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Guidebook Tour N

Soils and Landscapes in Denmark and Southern Sweden

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Soils and Landscapes in Denmark and Southern Sweden

Guidebook - Tour N

by

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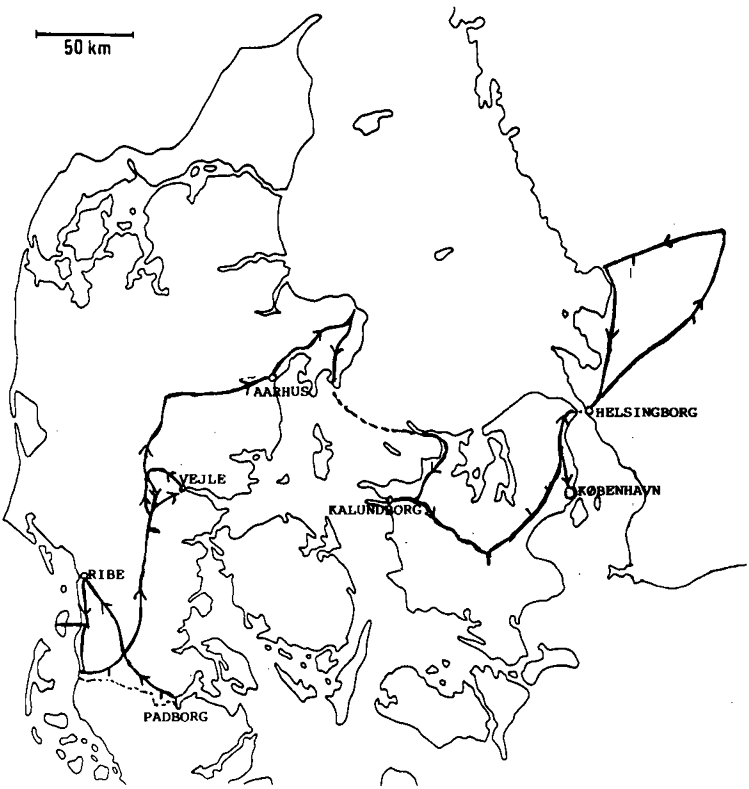


AUGUST 21-26 1986

CONTENTS

INTRODUCTION

Excursion N goes to Denmark and parts of Southern Sweden. It covers a rather small area with nearly the same climate. However, the soils of the region have developed on different parent materials and have been subject to different land use. The excursion has been planned with the aim to demonstrate how far these differences have influenced soil development.

The excursion has been planned by the following committee:

Dr. Mats Olsson and professor Tryggve Troedsson, Inst. of Forest Soil Science, Agricultural University of Sweden, Uppsala. Dr. Per Nørnberg and dr. Kristian Dalsgaard, Inst. of Geology, Århus University, Denmark. Dr. H. Breuning Madsen, Inst. of Geography, University of Copenhagen and Bureau of Land Data, Ministry of Agriculture, Vejle. Professor N. Kingo Jacobsen, Inst. of Geo-Geography, University of Copenhagen. Dr. Leif Petersen and professor Kjeld Rasmussen, Dep. of Chemistry, The Agricultural University of Denmark, Copenhagen.

Even if this committee has provided most of the soil data presented here it owes thanks to many colleages and institutions for providing material for this booklet.

ITINERARY

21/8	7.30	Departure Hamburg.
	10.30	Arrival Denmark.
	11.00-12.30	Frøslev. Placic Podzols. (1)
	13.00-14.00	Lunch. Tinglev.
	14.30-16.30	Eggebæk. Podzols. (2-3)
	17.00-18.00	Løgumbjerge. Saale Deposit.
	19.00	Arrival Ribe.
	20.00	Dinner Ribe.
		Overnight stay. Ribe.
22/8	8.00	Departure Ribe.
	10.45-12.45	Møgeltønder Kog, Podzols and Fluvisols. (4A-B)
	13.00-14.00	Lunch.
	15.00-17.30	Ny Frederikskog,
		Højer State Experimental Station, Fluvisols. (5)
	19.00	Arrival Vejle.
	20.00	Dinner Vejle.
		Overnight stay. Vejle.
23/8	8.00	Departure Vejle
	8.15- 9.15	Bureau of Land Data (ADK), Vejle.
	10.00-12.00	Gadbjerg. Acrisols. (6)
	12.30-13.30	Lunch. Gadbjerg.
	14.30-16.00	Askov State Experimental Station.
	19.00	Arrival Århus.
	20.00	Dinner Århus.
		Overnight stay. Århus.

24/8	8.00	Departure Århus.
	9.30-11.30	Kalø. Toposequence. Luvisols, Podzoluvisols, Phaeozems. (7A-C)
	12.00-13.00	Lunch. Rønde.
	14.00-15.30	Kolindsund. Gleysols. (8A-B)
	15.45-16.45	Sangstrup. Phaeozems, Rendzinas. (9A-B)
	18.00-19.30	Ferry to Sealand: Ebeltoft-Sjællands Odde. Dinner on board.
	21.00	Arrival Kalundborg. Overnight stay. Kalundborg.
25/8	8.00	Departure Kalundborg.
	9.30-12.00	Munkeskov. Podzoluvisols. (10)
	12.30-13.30	Lunch. Borup.
	14.00-16.00	Tune. Luvisols. (11)
	19.00	Arrival Helsingborg, Sweden. Dinner Helsingborg. Overnight stay. Helsingborg.
26/8	8.00	Departure Helsingborg.
	9.00-11.00	Skånes Värsjö. Podzols. (12)
	12.00-13.00	Lunch.
	14.00-16.00	Tönnersjö. Podzols. (13A-C)
	19.00	Arrival Helsingør, Denmark.
	19.00-21.00	Dinner Helsingør.
	22.00	Arrival Copenhagen. End of Excursion. Overnight stay. Copenhagen.

GEOLOGY, VEGETATION, LAND USE, CLIMATE AND SOILS

GEOLOGY

In Denmark and South-Western Sweden most soils are developed on Quaternary sediments deposited by glaciers and their melt water, mainly during the Weichsel Glaciation. The glaciers have not only carried material to the region. In many places they have also eroded deeply in the Pre-Quaternary deposits. As a result, the composition of the glacial deposits depends not only on origin of the glaciers, but also on the nature and composition of the Pre-Quaternary deposits underlying the Quaternary sediments. Fig. 1 shows the deposits occurring under the Quaternary sediments.

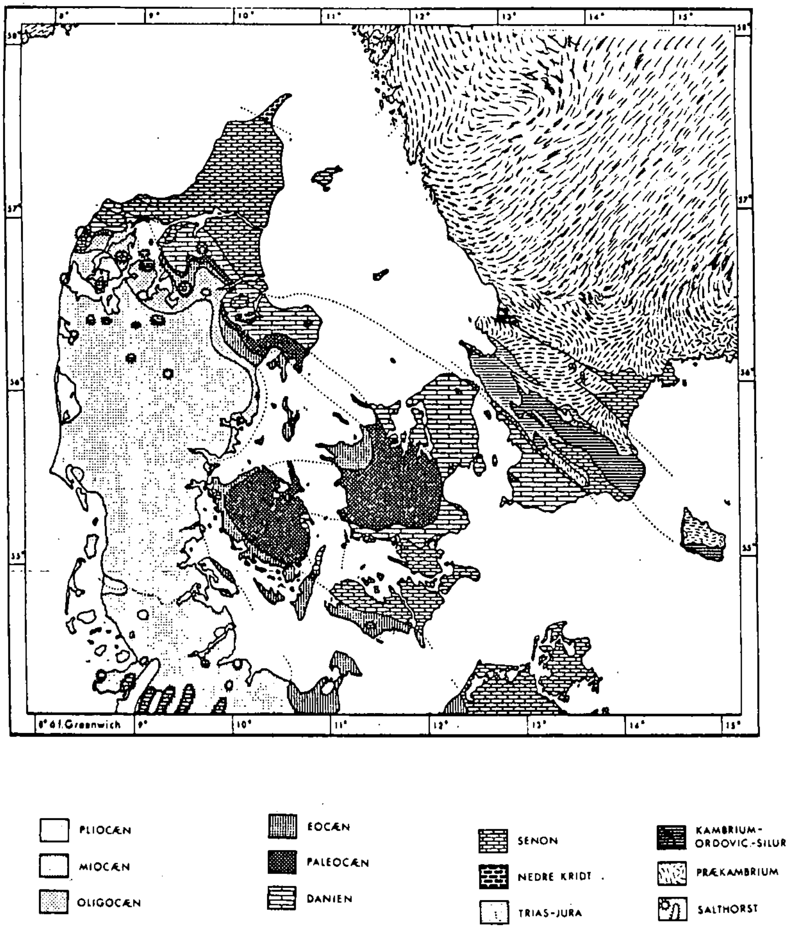
The Pre-Quaternary Deposits

The Fenno-Scandian fault zone passes through Southern Sweden in a NW-SE direction just NE of the cities Helsingborg and Ystad (Fig. 1). Since the Paleozoic era the region NE of this fault has undergone uplift and denudation. Here the rocks are often covered only by thin Quaternary deposits of local origin. SW of the fault zone the Quaternary deposits rest on sediments which generally have a thickness of several kilometers. Most of them are of marine origin, and with the exception of Devon and Carbon all geological periods since Cambrium are represented. The youngest and uppermost layers are marine sediments of Late-Cretacious and Tertiary age. Within the fault zone the Quaternary deposits rest on older marine sediments of varying composition, cf. Fig. 1.

From Fig. 1 it may be inferred that a regression of the coastline towards South-West has taken place during the last part of the Cretaceous period and through the Tertiary period in the region South and West of the fault zone. Hence, the youngest sediments are found in South-Western Jutland. In those parts of the region situated further North and East the sedimentation has stopped either earlier in the Tertiary or already in Late-Cretaceous time. As a result of the coastline regression and of different sedimentation conditions the top layers of the Pre-

Fig. 1.

Pre-Quaternary deposits of Denmark and Southern Sweden



Quaternary deposits vary considerably within the region. The Miocene top layers are generally sandy and do not contain calcium carbonate. The older Tertiary sediments are more or less clayey and may in some places contain calcium carbonate. The Danian and Senonian sediments, found in North Jutland, East Sealand and South-West Schweden, consist of limestone and chalk.

The Cretaceous and Silurian deposits occuring within the fault zone consist mainly of limestone, while the Triassic and Jurassic sediments here consist of clays, and the Cambrian deposits are dominated by sandstones and schists. The primary rocks which occur in the fault zone are generally similar to the gneisses dominating North and East of this zone.

The Danish island Bornholm is situated within the fault zone. Here the Pre-Quaternary underground consists mainly of Pre-Cambrian granites and gneisses, but along the South and West coast of the island also Cambro-Silurian and Mesozoic sediments are found.

