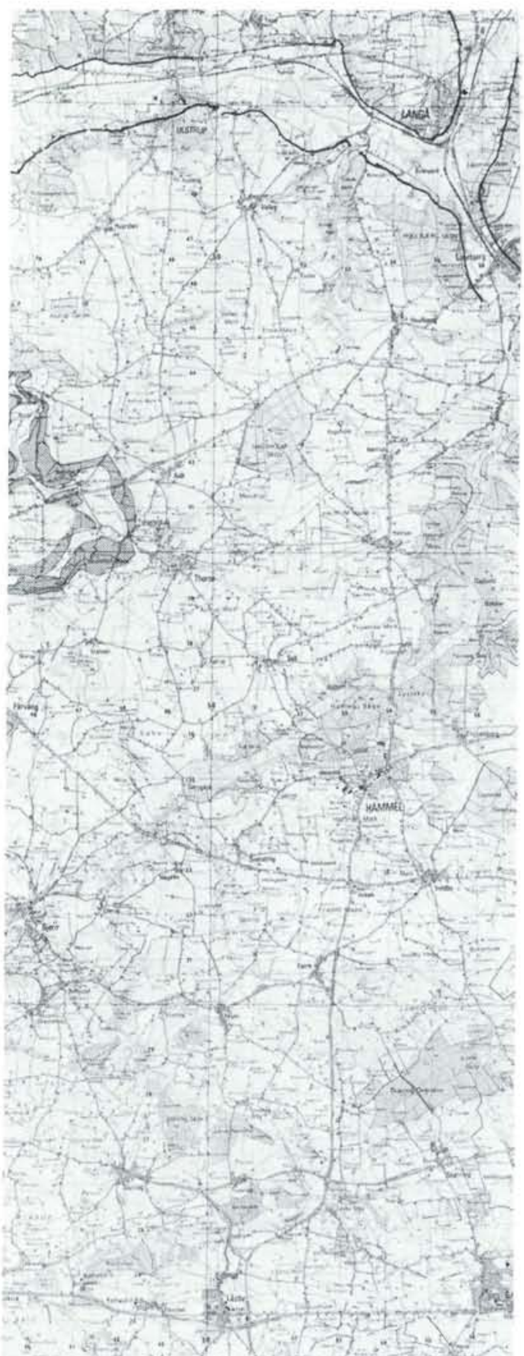

Fig. 1. Map of the area of study, reproduced by Copenhagen University, Geographical Institute, with permission (A454/72) of the Geodetic Institute. 1. Terrace surfaces belonging to Falborg valley's older stage. 2. Terraces belonging to Falborg valley's later stage. 3. The Gudenå's lower terrace. 4. Areas older than the last glaciation.

Fig. 2. The dry valley at Langå between the Nørreå valley and the Gudenå valley. The hills in the background are the northern side of the Nørreå valley.

Langsø and the riverplain on which Silkeborg lies are at the same level, which is also the uppermost level of the terrace lying along the northern side of Remstrup Å, Brassø, Borresø, to the western end of Julsø. This is in complete accordance with Ussing's opinion (1904) that at the beginning of Stage IV the melt water from the area south of Silkeborg was admitted to the Falborg valley.

The Skalså stage

As to the fifth stage of the melting of the ice, the Skalså stage, Ussing (1904) wrote only that the ice had now retreated so far that the river had disappeared from the Falborg valley, as the water could now follow the lower Gudenå valley almost as far as to Randers, but that it probably had to flow to the west, because the ice covered Kattegat. The river must have used part of the old fjord valley, where Nørresø now lies, and further on its way it must have used the Skalså valley.

Later on Ussing (1907) treated this stage in greater detail. At Onsild Bridge the bottom of the Skalså valley is 7 m above sea level, and the older terraces of the valley sides rise as far as 20 m above sea level. 10 km NW of Randers the Skalså valley bends abruptly to the west past the place where the present little Skalså emerges from the highland surrounding Lake Fussing. The course continues in zigzag fashion through a connecting valley, the Gudenå valley near Langå, having used over a certain distance the present Nørreå valley. This, Ussing thought, is made probable by the fact that in these parts of the Nørreå valley there are sizeable deposits of sand whose highest terraces reach 12-16 m above sea level, and by the presence of the southernmost connection canal, the valley from the Nørreå southwards to the Gudenå valley north of Langå, a part that is now dry (fig. 2). This part of the valley might have been formed precisely by a river like the one mentioned. Ussing stated that the sand bottom in the middle of this part of the valley has a height of 6-10 m above sea level, and that there are terraces at a height of 12-22 m above sea level along the sides of the valley.