The Quaternary Surface Deposits

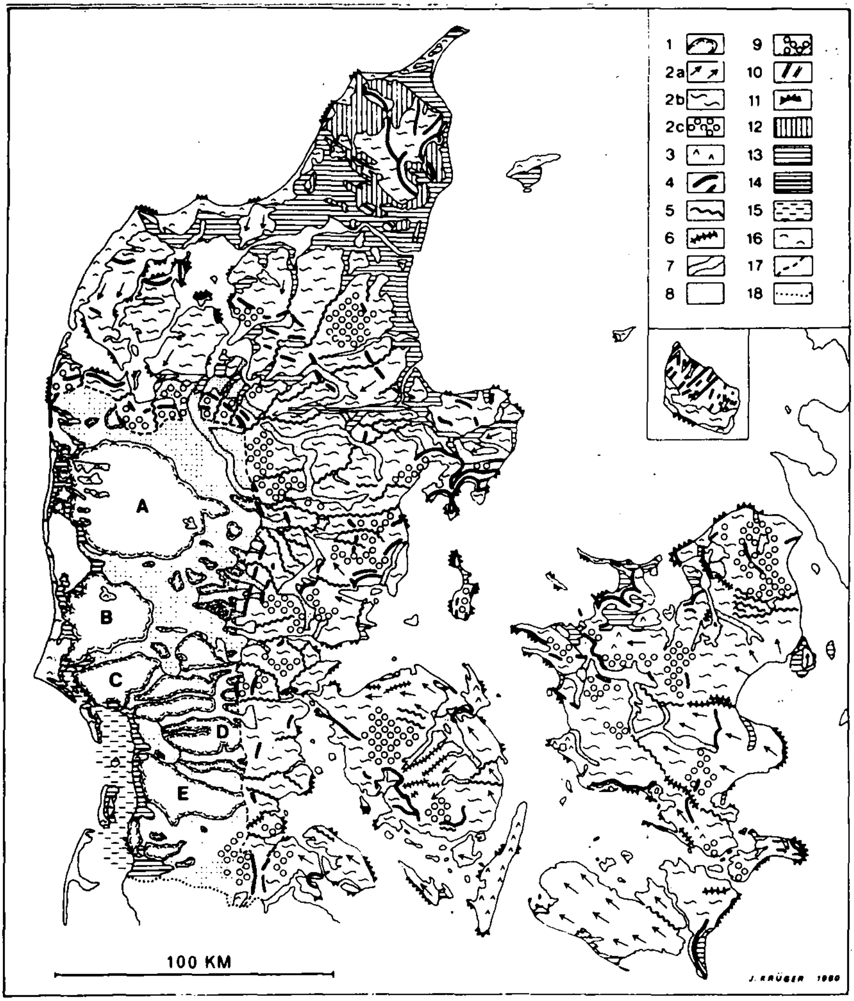
During the Saale Glaciation the glaciers covered all Scandinavia and reached South and West of Denmark, while the South-Western part of the country was not covered by glaciers during the Weichsel Glaciation. The main stationary line of the glaciers during the Weichsel Glaciation is shown in Fig. 2.

This line separates the country into two different geomorphological regions. South and West of the line the higher lying parts of the landscape consist of Saalian deposits (sandy tills and glaciofluvial sand), while the lower lying parts are covered by glaciofluvial sand of Weichselian age. East and North of the stationary line the glacial deposits are from the Weichsel Glaciation and consist mainly of till.

During the Weichsel Glaciation the Northern parts of Jutland were covered by glaciers coming from Norway. Generally the till deposited by them is rather sandy, but in some places more clayey and also calcareous deposits are found. At the same time the remaining area was covered by glaciers coming from Sweden. Some of these glaciers also deposited rather sandy tills. However, during

Fig. 2.

Geomorphological Map of Denmark



Geomorphological Map of Denmark
Legend

1. Morainic landscape from the Saalian glaciation.
2. Morainic landscape from the Weichselian glaciation:
   a. Drumlininized ground moraine, mainly till plains.
   b. Undulating ground moraine.
   c. Hummocky moraine or fields of kames.
3. Field of dislocated kames, so-called "hatshaped" hills.

4. Distinct ice-marginal hills.
5. Tunnel valley.
6. Esker.

7. Extramarginal meltwater valley or small outwash plain.
8. Extensive outwash plain.
9. Outwash plain with kettle holes.

10. Fissure-valley landscape.
11. High cliff.
12. Marine foreland of Late-glacial age (the Yoldia plateau).

13. Marine foreland built up since the Stone Age (the Litorina plains).
14. Salt marsh.
15. Tidal flat.

16. Dune landscape.
17. Main Stationary Line during the Weichselian glaciation.
18. The Danish-German border.

The capital letters on the map indicate the main morainic landscapes from the Saalian glaciation:
A. Skovbjerg, B. Varde. C. Esbjerg, D. Rødding, E. Toftlund.

Compilation based on maps by Geological Survey of Denmark, Axel Schou, Per Smed and Johannes Krüger.

the later stages of the Weichsel Glaciation glaciers advancing from South-East through the present Baltic Sea covered large parts of East Denmark and Southern Sweden. The sediments carried by these glaciers were rather clayey and, where limestone occurs within the glaciers' erosion depth, also calcareous. Hence the surface deposits in Eastern Denmark and South-Western Sweden are mainly glacial till with a fairly high clay content and often calcareous.

Also in East Denmark the Weichsel glacial deposits comprise meltwater sediments. In some places clays, deposited in iceborde-red lakes, may be found, but more often the sediments consist of coarse material as found on (small) outwash plains, in extra mar-ginal river valleys, tunnel valleys and cames. The occurrence of such sediments may be seen from Fig. 2.

Since the waning of the glaciers most of Scandinavia has been subject to a considerable isostatic uplift. At the same time the melting of the great icecaps caused an eustatic rise of the sea level. In Southern Denmark and Southern Sweden, therefore, trans-gressions have prevailed while in North Jutland and in the Northern parts of Sealand transgressions and regressions have alternated. In North Jutland and most of Sweden the isostatic uplift has dominated over the eustatic rise of sea level and still does. Here, in some places, the surface layers consist of Late Glacial marine clay or sand. In other places younger marine sedi-ments, deposited during the Atlantic transgressions, occur. In Sweden extensive areas with fresh water sediments of Late and Post Glacial age are found (cf. Fig. I).

In addition to the young marine deposits occurring in the Northern and Eastern parts of Denmark, and formed by uplift in the Post Glacial, areas with young marine and brackish water deposits are found in the tidal zone in the South-Western part of Denmark near the German border. These deposits are formed by seawater at high tide. The transgression of the sea has caused older sediments to become covered by marine deposits, and in the Eastern part of the area influenced by tidal deposits a development from fresh water to marine conditions can be seen. A characteristic layer sequence here is sandy glaciofluviol deposits covered by peat which in turn is covered by clay sediments formed in brackish water.

Younger salt marsh sediments are found further to the West and near the present coastline. Here the glaciofluvial deposits have been covered by thick layers of marine sand (wadden sand). When these sand flats build up to a level where salt-tolerant plants can thrive, fine material is held back by the vegetation. During storms also sandy material will be deposited. In this way a layered sediment, with a lighter texture than that of the above-mentioned basin clays, is formed. Fig. 11 shows a transect through the salt sea marsh in the Tønder region.

Geomorphology

The geology of the surface deposits covering Denmark and South-Western Sweden is reflected in the geomorphology. The highest point in Denmark is only 173 m above sea-level and in most places the land is flat to undulating.

Generally, the main stationary line of the Weichsel glaciers is not marked by steep ridges. More commonly it appears as a broad zone at a relatively high attitude. To the West it gradually falls off towards the sand plains formed by the melt water. These sand plains slope slightly towards the sea but the slopes are so small that they usually appear as practically level plains.

The deposits from the Saale Glaciation occur at slightly higher elevations in the landscape and frequently have the appearance of islands in the surrounding flat plains. Because of this, they are in Danish designated "Bakkeøer" which mean "Hill Islands". Their relief is subdued because they have been subject to erosion in the extensive period of time since the termination of the Saale Glaciation.

North and East of the main stationary line the landscapes are more varied. As may be seen from Fig. 2, tunnel valleys are common in East Jutland, while eskers and cames occur mainly in Sealand and Funen.

The areas covered by glacial till are in most places almost level to slightly undulating. Some of their most pronounced geormorphological features are developed during the period when the glaciers receded because the recession took place in a stepwise manner. The general recession was interrupted by temporary stops and even advances of the glacier front. Some of these are shown in Fig. 2. The advances caused the formation of distinct hilly areas, typically bordering a relatively lowlying slightly undulating plain formed as a ground moraine under the glaciers. Hills and plains formed in this way occur for example in Eastern Jutland and in the North-Western part of Sealand. In the South-Eastern part of Denmark and the South-Western part of Sweden most of the area covered by glacial till may be characterized as slightly undulating ground moraine landscapes.

The areas covered by Post Glacial marine sediments appear as flat plains. In North Jutland those of late glacial age are now situated about 20 m above sea level while those formed during the Post Glacial Atlantic transgression are at a lower attitude. Here extensive areas are covered by peat.

In the Fennoscandian fault zone the topograhpy varies in accordance with the geological history. North-East of the zone stony and hilly landscapes are common.

Vegetation and Land Use

Since agriculture in Denmark and Southern Sweden dates back thousands of years, a vegetation which can be considered original or natural is rarely found. During the Post Glacial several climatic changes have taken place and caused changes in the vegetation. At present the natural vegetation in the majority of Denmark and Southern Sweden is considered to be deciduous forest dominated by beech (Fagus sylvatica). However, since present Danish and Southern Swedish forests to a large extent are products of modern forestry, various other tree species occur, often as a monoculture, in existing forests. As an example many coniferous forests and plantations are found in Denmark, mainly on the sandy soils in the Western part of the country.

The total area of Denmark is 44000 km^2, 67% of which is used for agriculture and 11% for forestry. The main crops are small grains, beets and other forage crops. In the Eastern parts of Denmark the cultivation of arable cash crops like barley, wheat, oil seeds, and sugar beets dominate while animal husbandry is of smaller importance and dominated by pig production. On the contrary, animal husbandry, both dairy and pig production, is the foundation of the agriculture in the Western part of the country.

Climate

The climate of Denmark and Southern Sweden is characterized as cool temperate, atlantic. The location close to major sea areas usually counteracts large temperature fluctuations. As a result summers are relatively cool and winters are mild. Due to the limited geographical extension of Denmark and the absence of significant differences in altitude the yearly mean temperatures are almost identical throughout the country, cf. Fig. 3. This also applies to mean winter and summer temperatures, cf. Figs. 4 and 5.

Precipitation is largely due to front systems passing the area from West to East. The rainfall varies somewhat over the year with maximum in August (mean 60-100 mm) and minimum in March (mean 30-40 mm). In general the highest rainfall occurs in the Western part of the country, but differences in altitude cause some modifications as shown in Fig. 6. The mean precipitation of Denmark is 662 mm per year.

Fig. 3.

Mean Temperature °C
1931 - 60
YEAR

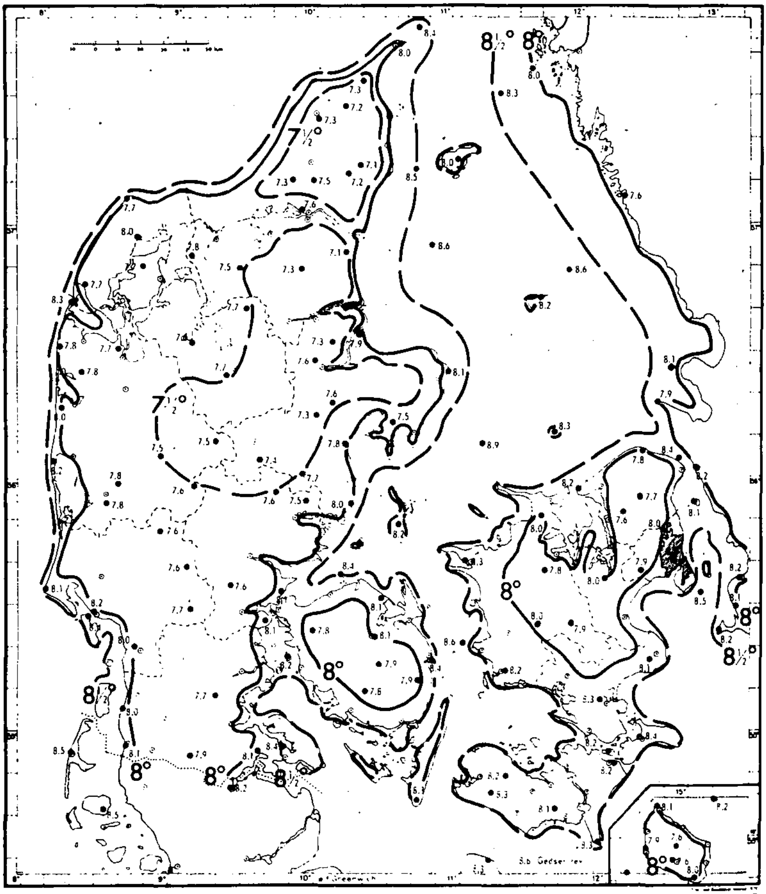


Fig. 4.

Mean Temperature °C
1931 - 60
JANUARY

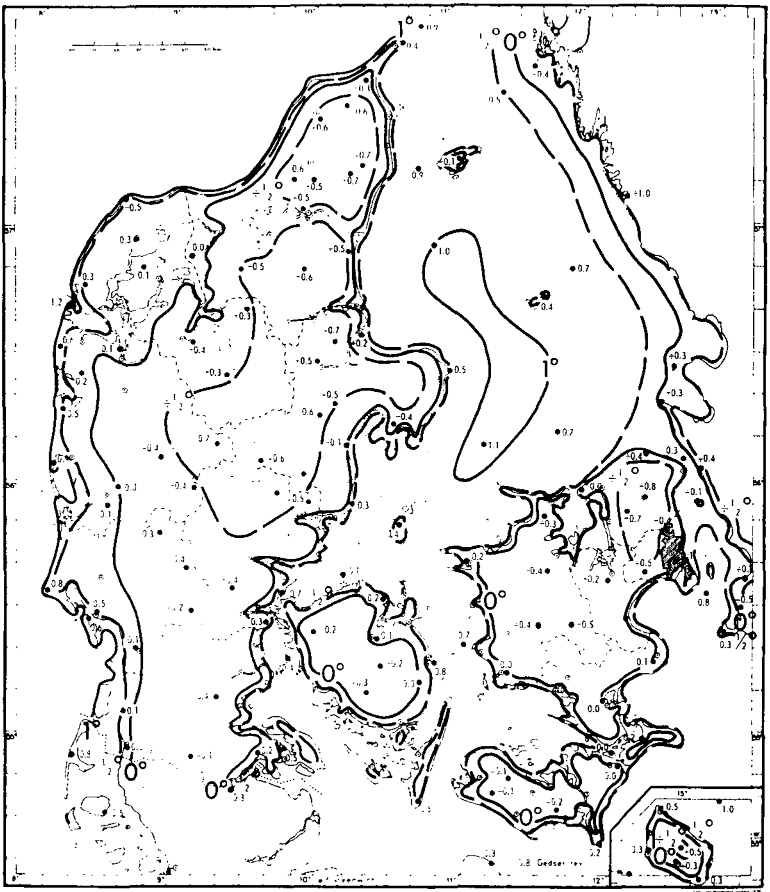
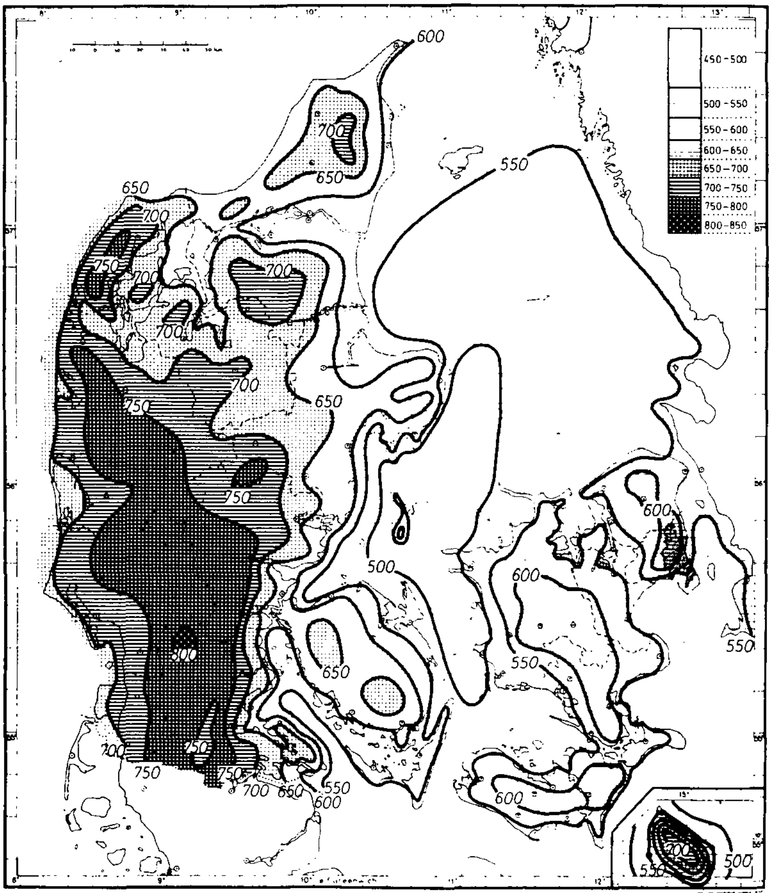


Fig. 5.

Mean Temperature °C
1931 - 60
JULY

Fig. 6.

Mean Precipitation
1931 - 60
mm per year



Soils

A soil map of Denmark is shown in Fig. 7. It must be admitted that this map is rather tentative, since a systematic pedologic mapping of Danish soils never has been carried out. Indeed, undisturbed soil profiles may be found only in few places.

However, during the years a number of typical soil profiles have been studied and selected areas have been mapped pedologically. Extensive soil profile investigations were carried out in connection with the establishment of a gas pipeline through Denmark in 1981-84 and about ten years ago the Ministry of Agriculture surveyed the texture and humus content of the surface layers of Danish agricultural soils. The results of this survey are shown on maps in scale 1:50.000 covering the entire country. The maps from the Danish Geological Survey give further information, mainly on the nature of the parent material.

Soil profile development depends on climate, time, topography, vegetation, and parent material. Some of these soil forming factors do not vary significantly between different parts of the region. For instance, Figs. 3-5 show that the different parts of the region have nearly the same temperature conditions. The whole region has a humid climate, which under natural conditions leads to leaching, acidification and clay eluviation or/and podsolization. Indeed, one or more of these processes have affected most of the soils but to a different degree in different parts of the region. In Denmark soil profile development is as a rule more pronounced in the Western parts of the country, which receive a higher precipitation.

Most of the region has a rather level topography, but there are local and regional differences in natural drainage conditions. All the soils in the region are young in the sense that soil profile development has started after the Weichsel Glaciation,that means not earlier than 10-12.000 years ago. Some of the alluvial soils are less than 1.000 years old. Of course, the Saale deposits represent formations which may be about 100.000 years old, but during the Weichsel Glaciation they have been subject to erosion and solifluction with the result that older soil profiles have been destroyed.

For all the region the natural vegetation was forest. However, in Denmark forests in their natural condition have disappeared long ago and most agricultural soils have been cultivated during centuries. Many villages date back to prehistoric time. Areas between the villages have been used for grazing. In many places this has damaged the forest vegetation and in Jutland extensive areas of sandy soils were covered with heather. Although most of these heath plains are now cultivated, the heather vegetation has influenced the pedological development.

However, the parent material is the soil forming factor which is mainly responsible for differences among the soils. The composition of the parent material depends on its geological history. Therefore, the geomorphological map of Denmark (Fig. 2) has many features in common with the soil map (Fig. 7). Hence this short description of Danish soils will be based on the geology and geomorphology of the areas in question.

In Jutland, West and South of the main stationary line, the glacial deposits are sandy. It has already been mentioned that generally they have also been more thoroughly leached than the more clayey tills which cover the Danish islands and South-Western Sweden. This is due to the higher precipitation in this part of the region and to the composition of the parent material. The melt water sand which covers the former heath plains is nearly free of clay and consists of more than 90 per cent of quartz. Potash feldspars make up most of the rest. The Saale deposits may contain some clay, but these also appear to be strongly weathered. For example, from the upper soil layers Ca- and Na-feldspars have disappeared nearly completely. In comparison the sand fraction of the soils developed on the Weichsel moraines in East Denmark contains less quartz and more feldspars, also Na- and Ca-feldspars.

Throughout the region illite seems to be the dominating clay mineral in the parent material, followed by vermiculite and smectite. These three clay minerals often occur as interstratifications. Besides, smaller amounts of chlorite and kaolinite are found. In strongly leached and weathered soil layers some illite seems to have been altered to smectite and in some soil profiles clay migration may have caused partial clay mineralogical separation.

Fig. 7.

Soils of Denmark

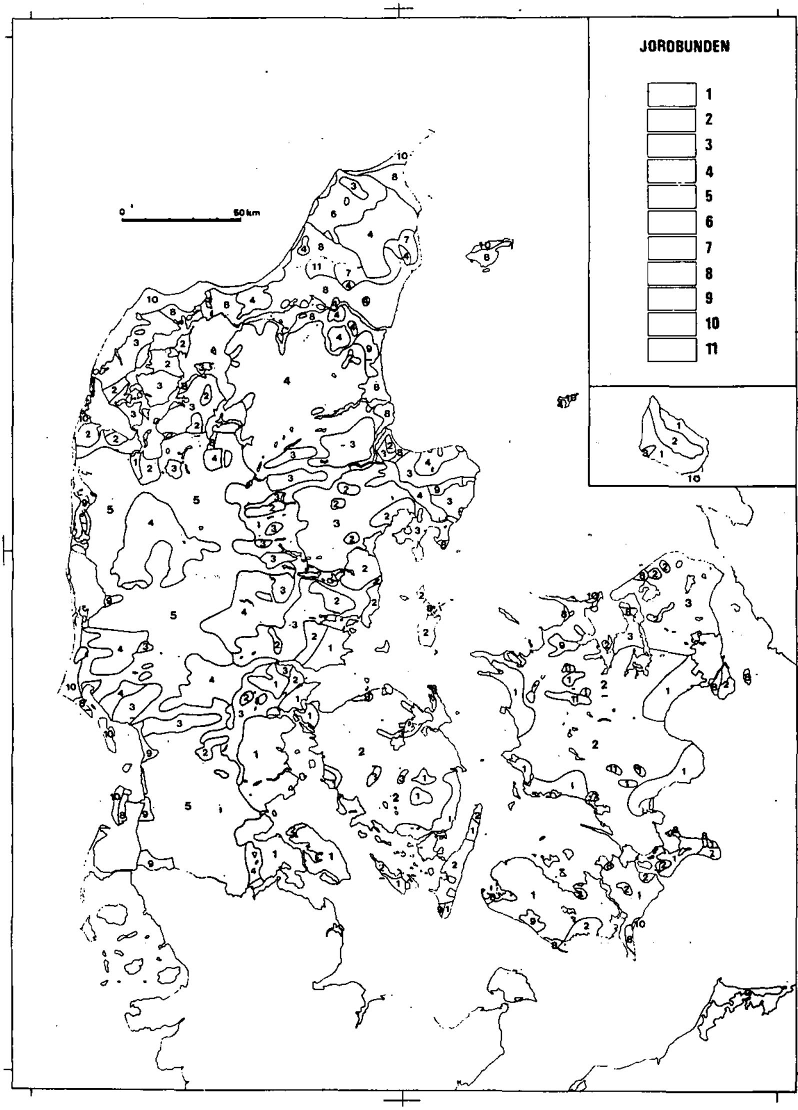


Fig. 7.