Apparently this dry valley north of Langå inspired Ussing with the idea of a Skalså stage during the withdrawal of the last ice cover, but he completely overlooked the fact that between the present Nørreå valley and the original Nørreå valley there is a threshold 15 m above sea level, and that this would have caused the formation of an ice dammed lake when both Nørreå valley and Gudenå valley to the east were barred by ice. This lake would have included the whole Nørreå valley and its continuation to the west in Vedsø and the Viborg-Hald valley in addition to the Gudenå valley as far up as to Grønbæk. The water surface of such an ice dammed lake would have been at least 15 m above sea level. There is nowhere the slightest sign of such an event having taken place.

Hartz & Østrup (1899), in their treatment of the interglacial diatomaceous earth occurrence at Hollerup, wrote that the lake where these diatoms were deposited had reached so far as out into the present Gudenå valley, which at the time either did not exist or did not go so far north. They also stated that the diatomaceous earth is only covered by glaciofluvial sand from de Geer's second ice era. Now this was written before Ussing showed the limit of the last glaciation along Karup outwash plain, but it is right that there is only sand from the meltwater covering the diatomaceous earth.

Milthers (1913) believed he could demonstrate the following series of strata in these areas:
Uppermost stoneless clay marl
Upper till
Interglacial diatomaceous earth
Stoneless clay marl
Lower till.

He also maintained that both Nørreå valley and the lower Gudenå valley are tunnel valleys which existed in the latest interglacial time. Now both his maps and the text show that he has nowhere any complete section through the whole series of strata. His upper till is only known from two localities, both lying west of Gudenå at Tange. His stoneless clay marl is almost limited to an area far to the north and west of the Gudenå, and his whole series of strata is highly dubious, for everywhere in the borings Tertiary clay and sand are overlain by glaciofluvial deposits. This is characteristic of large parts of mid-Jylland as far down as the Salten valley.

The dry valley north of Langå between the Gudenå valley and Nørreå valley (fig. 1) is 800 m wide in the northern part, and it has the same width southwards almost as far as to Helstrup. Here the valley widens like a funnel, and at the outfall into Gudenå valley it is 1200 m wide. At the nothern end the bottom is 9.5 m above sea level, and southwards it slopes down to 8 m where it opens into the Gudenå valley. The strange thing is that both to the north and to the south it stands with a steep slope 6 m above both Nørreå valley and Gudenå valley. As far as can be judged this dry valley was run through by water from north to south at a time when the bottom of the Nørreå valley was situated at least 6 m higher than today, i.e. 9.5 m above sea level. To some extent this corresponds to the terraces at Ålum and to the sand surfaces which are found partly along the sides of the Nørreå valley between Løvskal and Skern Kirke and partly in the connecting valley to the Skalså valley south-west of the threshold of this valley.

Ussing certainly maintains that there are terraces 12-22 m above sea level along the sides of the dry valley. However, visits to the area show that there are no river terraces at this level, but that the western side of the valley is specially influenced by solifluction.

There are several curious circumstances in connection with these systems of valleys. Geophysical-geological investigations (Schrøder 1974) have shown that the dry valley at Langå is found as far down as the pre-Quaternary to a depth of – 20 m, and that the same is the case at any rate with the eastern part of the Nørreå valley, whereas Gudenå valley is not indicated at all in the pre-Quaternary surface. Unfortunately these valleys are mostly outside the examined area, but the pre-Quaternary surface of the area between Langå and Hammel is furrowed by systems of valleys running southeast-northwest. One of these valleys runs under the hill between Torup and Langå at a depth of 60 m. This means that these systems of valleys are older than the last interglacial time for the occurrence of the interglacial diatomaceous earth at Hollerup lies on top of these pre-Quaternary valleys.

The Nørreå valley and the dry valley are old valleys that have been partly filled up. The Nørreå valley was so deep in the post-glacial time that it was a fjord, as marine sediments were found at almost the very western end of the valley (Mentz 1910).

Ussing's Skalså stage, therefore, is a highly dubious stage for which there is no evidence that drainage flowed this way. Indeed, there is much evidence to the contrary. The Gudenå valley is a large and wide valley cut by running water, and this also seems to have been Ussing's opinion; however, the period between the Falborg and Skalså stages is too short for such a large valley to be formed.

As all terraces stop at the bend at Tange, the lower Gudenå valley cannot have existed at the time of the Falborg stage, and the ice border cannot have been far away. The whole Nørreå valley must have been filled with ice at this time, as otherwise the water from the Falborg valley

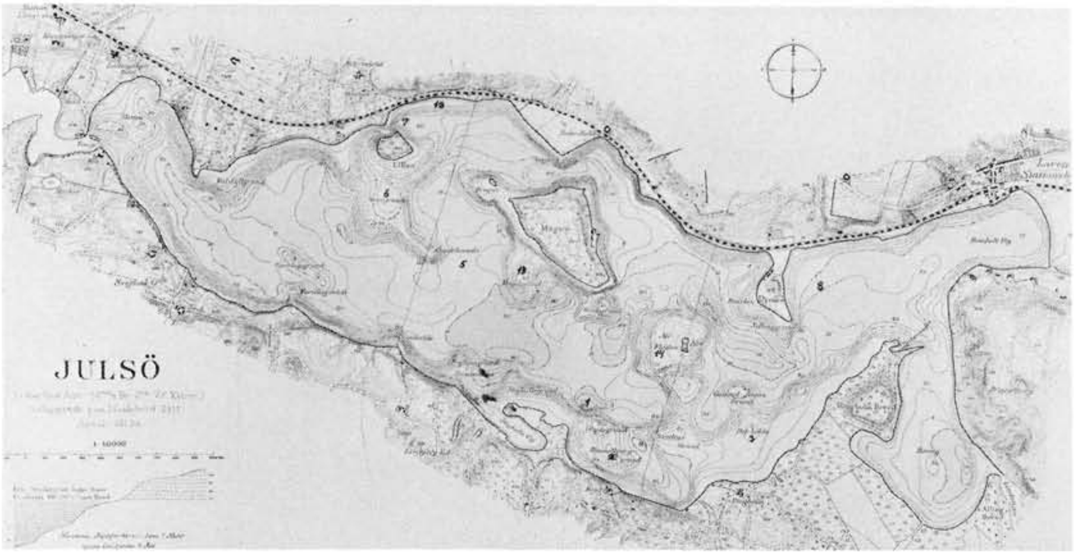

Fig. 3. Map of Julsø. The constant change between islands, shallows and deep holes indicates that buried ice remainders were essential causes of the formation of the lake. The numbers indicate bottom sample stations. Reproduced by Copenhagen University, Geographical Institute, with permission (A 454/72) of the Geodetic Institute.

would have run through it at Rindsholm, where it is united with Vedsø. However, it is impossible to say how the melting of this ice took place, and how the lower Gudenå valley was formed.

The Julsø, Borresø Torså valley

Both Ussing (1907) and Milthers (1948) considered these valleys to be the outer limits of a tunnel valley stretching from Århus through Brabrand Sø and Ravnsø to Knudsø. They considered the glacier cave to have been at Moselund, and the melting water to have shaped the so-called Moselund cone on the Karup outwash plains.

The valley area from Laven to Funder, however, is a considerably more complicated system. At Julsø the width is 1600 m, and from there the valley widens in a funnel shape to the west and northwest to 6 km between the south side of Torsø and the mouth of the Gudenå west of Silkeborg.

The valley area contains a series of lakes, Julsø, Borresø, Brassø, Almind Sø, Thorsø and Silkeborg Langsø.

Silkeborg Langsø is quite shallow with a depth of 4–5 m and a wide flat bottom. Almind Sø has a more uneven bottom relief with three deeps with water depths of 18–20 m separated by thresholds of 15 m water. Brassø forms two basins, one south of Hattenæs across the longitudinal direction of the lake, with 2 m water, and the other one from this point to the narrow passage at Sejs with 14 m water close against the south-western side of the valley. North and northwest of Hattenæs the lake forms two bays with only 2.5 m depth which continue into Almind Sø.

From Svejbæk to Sejs, Borresø forms a basin with depths from 8 to 9 m. Borresø is separated from Brassø by a threshold only 2 m deep, but it also sends a branch direct to the west with depths of about 6 m, enclosing the three "Paradise Islands"; Borre Ø, Langø, and Bredø.

While these lakes have a comparatively even bottom relief, Julsø differs from them in having in its eastern part various deep holes separated by shallows and islands, and thus it is an almost typical example of a bottom-relief caused by the melting of buried ice lumps (fig. 3). The sedi-

Fig. 4. Bottom sample from the Himmelbjerg shallow in Julsø. Quartz grains, calcareous internodes and sporangia from charaphytes and iron oolites. x 12. Halkjer photo.

ments along the coast in depths of water up to 2 m are coarse sand or gravel without any traces of iron, and beyond this limit there is a greyish brown diatomaceous gytje.

On shallow shoals in the body of the lake and around the islands, however, the quartz sands contain numerous iron oolites and internodes of Charaphytes (figs 4 & 5).