Legend

Soil Units

No.	Main Units Symbol	Main Units Name	Associations Symbol	Associations Name	Inclusions Symbol	Inclusions Name
1	Lo-2b	Orthic Luvisols	Be-2b	Eutric Cambisols	Lg Bec	Gleyic Luvisols Eutric and Chromic Cambisols
2	Be-2b	Eutric Cambisols	Lo-2b	Orthic Luvisols	Po	Orthic Podzols
3	Be-1b	Eutric Cambisols	Po-1a	Orthic Podzols	Oe	Eutric Histosols
4	Po-1a	Orthic Podzols	Ph-1a Bd-1b	Humic Podzols Dystric Cambisols	Pg Od	Gleyic Podzols Dystric Histosols
5	Ph-1a	Humic Podzols	Po-1a Od-a	Orthic Podzols Dystric Histosols	Pg Od	Gleyic Podzols Dystric Histosols
6	Be-1/2a	Eutric Cambisols	Bk-2a Gc-2a	Calcic Cambisols Calcaric Gleysols	Rd Re	Dystric Regosols Eutric Regosols
7	Po-1a	Orthic Podzols	Gh-2a	Humic Gleysols	Be Pg Ph	Eutric Cambisols Gleyic Podzols Humic Podzols
8	Gh-1a	Humic Gleysols	Je-1a	Eutric Fluvisols	Ge Od Ph	Eutric Gleysols Dystric Histosols Humic Podzols
9	Je-1/3a	Eutric Fluvisols	Jd-3a	Dystric Fluvisols	Jt Od	Thionic Fluvisols Dystric Histosols
1o	Rd-1b	Dystric Regosols	Re-1b	Eutric Regosols	Od	Dystric Histosols
11	Od-a	Dystric Histosols	Oe-a	Eutric Histosols	Gh	Humic Gleysols

Due to the sandy texture and high degree of leaching podsols are dominating South and West of the main stationary line. It seems that Orthic Podsols dominate on well drained localities, while Humic Podsols or Dystric Histosols occur where drainage is poor or where artificial drainage has been carried out. Some of the Saale deposits contain appreciable amounts of clay. Where that is the case, Dystric Cambisols or even Acrisols may be found.

Soils with rather varying textures occur along the main stationary line and on moraines in North Jutland. In a rather broad zone extending from North to South along the main line loamy sands are rather common. On the sands Podsols have developed while Dystric Cambisols and Cambic Arenosols dominate on the loamy sands. In some places Acrisols are found.

East of the main stationary line most of the soils are developed on more clayey material deposited by the Weichsel glaciers. Sandy loams, loams and sandy clay loams dominate. The sandy clay loams are most common in the areas which were covered by glaciers advancing through the present Baltic Sea (Mapping unit No. 1 in Fig. 7). Due to the glaciers' erosion in the calcareous underground the moraines in the eastern parts of the region often contained up to 20% calcium carbonate or more. In some places calcium carbonate still occurs from a depth of about 1 m. Even where the parent material did not contain calcium carbonate, the soils are less extensively leached and acidified due to the lower precipitation in East Denmark. Another reason may be that the glacial deposits to a lesser degree have been mixed with materials from the Saale Glaciation. Therefore, mapping units Nos. 1 and 2 (Fig. 7) indicate soils which have not been podsolized. In most places clay illuviation has taken place but not always to an extent where the formal requirements of a Bt-horizon are fulfilled. It should be added that sandy soils are found also in this part of the region. This is the case in North-East Sealand where podsols occur.

The soils developed on marine sediments are rather different. The Late-Glacial deposits in North Jutland consist in some places of clay loams (Mapping unit No. 6), in other places of sand (Mapping unit No. 7). On the clay loams Cambisols are found, while Podsols dominate on the sands.

The soils indicated by No. 8 are younger and more weakly developed. They are formed on Post Glacial marine sand, and often have a high content of fine sand and/or humus. In many places the ground water table is high. Podsols may occur, but most of the mineral soils are Fluvisols. Extensive parts of these sediments are covered by peat and should be classified as Dystric Histosols (Mapping unit No. 11, Fig. 7).

The marsh soils in South-West Jutland consist mainly of loams, clay loams and clays. The clays are found in the inner basins while the sediments presently formed along the coast are loams or clay loams. Especially the basin soils are influenced by a high ground water level. Most of the Danish marsh soils are classified as Eutric Fluvisols (Mapping unit No. 9, Fig. 7).

Dune sand occurs along the West coast of Jutland and the North-East coast of Sealand (No. 10, Fig. 7). Most of these dunes are young formations so that only Regosols are formed. In some parts of Jutland older inland dunes occur. On these Podsols have developed.

It has already been mentioned that Histosols (No. 11, Fig. 7) are found on marine sediments in North Jutland. They are developed on Sphagnum peat and accordingly are Dystric Histosols. Besides these, Histosols have developed on Eutrophic peat, especially in the Eastern parts of Denmark. Some of these should be classified as Eutric Histosols.

EXCURSION ROUTE AND PROFILE DESCRIPTIONS

DAY 1

The excursion will start at Kruså on the border between Denmark and The Federal Republic of Germany. Kruså is situated near the line of the maximum extension the Weichsel glaciers. From Kruså the route will proceed towards West through landscapes formed on glacial outwash plains from the Weichsel glaciation and deposits from the Saale glaciation.

Fig. 8.

Day 1. Route Kruså - Ribe

The first stop will be at a gravel pit in Frøslev Plantage where profile No. 1 will be studied. This profile is mainly developed in aeolian sand. Several soil forming processes have contributed to the profile which is classified as a Placic Podzol.

Following the visit to Frøslev Plantage there will be a lunch stop at Tinglev.

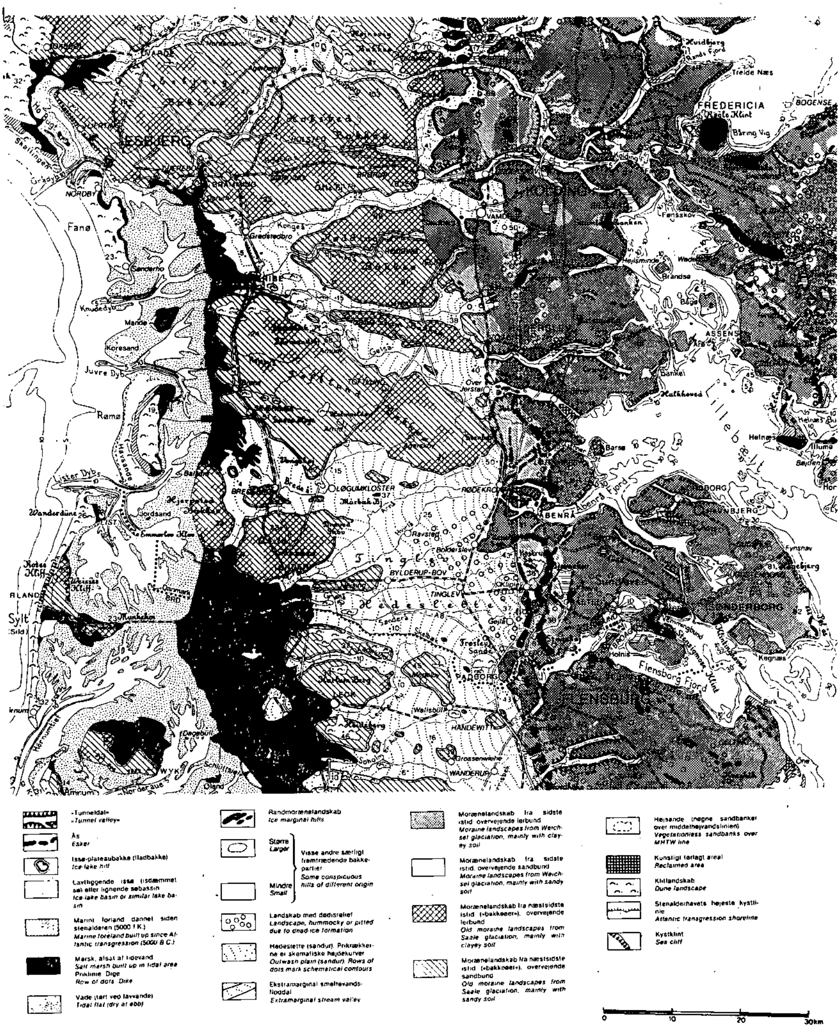
The main theme of the afternoon is the study of profiles Nos. 2 and 3 at Eggebæk about 6 km SW of Tinglev. These soils are Podsols on glaciofluvial sand. They are at a low altitude and have a rather high groundwater level. They are presently cultivated.

From Eggebæk the bus travels NW through glaciofluvial heath plains. At Løgumkloster, about 30 km from Eggebæk, the landscape changes into an undulating plain on deposits from the Saale glaciation. A short stop will be made at a gravel pit at Løgumbjerge where the Saalian sediments will be demonstrated.

After this stop the bus continues further about 30 km to Ribe where there will be overnight stay. Ribe is one of the oldest towns in Denmark. It is first mentioned about year 850. The most remarkable and well-known building is the Cathedral which is located near the town center. Several archaeological findings have been made on the town site. The site of an old castle, Riberhus, is found in the North-Western part of the town.

Fig. 9.

Geomorphology of Southern Jutland



Profile No. 1

UTM: 32U NF 198771
Elevation: 39 m a.s.l.
Temperature: January o,1 °C, July 16,4 °C, Year 7,9 °C
Precipitation: 750 mm per year
Parent material: A complicated sequence of aeolian sand overlying recent fresh water deposits (peat), another layer of aeolian sand and glaciofluvial sand.
Vegetation: Herbs, mainly grasses. Formerly covered by coniferous forest
Classification: USDA: Typic Placohumod
FAO-Unesco: Placic Podzol

Description:

O -8-0 cm Litter

Ah 0-14 cm Very dark greyish brown (10 YR 3/2) moist, sand; very weak very fine subangular blocky; very friable; frequent fine, medium and coarse roots; abrupt wavy boundary.

Bsw1 14-24 cm Dark yellowish brown (10 YR 4/4) moist, sand; very weak very fine subangular blocky; very friable; frequent fine roots; abrupt smooth boundary.

Bsw2 24-41 cm Dark yellowish brown (10 YR 4/4) moist, sand; few brown to dark brown (10 YR 4/3) moist, fine faint clear mottles; very weak very fine subangular blocky; very friable; common fine roots; abrupt wavy boundary.

Bsw3 41-47 cm Dark yellowish brown (10 YR 4/4) moist, sand; very weak very fine subangular blocky; very friable; few fine roots; abrupt wavy boundary.

2Hab	47-68 cm	Black (10 YR 2/1) moist, sapric material; weak fine platy; very friable; frequent fine, medium and coarse roots, clear wavy boundary.
3Ahb	68-78 cm	Black (2.5 Y 2/0) moist, sand; weak very fine subangular blocky; very friable; few fine and medium roots; gradual wavy boundary.
3Eb	78-89 cm	Very dark grey (5 YR 3/1) moist, sand; very weak very fine subangular blocky; very friable; few fine and medium roots; abrupt smooth boundary.
3Bhb1	89-97 cm	Very dark brown (10 YR 2/2) moist, sand; weak very fine subangular blocky; friable; few fine roots; clear wavy boundary.
3Bhb2	97-105 cm	Black (10 YR 2/1) moist, sand; weak very fine subangular blocky; friable; common fine roots; abrupt wavy boundary.
3Bhsmb	105-106 cm	Placic horizon; sand
3Bsgb1	106-128 cm	Yellowish red (5 YR 4/6) moist, sand; few coarse distinct clear yellowish brown (10 YR 5/6) moist, mottles; weak very fine subangular blocky; friable; gradual wavy boundary.
3Bsgb2	128-159 cm	Yellowish brown (10 YR 5/6) moist, sand; few coarse distinct clear pale yellow (2.5 Y 7/4) moist, mottles; weak very fine subangular blocky; friable; abrupt wavy boundary.