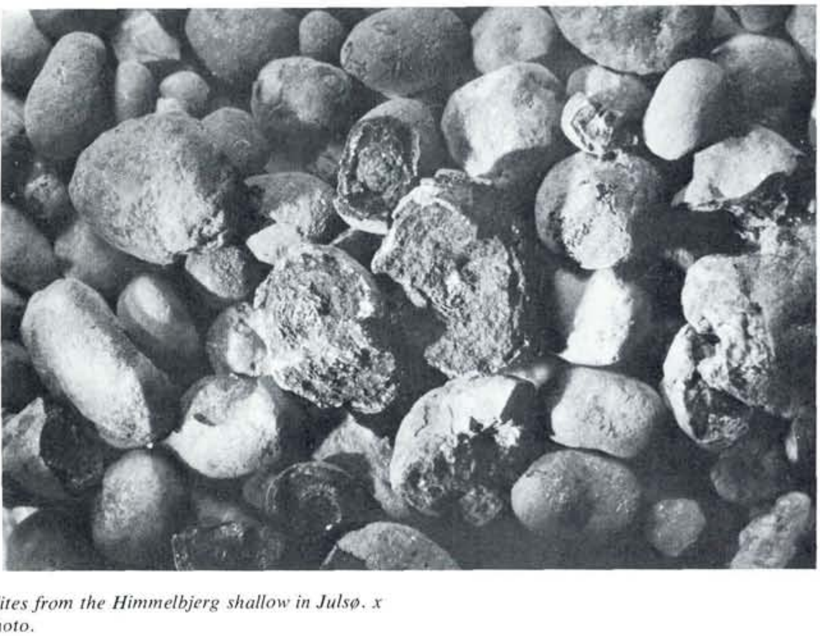

Fig. 5. Iron oolites from the Himmelbjerg shallow in Julsø. x 60. Wolthers photo.

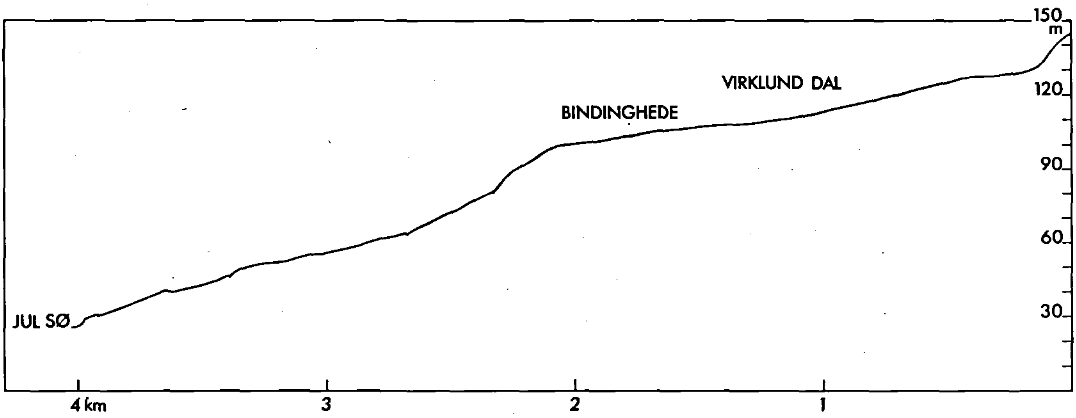

Fig. 6. Longitudinal profile through Virklund valley and Bindinghede. The profile shows how the base of erosion sank stepwise as a consequence of lowering of the ice surface owing to superficial melting.

In Almind Sø the sands and gravels are often cemented by a precipitated ochre, part of which is transported into the lake itself, while another part is precipitated on stones and vegetation along the sides and bottom of the rivulet.

Along the north side of Julsø the high slopes stretch right down to the lake, but from the western end of the lake to Silkeborg there are two terraces in front of the steep slopes.

The uppermost terrace is about 32 m above sea level and can be followed the whole way to Silkeborg. Further on it can be identified as a terrace belonging to the younger phase of the Falborg stage. The terrace forms the river level on which Silkeborg lies and the crescent-shaped plain at the north side of Silkeborg Langsø.

In front of this surface lies the lower terrace, which can be followed – although with interruptions – right into the Gudenå valley below Silkeborg, or at any rate past Sminge.

The south side of the valley has a more complicated form. The side of the valley runs from Birksø to the NW as far as to the south side of Julsø. From Himmelbjerget it bends more to the west along the north side of Limbjerg and Storeknøs, and from here it bends into Stenhule south of Rødkjær to the eastern end of Thorsø, and after that along the south side of this lake and Jenskjær to the Funder valley.

The south side of Julsø is formed by a long area of hills the highest point of which – 157 m above sea level – lies exactly north of the farm Himmelbjerggaard. To the south it is limited by a wide hollow from a hill crest running N–S in Ry Sønderskov, whose west side is furrowed by erosion grooves and which is probably an end moraine (Hansen 1975).

The hill area between Himmelbjerget and Stenhule bears various interesting features. About 400 m NW of Himmelbjerggaarden there is a small lake which forms the uppermost end of Virklund valley. A longitudinal profile through the valley (fig. 6) shows that the first 1.7 km the direction of the valley is SE–NW, and the gradient is 30 m in 2 km = 1 : 66. In front of the outfall of the valley at the farm Bindinghede there is a surface that must be understood as the cone of an outwash plain. The outer edge of the plain lies 100 m above sea level and to the north it is limited by the hill crest Storeknøs whose top is 129 m above sea level (fig. 7). The surface is cut through by Virklund valley, the gradient of which suddely increases to 1 : 20 down to a height of 65 m above sea level, after which the gradient decreases again to 1 : 40 to a height of 50 m above sea level. After a very short distance where the bottom of the valley is again a little steeper, and shortly before the outlet into Julsø it cuts through a terrace the outer edge of which is 32 m above sea level, that corresponds to the upper terrace on the north side of the valley.

It is evident that here a stepwise lowering of the base level of erosion took place as a result of the melting of the ice mass which lay in Julsø.

Fig. 7. View from Storeknøs. To the right Lilleknøs is seen as an isolated hill in the valley. Below the hills the 50 m terrace is seen stretching into the Stenhule valley. Behind it the hill areas around Slåensø. The lake in the background is Julsø.

The 50 m level corresponds to the plain in Stenhule valley to the west.

At the farm Bøgedal a deposit of freshwater marl was found stretching along the wall of the valley to a height of 90 m above sea level. In his diary for 16th June 1879 Johnstrup wrote that here an excellent stratified marl is found containing thin beds of sand deposited during the ice age, owing to an embankment in the valley – either of ice or of sand – that was later washed away. He wondered at the large chalk content, 30.75%, since everywhere the soil was free of calcium carbonate. This marl was still being exploited in 1953 and the section showed stone-free clay with centimetre thick layers of sand; by 1959 the whole occurrence of marl had been dug away.

The curves of the topographical maps clearly show that the northern side of the hill ridge that stretches from Himmelbjerget to the north-west as far as Bindinghede is cut through by long erosion valleys and small terraces showing the

Fig. 8. Gravel pit at Himmelbjerget with stratified terrace gravel.

Fig. 9. Gravel pit at the outlet from Slåensø with moraine gravel.

stepwise lowering of the base level of erosion during the melting of the ice in Julsø, and that this mostly took place from above and downwards and not as a regression of a glacier tongue.

The 50 m level is repeated as terrace plains. Such a surface stretches within Stigsballevig in between Himmlebjerget and the hills about Limbjerg. At the road exactly west of Himmelbjerget there is a terrace 60 m above sea level. A section in the terrace showed uppermost 2.5–3 m stratified gravel-bars and intercallated sand lenses (fig. 8). Under this followed 30 cm fine sand which in turn overlay 30 cm gravel.

From Svejbæk and further to the west several large hill areas are found; Kongestolen 81 m, Åsen 107 m and the hills about Slåensø form a

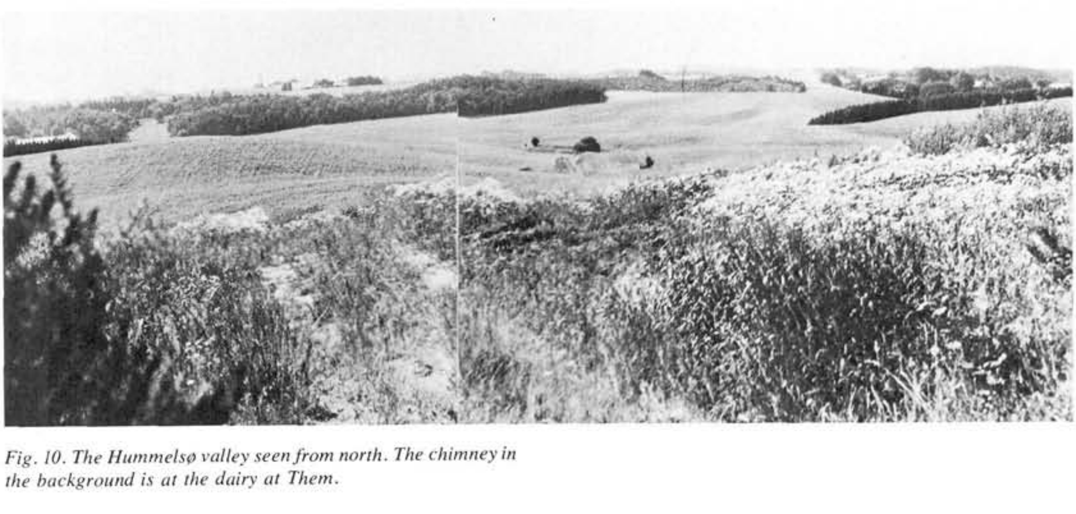

Fig. 10. The Hummelsø valley seen from north. The chimney in the background is at the dairy at Them.