3Bsmb	159-160	cm	Placic horizon; sand
3Bsb	160-202	cm	Olive (5 Y 5/3) moist, sand; very weak very fine subangular blocky; very friable; gradual irregular boundary
3Bsmb	202-203	cm	Placic horizon; sand
4Cgb	203-	cm	Light olive brown (2.5 Y 5/6) moist, gravelly coarse sand; common medium distinct diffuse olive yellow (2.5 Y 6/8) moist, and pale olive (5 Y 6/4) moist, mottles; very weak very fine subangular blocky; very friable.

Analytical data
Profile No. 1

Horizon	Depth cm	Texture, % of humus and calcium carbonate free fine earth: Sand Coarse	Sand Medium	Sand Fine	Sand Total	Silt Coarse	Silt Medium	Silt Fine	Silt Total	Clay	Org. Carbon %	Nitrogen mg/g	C/N
Ah	0- 14	2.3	46.9	37.6	86.8	6.6	1.8	1.1	9.5	3.7	1.90	1.02	18.5
Bsw1	14- 24	3.3	72.2	21.3	96.8	0.2	0.7	0.7	1.6	1.6	0.51	0.25	20.4
Bsw2	24- 41	7.4	72.9	16.7	97.0	1.0	0.5	0.5	2.0	1.0	0.22	-	-
Bsw3	41- 47	3.7	77.0	16.5	97.2	0.3	0.7	0.7	1.7	1.1	0.36	-	-
2Hab	47- 68	-	-	-	-	-	-	-	-	-	53.29	11.07	48.1
3Ahb	68- 78	3.9	52.4	30.5	86.8	10.6	1.0	0.9	12.5	0.7	4.98	2.39	20.8
3Eb	78- 89	5.8	53.1	35.5	94.4	2.0	1.2	1.2	4.4	1.2	0.25	0.28	9.0
3Bhb1	89- 97	-	-	-	-	-	-	-	-	-	-	-	-
3Bhb2	97-105	7.8	50.6	32.1	90.5	2.5	1.2	1.2	4.9	4.6	2.60	0.99	26.3
3Bhsmb	105-106	6.6	50.5	31.4	88.5	4.2	1.9	1.7	7.8	3.7	2.87	1.09	26.3
3Bsgb1	106-128	3.0	54.0	39.0	96.0	0.5	0.7	0.7	1.9	2.1	0.41	0.19	21.6
3Bsgb2	128-159	3.7	50.0	43.1	96.8	0.6	0.5	0.5	1.6	1.6	0.20	0.08	24.9
3Bsmb	159-160	4.7	44.4	41.3	90.4	6.1	0.8	0.6	7.5	2.1	0.58	-	-
3Bsb	160-201	2.9	55.7	32.9	91.5	6.0	0.5	0.4	6.9	1.6	0.16	-	-
3Bsmb	201-202	-	-	-	-	-	-	-	-	-	-	-	-
4Cgb	202-	42.8	37.3	7.7	87.8	4.2	1.9	1.0	7.1	5.1	0.18	-	-

Horizon	Depth cm	pH H_2O	pH $CaCl_2$	Phosphorus mg/kg	Fe, mg/g Dithion.	Fe, mg/g Pyrophos.	Al, mg/g Dithion.	Al, mg/g Pyrophos.
Ah	0- 14	3.8	3.3	76	1.13	1.03	0.78	0.70
Bsw1	14- 24	4.5	4.1	22	0.34	0.27	0.72	0.76
Bsw2	24- 41	4.7	4.3	-	0.23	0.15	0.56	0.58
Bsw3	41- 47	4.5	4.1	-	-	-	-	-
2Hab	47- 68	3.8	3.1	145	4.18	3.78	4.00	3.20
3Ahb	68- 78	4.3	3.2	30	0.57	0.50	1.10	0.96
3Eb	78- 89	4.6	3.6	13	0.08	0.06	0.30	0.26
3Bhb1	89- 97	-	-	-	-	-	-	-
3Bhb2	97-105	4.5	3.8	-	0.08	0.07	3.24	2.56
3Bhsmb	105-106	4.4	3.9	49	16.08	9.35	3.52	3.00
3Bsgb1	106-128	4.8	4.5	14	0.82	0.56	1.80	1.60
3Bsgb2	128-159	4.8	4.7	-	-	-	-	-
3Bsmb	159-160	4.6	4.4	-	39.26	4.48	2.60	1.22
3Bsb	160-201	4.8	4.6	-	0.09	0.07	0.68	0.82
3Bsmb	201-202	-	-	-	-	-	-	-
4Cgb	202-	5.0	4.4	-	2.82	0.86	1.40	1.28

Interpretation:

As evidenced from the description the profile represents several stages of soil formation. The initial soil development that can be observed has taken place in a layer of aeolian sand extending from 68 cm to 203 cm below the present mineral soil surface. Below a depth of 203 cm the material is characterized as glaciofluvial sand without any visible soil development. In the aeolian sand a humic podzol with two well developped placic horizons has formed. Due to the placic horizons being practically impervious water has been ponded in the soil layers above and on the surface. This has caused the accumulation of a peat layer, which at present is about 20 cm thick, despite the fact that it is situated at a rather high attitude compared with the surroundings.

Due to the wetness, later sand drift has caused accumulation of a new sand layer on top of the peat. In this layer a new soil profile is being developed. The profile is developing towards a podzol, but at the present stage the development is too weak to qualify for this classification.

Profile No. 2

UTM:	32U NF 136839
Elevation:	20 m a.s.l.
Temperature:	January -0.1 °C. July 16.4 °C. Year 7.9 °C.
Precipitation:	750 mm per year
Parent material:	Glaciofluvial sand from the Weichsel Glaciation
Vegetation:	Field crops
Classification:	USDA: Typic Haplorthod FAO-Unesco: Orthic Podzol

Description:

Ap	0-25 cm	Very dark grey (10 YR 3/1) moist, sand; weak medium granular, loose to very friable; many very fine and fine, few medium random discontinuous pores; many very fine and few medium roots; abrupt smooth boundary.

35-45 cm	Very dark greyish brown (10 YR 3/2) moist, sand; single grain; loose to very friable; few, weak oxyhydroxide-organo cutans between sand grains; few very fine and fine random discontinuous pores; few very fine roots; gradual wavy boundary.
45-63 cm	Dark reddish brown (5 YR 3/3) moist, sand; very weak medium subangular blocky; loose to very friable; common very fine random discontinuous pores; common very fine roots; gradual wavy boundary.
63-95 cm	Strong brown (7.5 YR 5/6) moist, sand; many distinct, medium to coarse, red (2.5 YR 4/6) moist, mottles; very weak medium subangular blocky; loose to very friable; many very fine random discontinuous pores; few very fine roots; gradual wavy boundary.
95-140+cm	Yellowish brown (10 YR 5/4) moist, sand; common distinct reddish brown mottles, which grade into moderate hard nodules; loose to very friable; many very fine and fine random discontinuous pores; no roots.

Analytical data
Profile No. 2

Horizon	Depth cm	Texture, % of humus and calcium carbonate free fine earth									Org. Carbon %	Nitrogen mg/g	C/N
		Sand				Silt				Clay			
		Coarse	Medium	Fine	Total	Coarse	Medium	Fine	Total				
Ap	0-25	7.3	71.6	15.8	94.7	0.2	0.9	1.0	2.1	3.2	0.98	0.62	15.8
E	25-35	7.6	67.3	18.8	93.7	0.2	1.2	1.2	2.6	3.7	0.80	0.55	14.5
Bh	35-45	5.4	71.9	15.7	93.0	0.4	1.0	1.0	2.4	4.6	1.00	0.54	18.5
Bs	45-63	6.2	72.8	15.1	94.1	0.3	0.5	0.6	1.4	4.5	0.57	0.43	13.3
Bsg	63-95	12.7	68.2	14.5	95.4	0.6	0.4	0.5	1.5	3.1	0.22	0.14	15.7
C	95-	3.9	56.8	34.8	95.5	0.5	0.4	0.5	1.4	3.1	0.15	0.10	15.0

Horizon	Depth cm	pH		Exchangeable cations, meq./kg					CEC pH 8.1 meq./kg	Base-sat. %	$CaCO_3$ %	Phosphorus mg/kg
		H_2O	$CaCl_2$	Ca	K	Mg	Na	H				
Ap	0-25	5.3	4.2	9.0	0.6	0.4	0.1	43	53	19		132
E	25-35	5.3	4.3	10.5	0.6	0.4	0.1	47	59	20		141
Bh	35-45	5.6	4.8	24.2	0.6	0.7	0.1	78	104	25		172
Bs	45-63	5.7	4.9	11.0	0.5	0.5	0.2	91	103	12		114
Bsg	63-95	5.9	4.9	3.0	0.4	0.1	<0.1	41	45	8		32
C	95-	5.8	4.9	2.5	0.5	0.1	0.1	31	34	9		24

Horizon	Depth cm	Bulk Density g/cm^3	Pore volume %	Water content (%) at pF				Fe, mg/g		Al, mg/g	
				0.6	1.8	2.5	4.2	Dithion.	Pyrophos.	Dithion.	Pyrophos.
Ap	0-25							1.34	0.81	0.56	0.44
E	25-35							1.69	1.15	0.68	0.52
Bh	35-45							4.52	3.69	1.70	1.40
Bs	45-63							3.48	2.32	3.50	3.20
Bsg	63-95							1.81	0.91	1.90	1.54
C	95-							0.93	0.42	1.50	1.30

Interpretation:

The profile is a fairly well developed podzol. The parent material is characterized as glaciofluvial sand but it may have been affected by sand drift. The ground water level is rather high. When the description was made (January 16, 1986) the ground water level was 110 cm below the surface but it has probably been lowered recently due to cleaning and deepening of streams and ditches.

However, except for the red and reddish brown mottles occuring below a depth of 63 cm the profile is not strongly influenced by ground water.

Profile No. 3

UTM:	32U NF 141831
Elevation:	22 m
Temperature:	January -0.1 °C. July 16.4 °C. Year 7.9 °C.
Precipitation:	750 mm per year
Parent material:	Glaciofluvial sand from the Weichsel Glaciation
Vegetation:	Field crops
Classification:	USDA: Typic Haplorthod FAO-Unesco: Orthic Podzol

Description:

Ap	0-35 cm	Very dark grey (10 YR 3/1) moist, sand; very weak medium granular, loose; many fine and few medium pores; few fine roots; abrupt smooth boundary.
E	35-50 cm	Light brownish grey (10 YR 5/2) moist, to dark greyish brown (10 YR 4/2) moist sand; single grain to very weak medium granular; loose; many fine and few medium pores; very few fine roots; clear wavy boundary.