Fig. 11. The western end of Borresø seen from Freshwater biological Laboratory. In the background the long ridge-like hill Oringen and the innermost Paradisøer.

barrier across the valley. At first glance these would be taken for an endmoraine area analogous with the barriers found in Salten valley (Hansen 1975). Slåensø forms a regular basin with a shallow bottom and a water depth of 10–11 m. The surface of the lake is 24.2 m above sea level, that is 3.5 m higher than Julsø. At the mouth of Slåensø there is a section of very coarse gravel (fig. 9), but at the northern side of the large hill area Lilleknøs there is a section with Tertiary sand, and at Slåensø Tertiary brown coals are exposed in the slope. This indicates that these hills are not end-moraines.

Along the southern side of the Borresø and as far as Virklund the bottom of the valley lies at the same level as the terrace along the northern side of the valley, but also here there are hill ridges reaching into the valley and the "Paradise Islands" in Borresø. Close to the western end of the valley at Virklund a valley stretches towards south-west into Hummelsø north of Them (fig. 10). Its mouth, which is now furrowed by water erosion, originally lay about 50 m above the bottom of the Borresø valley.

Hummelsø lies 77 m above sea level, and to the west of it the large dry valley starts that was mentioned in an earlier work (Hansen 1975). There must once have been a glacier tongue here.

The whole terrain between the western end of Borresø and Brassø has a very rough surface with many small lakes, Ellesø, Marksø, Avnsø and Uglesø, that can only have been produced by melting of buried ice lumps. The two elongated hills Tindberg and Oringen might be suggestive of eskers (fig. 11), but nowhere in them are there any sections giving information of their composition. Morphologically they are of a clearly glacial character, but the large hill area in Vesterskoven, west of this glacial landscape consists of Tertiary material and contains brown coal (Hartz 1909).

Here as in Saltendalen it can be maintained with certainty that the valley area in question (at Julsø, Borresø and Thorsø) is not a tunnel valley carved out by a subglacial melt water river; it is a result of a number of different glacial and periglacial processes and composed of elements from glacial periods older than the latest. Nor is there any direct connection between this valley area and the Moselund cone of the big Karup outwash plains. Between them lies a 15 km wide area characterized by a morphology resulting from a melting period in which the ice cover was gradually reduced and became thinner and thinner. There is no exact cone summit at Moselund, which lies in a depression at the upper end of the valley of Karup Å. Quite considerable quantities of melt-water ran out along the northern side of the valley from the western end of Julsø, having outlet through the upper terrace systems of the Gudenå to the Falborg valley.

The large plain on which Silkeborg lies and the crescent-shaped surface north of Silkeborg Langsø might be regarded as a delta deposit from this river. The question is now how the Langsø

Fig. 12. The Funder valley at Løgagergård. At the railway to the left the valley to Bølling Sø starts. The surface in the foreground is the westernmost part of the Bakkesø. The valley behind it consists of several elongated hills.

arose. As mentioned above, the latter is quite shallow, but still forms a basin so regular that it seems quite improbable that it arose from the melting of buried ice lumps. The Silkeborg lakes, I believe, must be regarded as part of the Funder valley. Ussing (1903) did not write much about this valley, only that the watershed between Limfjorden and Kattegat lies at Bølling Lake 70 m above sea level. From here the Karup Å valley continues southwards with terrace-shaped slopes deeply cut into the moraine landscape towards the Silkeborg lakes.

Milthers (1948) treated the question more thoroughly. He maintained that the highest point of the late glacial Karup Å valley is 82 m above sea level at Løgagergård (fig. 12) and that the valley is a feeding canal to the eastern edge of the plain at a height of 79 m.

The Funder valley may be divided into sevaral differently shaped parts. From Silkeborg to Funder railway town it is 1200 m wide and lies 20 m above sea level, but contains a large and wide hollow and the lake Ørnsø. On its northern side at Lysbro there is a flat hill whose top lies 40 m above sea level. Both in this and similar hills a little more to the south clay was formerly dug for brickmaking, but the clay is mixed with sand and contains discrete beds of sand (Hansen 1940). The remainder of this part of the valley as far as to the continuation of the southern side of the Torsø valley is filled up with various small hills and hollows. Further to the west the Funder valley forms a 400 m wide erosion valley up to Bølling Lake. The length is 3.5 km and the fall 35 m. At the foot of this valley the large dry valley ends that comes from the Hummelsø hollow east of Them. It is not possible to give any unambiguous explanation of the development history of this valley. However, the highly undulating

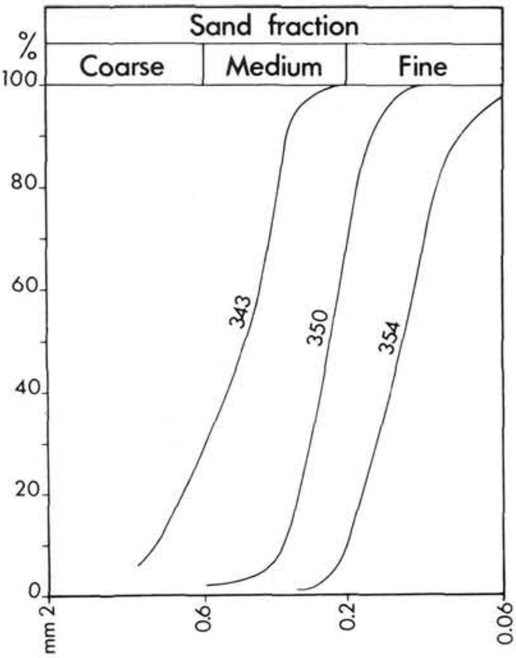

Fig. 13. Granulometric diagram of Tertiary sediments. 343 from the northern side of Lilleknøs. 350 gravel pit at the mouth of Slåensø. 354 the hill along the northern side of Thorsø.

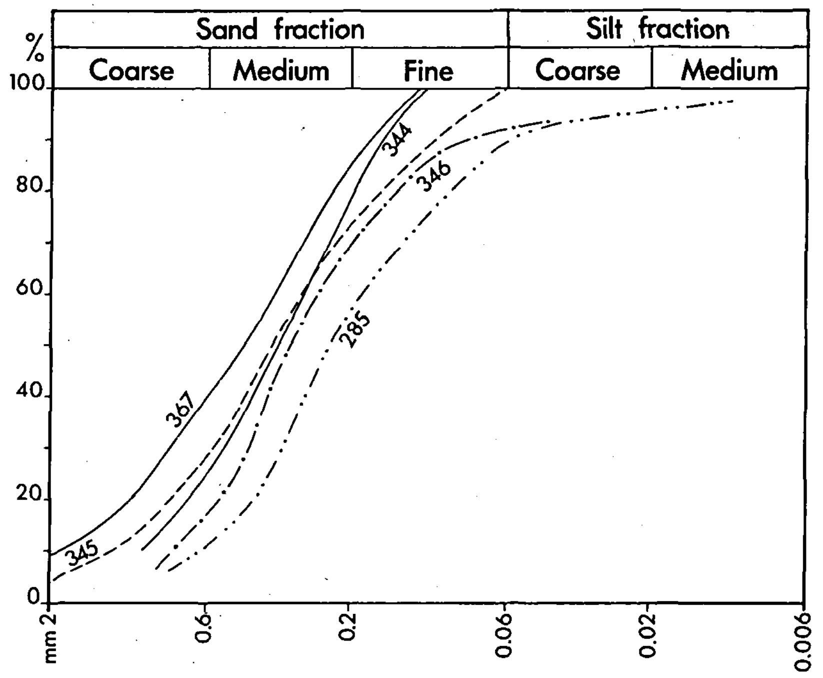

Fig. 14. Granulometric diagram of Quaternary sediments. 245 from the Gudenå terrace north of Caroline Amaliehøj. 344 glaciofluvial gravel at Himmelbjerget. 345 the terrace in front of Lillknøs, beach ridge. 346 the terrace in front of Lilleknøs. 367 the terrace at Hotel Himmelbjerget.

part seems to be a terminal moraine originating from a glacier tongue through the Thorsø valley.

The terrace at Løgagergård which Milters wrote of is no terrace but one of the small hills in this part of the valley. More of these are found just north of this one, all having an elongate form orientated E-W.

The sediments

There are only very few places in the area in question where gravel pits or natural sections are found to show what the hills consist of. But in such places only two kinds of sediments are found. Tertiary sand and glaciofluvial sand and gravel. Figs 13 & 14 show granulometric analyses of these sediments.

The three samples in fig. 13 are Tertiary sand.

Sample no.	M	Q_3	Q_1	So
343	470	660	380	1.31
350	256	280	195	1.20
354	130	170	108	1.26

Thus the Tertiary sand is well sorted with a sorting coefficient ($\sqrt{Q_3/Q_1}$) of about 1.2 – 1.3. Fig. 14 shows the Quaternary sediments.

Sample no.	M	Q_3	Q_1	So
285	230	380	110	1.85
344	340	590	210	1.90
345	310	480	170	1.68
346	340	640	185	1.85
367	420	900	250	1.90

It is evident that the sorting is inferior to that of the Tertiary sand, but also more varied, fluctuating from 1.68 to 1.90.

Conclusions

The result of these examinations must be that Ussing's and Milther's representation of the development of the Gudenå system and the melting of the ice must be considerably revised.