Bhm	50-65 cm	Dark brown (7.5 YR 3/2) moist, to dark reddish brown (5 YR 2.5/2) moist, sand; compact; strongly cemented by sesquioxides and/or humus; breaks into a platy structure; few fine pores; no roots; clear wavy boundary.
Bsm	65-74 cm	Reddish brown (5 YR 4/4) moist, sand with a few 1 cm thick dark brown (7.5 YR 3/4) moist wavy bands; compact; strongly cemented mainly by sesquioxides, breaks into angular blocky; few fine pores; fine roots; gradual smooth boundary.
Bsm	74-120 cm	Yellowish brown (10 YR 5/6) moist, sand; compact; cemented by sesquioxides; breaks into platy to angular blocky; few small dark brown manganese oxide nodules; few fine pores; no roots; gradual smooth boundary.
C	120- cm	Brownish yellow (10 YR 6/6) moist, sand; very weak coarse subangular to angular blocky; loose; many fine pores; no roots.

Analytical data
Profile No. 3

Analytical data. Profile No. 3

Horizon	Depth cm	Texture, % of humus and calcium carbonate free fine earth: Sand Coarse	Sand Medium	Sand Fine	Sand Total	Silt Coarse	Silt Medium	Silt Fine	Silt Total	Clay	Org. Carbon %	Nitrogen mg/g	C/N
Ap	0- 35	6.3	60.2	27.5	94.0	0.4	1.2	1.3	2.9	3.1	0.81	0.59	13.7
E	35- 50	6.1	57.1	30.6	93.8	1.7	0.7	0.7	3.1	3.1	0.22	0.15	14.7
Bhm	50- 65	4.9	66.4	22.7	94.0	0.4	0.7	0.7	1.8	4.2	1.15	0.43	26.7
Bsm1	65- 74	3.2	52.5	37.0	92.7	3.3	0.5	0.4	4.2	3.1	0.41	0.17	24.1
Bsm2	74-120	2.6	54.9	30.4	87.9	6.1	0.9	0.5	7.5	4.6	0.26	0.12	21.7
C	120-	0.8	56.3	36.0	93.1	2.4	0.5	0.5	3.4	3.5	0.17	0.09	18.9

Horizon	Depth cm	pH H_2O	pH $CaCl_2$	Exchangeable cations, meq./kg Ca	K	Mg	Na	H	CEC pH 8.1 meq./kg	Base-sat. %	$CaCO_3$ %	Phosphorus mg/kg
Ap	0- 35	6.6	5.8	23.7	0.4	3.6	0.1	18	46	60		75
E	35- 50	6.8	5.8	8.7	0.1	1.7	0.1	<1	11	-		24
Bhm	50- 65	6.4	5.3	33.4	0.9	4.0	0.2	123	162	24		56
Bsm1	65- 74	6.4	5.3	10.0	0.7	1.1	<0.1	50	62	19		24
Bsm2	74-120	6.3	5.2	5.5	0.8	0.4	<0.1	45	52	13		15
C	120-	6.3	5.1	3.7	0.7	0.2	<0.1	33	38	12		11

Horizon	Depth cm	Bulk Density g/cm^3	Pore volume %	Water content (%) at pF 0.6	1.8	2.5	4.2	Fe, mg/g Dithion.	Fe, mg/g Pyrophos.	Al, mg/g Dithion.	Al, mg/g Pyrophos.
Ap	0- 35							0.91	0.44	0.36	0.34
E	35- 50							0.26	0.18	0.22	0.26
Bhm	50- 65							2.53	2.14	3.40	2.40
Bsm1	65- 74							0.94	0.73	1.82	1.42
Bsm2	74-120							0.82	0.47	1.92	1.20
C	120-							0.56	0.40	1.46	1.04

Interpretation:

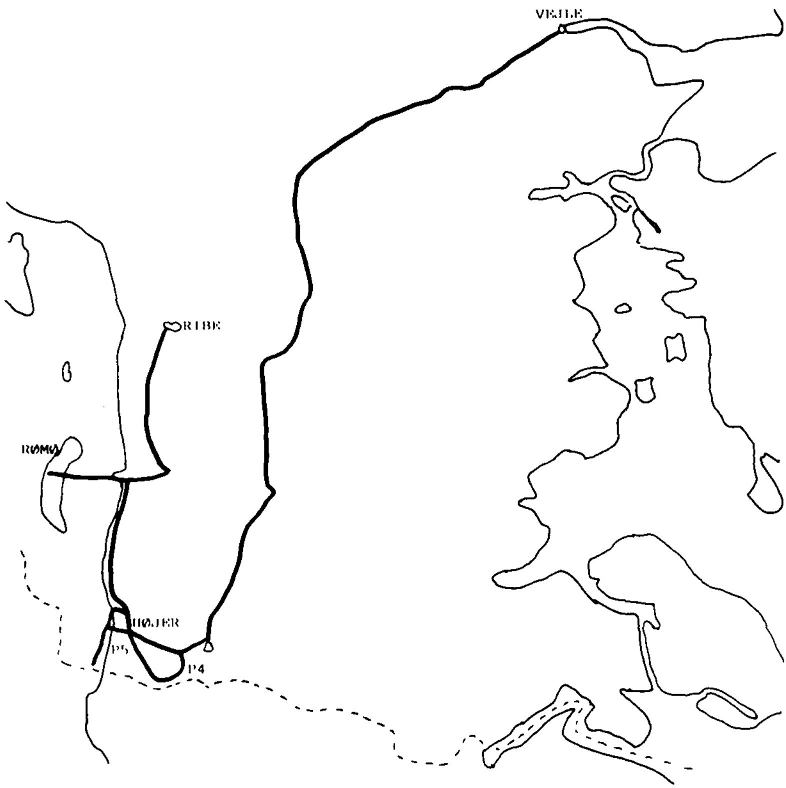
The profile is developed under conditions and on a parent material similar to those of profile No. 2. The podzol development is slightly more pronounced and despite a low altitude and neighbouring areas with peat and bog iron ore, the influence of ground water is slight. However, the compactness of the B horizon is probably due to a periodic high ground water level, perhaps in seasons with low biological activity. Profiles nearby have been found to have a placic horizon.

DAY 2

The excursion proceeds from Ribe towards South to the salt marshes at Tønder.

As mentioned previously the occurrence of coastal deposition is largely limited to the Southern part of the West coast of Jutland, where the tide amplitude is sufficiently large to cause significant sedimentation. The deposition has taken place during a continued rise of the sea level which has caused flooding of glaciofluvial plains situated at low altitude.

Fig. 10.
Day 2. Route Ribe - Rømø - Tønder - Vejle



In the Eastern part of the marsh area this development can be observed in profiles 4A and 4B where glaciofluvial sand is found at shallow depth and covered by peat and marine clay.

In the Western part of the marsh area the sedimentation has taken place along a coast more exposed to the sea. Here, the original glaciofluvial deposits are covered by thick layers of marine sand. The sand layers are in turn covered by marine clay whose deposition is promoted by vegetation. The clay is to a certain and varying extent mixed with sand, see Fig. 11. Profile No. 5 represents an example of this layer sequence.

The two kinds of salt marsh are found in several places along the Southern part of the West coast of Jutland. It is expressed most clearly in the marsh area at Tønder which is situated near the German border and in fact extends across the border. Here, where the river Vidå empties into the North Sea, the Danish marsh area has it largest extension in the East-West direction.

Ribe is situated at the mouth of a stream and marine sediments extends from the sea until the town. The first part of the route towards South passes a landscape on Saale glacial deposits separated from the sea by a rim of marine sediments.

From Skærbæk, approx. 20 km South of Ribe, a trip is made along the dam connecting the island of Rømø with the mainland. Along the dam a rapid deposition of marine sediments, promoted artificially, takes place. Along the East coast of Rømø deposition also takes place while the central part of the island and its West coast are covered with sand dunes.

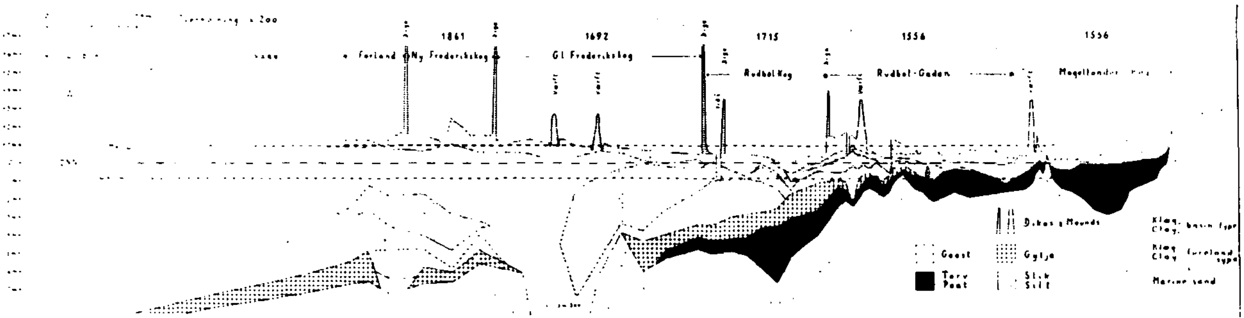
The trip continues until the West coast of Rømø from where it is reversed to the coast of Jutland and continues towards South across the marsh area at Ballum and the Saale landscape at Hjerpsted to the marsh area at Tønder. Here profiles 4A and 4B, which are located South of Tønder town, will be studied.

In the neighbourhood stands the baroque castle Schackenborg which was built partly during the seventeenth century.

After lunch the State Experimental Station at Højer will be visited. The research carried out here includes soil physics and problems connected with artificial soil drainage, especially pertaining to soils of marsh areas. Profile No. 5, which represents young marine sediments deposited in an environment exposed to the

Fig. 11.

Cross section of sediments in the Tønder salt marsh area



sea, is located within the premises of the Experimental Station.

Following the visit to the Experimental Station, the excursion proceeds across the newly reclaimed Margrethe Polder to its dike which was completed in 1982. The river Vidå empties into the North Sea through a sluise gate in the dike. A short stop will be made at the sluise gate.

From the marsh area the excursion proceeds directly to Vejle for overnight stay. In South-Western Jutland the route passes glaciofluvial plains, Saale landscapes and stream valleys. About 20 km SW of Vejle the line of the maximum extention of the Weichsel glasiers is passed near a tunnel valley extending from SE towards NW. From here the trip continues across an undulating Weichselian moraine landscape to Vejle which is located in another tunnel valley with an East-West direction.

Profile No. 4A

UTM:	32U MF 854864
Elevation:	1 m a.s.l.
Temperature:	January 0.0 °C. July 16.4 °C. Year 8.1 °C.
Precipitation:	720 mm per year
Parent material:	Post Glacial brackish water deposits overlying glaciofluvial deposits
Vegetation:	Field crops
Classification:	USDA: Entic Haplaquod FAO-Unesco: Gleyic Podzol

Description:

Ap	0-16 cm	Very dark greyish brown (10 YR 3/2) moist, clay loam; few yellowish red (5 YR 4/6) moist, fine distinct sharp mottles; strong coarse subangular blocky; very firm, frequent fine roots; clear smooth boundary.
Ahg	16-20 cm	Brown to dark brown (10 YR 4/3) moist, clay; common yellowish red (5 YR 4/6) moist, fine distinct sharp mottles; moderate coarse subangular blocky; firm; common fine roots; abrupt wavy boundary.
Cg	20-34 cm	Dark grey (10 YR 4/1) moist, clay loam; common yellowish red (5 YR 4/6) moist, fine distinct sharp mottles; strong coarse angular blocky; common fine roots; abrupt wavy boundary.
2Ahgb	34-36 cm	Very dark grey (10 YR 3/1) moist, loamy sand; few yellowish red (5 YR 4/6) moist, fine distinct sharp mottles; very friable; few fine roots; abrupt wavy boundary.