The last glaciations have not had much influence, especially in the Baltic phase. The ice advanced through a landscape that was already modelled with hills, valleys and plains, and several of them were too large for the ice to cause any disturbance or the ice went across them – Gunnar Larsen and his colleagues in Århus showed that as far east as at the Galten-Ølst area there are hills with Tertiary clay that the ice went past. (Larsen et al. 1972). Another area of hills is the large ridge to the south of Mossø containing the highest points of the country, Ejer Bavnehøj and Yding Skovhøj. This area is probably also older than the last glacial time, and must have towered over the ice as a nunatak, but so far, strangely enough, it has not received the attention of geologists. Ussing's Quaternary-geological works are pioneer works inspiring further studies of the shapes of landscapes. Milthers continued these works, but arrived at the conclusion that the indicator boulders and ice-border-lines became panaceas of understanding. Today the problems of Quaternary geology are being attacked from many more different sides. Most important is the Århus geologists' demonstration of foraminifera from the Skærumhede-series in the Weichselian hills. Asger Berthelsen's and his pupils' structure analyses and Johannes Krüger's till fabric analyses are all methods that show new aspects of the Quaternary, but at many places it will also be necessary to analyse the morphology of the landscape. It will be the problem of geologists of the future to coordinate these various methods of examination.

Dansk sammendrag

Gudenå-systemets udviklingshistorie.
I arbejdet gennemføres en kritisk gennemgang af den tidligere litteratur om isens afsmeltning fra hovedstilstands*linien til* isens bortsmeltning fra Jylland.

Nye undersøgelser af terrasseniveauerne i de østjyske dalsystemer viser, at Ussing (1904 og 1907) opfattelser af Falborg stadiet er korrekt, og at forklaringen på Skalså stadiet og på isafsmeltningen fra Falborg stadiet til Skalså stadiet behøver fornyede undersøgelser, idet de forklaringer, der hidtil er fremkommet herpå, ikke er holdbare.

Gudenåens søsystemer og de tilgrænsende dales dannelse behøver også nye undersøgelser, idet flere processer med forskellig styrke synes at være ansvarlig for disse erosionsformers fremkomst.

De gennemførte undersøgelser synes at vise, at den sidste isoverskridelse (Baltiske fase) ikke har påvirket områdets morfologi i synderligt omfang, idet landskabets udformning er bestemt af ældre isoverskridelser og de processer der følger med isoverskridelser og isafsmeltning, og det vises, at morfologiske studier, sammen med *stratigrafiske og strukturelle* undersøgelser, er nyttige og nødvendige, for at opklare det geologiske hændelsesforløb.

References

De Geer, G. 1896: *Om Skandinaviens geografiska utveckling efter Istiden. Stockholms Högskolas* populära Föreläsningar. 160 pp. Stockholm.

Hansen, K. 1971: De Miltherske spaltedale i Jylland. *Dansk geol. Foren., Årsskr. for 1970,* 47–53.

Hansen, K. 1971: Tunnel valleys in Denmark and northern Germany. *Bull. geol. Soc. Denmark* 20: 295–306.

Hansen, K. 1975: The Salten Valley. *Dansk geol. Foren., Årsskr. for 1974,* 5–24.

Hansen, S. 1940: Varvighed i danske og skånske senglaciale aflejringer. *Danmarks geol. Unders.* (2) 63: 478 pp.

Hartz, N. 1909: Bidrag til Danmarks tertiære og diluviale Flora. *Danmarks geol. Unders.* (2) 20: 292 pp.

Hartz, N. & Østrup, E. 1899: Danske diatome-aflejringer og deres diatomer. *Danmarks geol. Unders.* (2) 9: 81 pp.

Larsen, G., Liboriussen, J. & Villumsen, A. 1972: Kvartærgeologiske undersøgelser på kortbladet Randers. *Dansk geol. Foren., Årsskr. for 1971,* 27–40.

Mentz, A. 1910: *Nørreådalens moser og enge.* 55 pp. Viborg: Det danske Hedeselskab.

Milthers, V. 1948: Det danske istidslandskabs terrænformer og deres opståen. *Danmarks geol. Unders.* (3) 28: 233 pp.

Milthers, V. & Westh, T. C. 1913: Viborg Egnens Mergellag. *Danmarks geol. Unders.* (3) 9: 70 pp.

Schrøder, N. 1974: De geofysiske-geologiske undersøgelser af området nord for Århus. *Lab. Geofysik, Aarhus Universitet.* 101 pp.

Ussing, N. V. 1903: Om Jyllands hedesletter og teorien for deres dannelse. *Oversigt kgl. danske Vidensk. Selsk. Forhandl.* 2: 99–164.

Ussing, N. V. 1904: Danmarks geologi. 2. udg. *Danmarks geol. Unders.* (3) 2: 258–267.

Ussing, N. V. 1907: Om floddale og randmoræner i Jylland. *Oversigt kgl. danske Vidensk. Selsk. Forhandl.* 4: 161–213.