2Egb 36-47 cm Greyish brown (10 YR 5/2) moist, sand; few yellowish red (5 YR 4/6) moist, fine distinct sharp mottles; very weak very coarse subangular blocky; very friable; very few fine roots; abrupt wavy boundary.

2Bhsgb1 47-70 cm Dark brown (7.5 YR 3/3) moist, sand; common yellowish red (5 YR 4/6) moist, and very dusky red (2.5 YR 2.5/2) moist, fine distinct sharp mottles; very weak very coarse angular blocky; very friable; diffuse wavy boundary.

2Bhsgb2 70-102cm Dark brown (7.5 YR 4/3) moist, sand; common yellowish red (5 YR 4/6) moist, and very dusky red (2.5 YR 2.5/2) moist, fine distinct sharp mottles; very weak very coarse angular blocky, very friable; abrupt wavy boundary.

2Cb 102-111 cm Dark brown (7.5 YR 3/2) moist, sand; weak thick platy, firm; abrupt wavy boundary.

2Cgb 111- cm Brown to dark brown (10 YR 4/3) moist, sand; common yellowish red (5 YR 4/6) moist, and very dusky red (2.5 YR 2.5/2) moist, fine distinct sharp mottles; structureless; loose.

Analytical data
Profile No. 4A

Analytical data. Profile No. 4A

Horizon	Depth cm	Texture, % of humus and calcium carbonate free fine earth: Sand Coarse	Sand Medium	Sand Fine	Sand Total	Silt Coarse	Silt Medium	Silt Fine	Silt Total	Clay	Org. Carbon %	Nitrogen mg/g	C/N
Ap	0- 16	0.1	9.1	9.1	18.3	21.5	15.0	11.8	48.3	33.4	2.86		
Ahg	16- 20	0.7	7.8	6.3	14.8	23.0	11.9	4.9	39.8	45.4	1.24		
Cg	20- 34	0.7	31.1	10.1	41.9	10.0	10.3	8.0	28.3	29.8	0.85		
2Ahgb	34- 36	3.0	61.0	19.3	83.3	2.6	2.2	2.3	7.1	9.6	0.27		
2Egb	36- 47	3.8	76.0	15.8	95.6	0.8	0.7	0.8	2.3	2.1	0.05		
2Bhsgb1	47- 70	-	-	-	-	-	-	-	-	-	0.18		
2Bhsgb2	70-102	-	-	-	-	-	-	-	-	-	0.41		
2Cb	102-111	-	-	-	-	-	-	-	-	-	-		
2Cgb	111-	-	-	-	-	-	-	-	-	-	-		

Horizon	Depth cm	pH H_2O	pH $CaCl_2$	Exchangeable cations, meq./kg Ca	K	Mg	Na	H	CEC pH 8.1 meq./kg	Base-sat. %	$CaCO_3$ %	Phosphorus mg/kg
Ap	0- 16	6.7	6.2									
Ahg	16- 20	6.5	5.8									
Cg	20- 34	6.1	5.7									
2Ahgb	34- 36	6.4	5.6									
2Egb	36- 47	6.0	5.5									
2Bhsgb1	47- 70	6.1	5.6									
2Bhsgb2	70-102	3.9	3.8									
2Cb	102-111	-	-									
2Cgb	111-	-	-									

Horizon	Depth cm	Bulk Density g/cm³	Pore volume %	Water content (%) at pF 0.6	1.8	2.5	4.2	Fe, mg/g Dithion.	Fe, mg/g Pyrophos.	Al, mg/g Dithion.	Al, mg/g Pyrophos.
Ap	0- 16							-		-	
Ahg	16- 20							18.08		0.80	
Cg	20- 34							7.11		0.46	
2Ahgb	34- 36							0.64		0.11	
2Egb	36- 47							0.18		0.04	
2Bhsgb1	47- 70							0.18		0.30	
2Bhsgb2	70-102							1.15		0.82	
2Cb	102-111							0.85		0.72	
2Cgb	111-							-		-	

Interpretation:

The horizon sequence reflects the transgression of the sea due to the eustatic sea level rise. Before inundation a rather well developed podzol profile was formed in the glaciofluvial sand underlying the brackish water lagune deposits. The podzol profile is covered directly by deposits consisting a rather heavy clay indicating a rather abrupt change to the inundated stage.

The fine texture of the clay covering the glaciofluvial sand indicates that sedimentation has taken place in a protected environment. Except for an A horizon, the soil development in the clay is slight. The grey colours and mottling indicate reducing conditions which however, are now relieved through artificial drainage.

Since the clay deposits is only 34 cm thick the classification is formally based on the underlying podzol profile.

Profile No. 4B

UTM:	32U MF 856862
Elevation:	1 m a.s.l.
Temperature:	January 0.0 °C. July 16.4 °C. Year 8.1 °C.
Precipitation:	720 mm per year
Parent material:	Post Glacial brackish water deposits overlying glaciofluvial deposits
Vegetation:	Field crops
Classification:	USDA: Thapto-Histic Fluvaquent FAO-Unesco: Eutric Fluvisol

Description:

Ap	0-20	cm	Dark brown (10 YR 3/3) moist, silty clay few red (2.5 YR 4/6) moist, fine distinct sharp mottles; weak medium subangular blocky; extremely firm, very few fine roots; abrupt smooth boundary.
Cg1	20-33	cm	Greyish brown (10 YR 5/2) moist, clay; common red (2.5 YR 4/6) moist, fine distinct sharp mottles; massive; very firm; very few fine roots; abrupt smooth boundary.
Cg2	33-37	cm	Grey (10 YR 5/1) moist; clay; few strong brown (7.5 YR 5/6) moist, fine faint clear mottles; massive; very firm; very few fine roots; abrupt smooth boundary.
Ahb	37-40	cm	Very dark grey (10 YR 3/1) moist, clay; moderate medium prismatic; very firm; very few fine roots; abrupt smooth boundary.
Cgb	40-47	cm	Grey (10 YR 5/1) moist, silty clay; few strong brown (7.5 YR 5/6) moist, fine faint clear mottles; moderate medium prismatic; very firm, very few fine roots; abrupt smooth boundary.
2Hab	47-66	cm	Black (5 YR 2.5/1) moist, sapric material; moderate fine subangular blocky; loose; few fine roots; clear smooth boundary.
3Eb	66-76	cm	Dark grey (5 YR 4/1) moist, sand; structureless; loose; very few fine roots; clear smooth boundary.
3Bhb	76-	cm	Black (5 YR 2.5/1) moist, sand; very weak medium angular blocky; friable.

Analytical data
Profile No. 4B

Analytical data. Profile No. 4B

Horizon	Depth	Texture, % of humus and calcium carbonate free fine earth									Org.	Nitrogen	C/N
	cm	Sand				Silt				Clay	Carbon	mg/g	
		Coarse	Medium	Fine	Total	Coarse	Medium	Fine	Total		%		
Ap	0-20	0.4	2.9	6.7	10.0	21.9	14.8	10.5	47.2	42.8	3.05	-	-
Cg1	20-33	0	0.4	3.2	3.6	14.2	13.6	13.2	41.0	55.4	1.40	1.31	10.7
Cg2	33-37	0	0	2.9	2.9	10.9	13.7	15.1	39.7	57.4	1.47	-	-
Ahb	37-40	0	0.8	4.4	5.2	10.6	13.8	17.0	41.4	53.4	2.12	1.73	12.2
Cgb	40-47	0	0	2.4	2.4	13.4	14.3	16.8	44.5	53.1	1.68	-	-
2Hab	47-66	-	-	-	-	-	-	-	-	-	25.74	-	-
3Eb	66-76	2.0	62.1	28.9	93.0	3.4	1.1	0.9	5.4	1.6	1.55	-	-
3Bhb	76-	-	-	-	-	-	-	-	-	-	2.49	-	-

Horizon	Depth	pH		Exchangeable cations, meq./kg					CEC	Base-	$CaCO_3$	Phosphorus
	cm	H_2O	$CaCl_2$	Ca	K	Mg	Na	H	pH 8.1 meq./kg	sat. %	%	mg/kg
Ap	0-20	6.5	6.0	200.8	7.2	34.7	2.6	76.9	322.2	76		-
Cg1	20-33	6.4	5.9	189.6	8.7	50.4	3.3	58.6	310.6	81		99
Cg2	33-37	6.4	5.9	160.9	8.5	59.1	4.1	59.3	301.9	80		-
Ahb	37-40	6.1	5.6	154.7	7.7	77.7	3.9	82.9	327.0	75		91
Cgb	40-47	6.0	5.4	129.7	7.7	78.1	3.5	78.9	298.0	74		-
2Hab	47-66	5.5	5.0	-	-	-	-	-	-	-		-
3Eb	66-76	5.1	4.3	-	-	-	-	-	-	-		-
3Bhb	76-	4.2	3.9	-	-	-	-	-	-	-		-

Horizon	Depth	Bulk	Pore	Water content (%) at pF				Fe, mg/g		Al, mg/g	
	cm	Density g/cm^3	volume %	0.6	1.8	2.5	4.2	Dithion.	Pyrophos.	Dithion.	Pyrophos.
Ap	0-20										
Cg1	20-33										
Cg2	33-37										
Ahb	37-40										
Cgb	40-47										
2Hab	47-66										
3Eb	66-76										
3Bhb	76-										

Interpretation:

The geological and pedological development is similar to that of profile 4A. However, a peat layer has developed on top of the glaciofluvial sand prior to the deposition of the brackish water clay also found in profile 4A. At present the peat layer is about 20 cm thick. Furthermore, the horizon sequence shows a temperary stop in the clay sedimentation at a depth of about 37 cm below the present surface, where a buried A horizon is found. However, except for this and the top A-horizon the horizon development in the clay is weak.

Like in profile 4A there is evidence of reducing conditions. Soils of this nature often contains iron pyrites, which may cause strong acidification when the ground water level is lowered.

Since the clay and peat deposits are thicker than in profile 4A, the formal classification of profile 4B is based on the soil development in the clay and peat deposits.

Profile No. 5

UTM:	32U MF 803898
Elevation:	1 m a.s.l.
Temperature:	January 0.0 °C. July 16.4 °C. Year 8.1 °C.
Precipitation:	700 mm per year
Parent material:	Post Glacial marine deposits (tidal area)
Vegetation:	Grass
Classification:	USDA: Typic Fluvaquent
	FAO-Unesco: Eutric Fluvisol

Description:

Ap	0-23 cm	Dark greyish brown (10 YR 4/2) moist, silt loam; common yellowish brown (10 YR 5/6) moist, fine distinct sharp mottles; strong fine granular; firm; frequent fine roots; clear smooth boundary.
Cg1	23-34 cm	Dark greyish brown (10 YR 5/2) moist, silt loam; common yellowish brown (10 YR 5/8)

			moist, fine distinct clear mottles; strong fine subangular blocky; firm; common fine roots; clear smooth boundary.
Cg2	34-80	cm	Light grey to grey (5 Y 6/1) moist, silt loam; common grey (5 Y 5/1) moist, and yellowish red (5 YR 4/6) moist, medium distinct clear mottles; weak fine subangular blocky; friable, few fine roots; clear smooth boundary.
Cg3	80-	cm	Light grey to grey (5 Y 6/1) moist, very fine sandy loam; common grey (5 Y 5/1) moist, and yellowish red (5 YR 4/6) moist, medium faint clear mottles; weak fine subangular blocky; firm.

Analytical data
Profile No. 5

Analytical data. Profile No. 5

Horizon	Depth cm	Texture, % of humus and calcium carbonate free fine earth: Sand Coarse	Sand Medium	Sand Fine	Sand Total	Silt Coarse	Silt Medium	Silt Fine	Silt Total	Clay	Org. Carbon %	Nitrogen mg/g	C/N
Ap	0-23	0.5	1.6	14.7	16.8	46.1	13.8	5.7	65.6	17.6	2.52		
Cg1	23-34	0.7	1.0	13.9	15.6	41.4	12.6	7.4	61.4	23.0	0.85		
Cg2	34-80	0	0.5	8.8	9.3	46.9	9.4	8.9	65.2	25.5	0.64		
Cg3	80-	0	0.4	49.4	49.8	24.7	4.4	3.5	32.6	17.6	0.37		

Horizon	Depth cm	pH H_2O	pH $CaCl_2$	Exchangeable cations, meq./kg: Ca	K	Mg	Na	H	CEC pH 8.1 meq./kg	Base-sat. %	$CaCO_3$ %	Phosphorus mg/kg
Ap	0-23	6.2	5.6	132.2	2.8	36.2	2.5	54.3	228.0	76	0.0	
Cg1	23-34	7.6	7.1	-	-	-	-	-	-	-	2.1	
Cg2	34-80	7.5	7.3	-	-	-	-	-	-	-	3.8	
Cg3	80-	8.2	7.1	-	-	-	-	-	-	-	1.6	

Horizon	Depth cm	Bulk Density g/cm^3	Pore volume %	Water content (%) at pF 0.6	1.8	2.5	4.2	Fe, mg/g Dithion.	Fe, mg/g Pyrophos.	Al, mg/g Dithion.	Al, mg/g Pyrophos.
Ap	0-23							-	-	-	-
Cg1	23-34							-	-	-	-
Cg2	34-80							6.84	0.43	0.37	0.11
Cg3	80-							-	-	-	-

Interpretation:

The profile is a typical representative of the young soils on recent marine deposits formed in an environment exposed to the sea. The deposition takes place under conditions where the surface is dry at low tide and inundated at high tide. Under these conditions the surface is covered by a vegetation which promotes sedimentation. The sediment is dominated by silt and clay size particles but under extreme weather conditions such as strong winds some sand will be deposited as well. This appears as thin coarse textured layers in the profile. Further, the sediment contains some calcium carbonate and organic matter, the latter originating from the vegetation.

Having been in contact with sea water the soil has earlier had a significant content of adsorbed sodium. However, during reclamation this has to a large extent been replaced by adsorbed calcium.

The pedological development is limited to the formation of an A horizon and some leaching of calcium carbonate from the layers close to the surface. Due to its low altitude the soil would be poorly drained in the absence of artificial drainage.

DAY 3

The programme starts with a visit to The Bureau of Land Data which is affiliated with the Ministry of Agriculture. The Bureau of Land Data was established in 1975 and its first task was to compile data for Danish agricultural soils and produce soil maps covering the entire country. Later various other projects have been assigned to the Bureau. At the Bureau extensive use is made of electronic data processing.

Later in the morning profile No. 6 which is classified as an Orthic Acrisol is studied. It is located on Weichsel glacial till in Refstrup Forest approx. 18 km NW of Vejle.

After lunch Askov State Experimental Station is visited. It was established in 1885 and is well-known, in particular for its research concerning soil fertility, fertilizer application and plant nutrition.

The excursion will proceed as shown in Fig. 12. The route has been chosen as to pass some of the characteristic features of the Weichsel moraine landscapes and the area East and West of the main stationary line of the Weichsel glaciers, cf. Fig. 2.

Vejle is situated in a tunnel valley excavated by subglacial melt water streams during the Weichsel glaciation. Just NW of Vejle the route passes another tunnel valley which runs roughly parallel with that at Vejle. The undulating and rolling topography of the area is partly due to temporary advances of the glaciers during their general recession. In these areas the glacial till has a rather high clay content, and is similar to the till occuring on the Danish Eastern islands. Further to the West, i.e. near the main stationary line, the till is generally more sandy and more strongly leached.

West of Gadbjerg (The site of profile No. 6) the landscapes are similar to those studied during day 1 and day 2, i.e. glaciofluvial plains and Saalian deposits. These are passed when travelling to Askov Experimental Station which is situated on moraine, possibly deposited by a glacier lobe during the Weichsel glaciation.

The first part of the trip from Askov to Århus also passes glaciofluvial and Saale landscapes. Between Give and Nørre Snede the marginal area of the Weichsel glaciers is passed. At Hjøllund

Fig. 12.

Day 3. Route Vejle - Askov - Århus

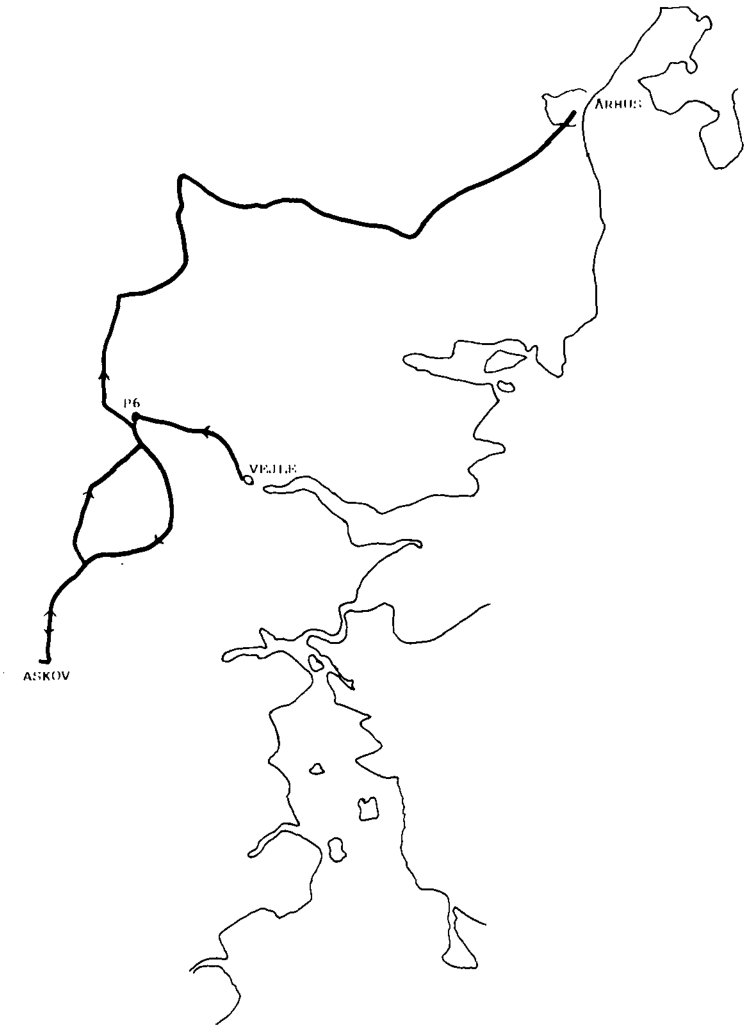
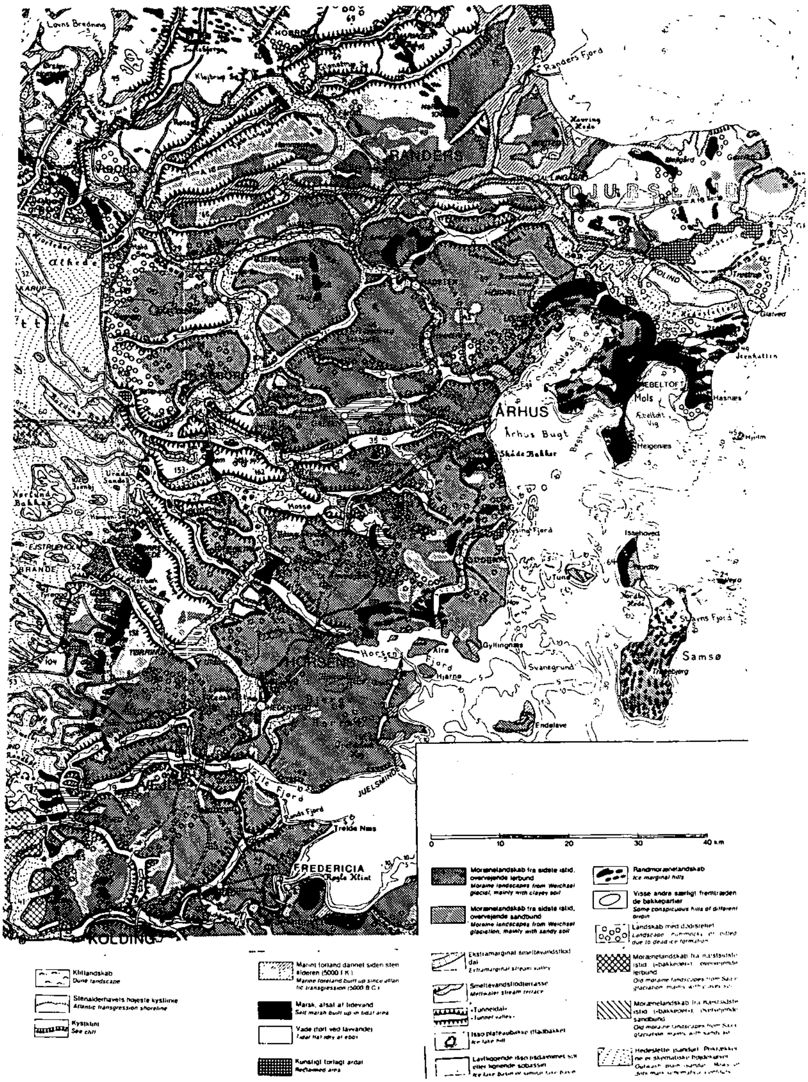


Fig. 13.

Geomorphology of the Vejle - Århus Area



the mouth of a large valley system formed by melt water during the Weichsel glaciation is apparent. The excursion proceeds East along the valley and across an inland sand dune landscape, Vrads Sande. Next, it continues across a sandy moraine plateau to Sønder Vissing where the Gudenå valley, running South-North, is passed. This valley is formed by melt water at a late stage during the Weichsel glaciation when the glacies had receded somewhat towards East. At this stage the melt water flow had a direction towards North along the glacier front.

East of the Gudenå valley the road passes through a moraine landscape South of the largest lake in Jutland, Mossø, which is a part of a tunnel valley with an East-West direction. Another, roughly parallel, tunnel valley is passed immediately South of Århus.

Århus is the second largest city in Denmark and an important industrial centre. It houses Århus University and a number of other education and research institutions. Recently a remarkable Concert Building was constructed in the center of the city.

Profile No. 6

UTM:	32U NG 199814
Elevation:	88 m a.s.l.
Temperature:	January -0,3 °C, July 16,4 °C, Year 7,7 °C
Precipitation:	760 mm per year
Parent material:	Glacial till
Vegetation:	Forest, Fagus sylvatica
Classification:	USDA: Humic Hapludult
	FAO-Unesco: Orthic Acrisol

Description:

O	-2-0 cm	Partly decomposed plant residues
Ah	0-5 cm	Dark greyish brown (10 YR 4/2) wet, fine sandy loam; weak fine subangular blocky; non-sticky slightly plastic; few fine medium and coarse roots; clear irregular boundary.
E	5-23 cm	Yellowish brown (10 YR 5/4) wet, fine sandy loam, moderate fine subangular blocky; non-sticky slightly plastic; few stones; very frequent fine and medium roots; clear smooth boundary.
Bt1	23-53 cm	Yellowish brown (10 YR 5/6) wet, sandy clay loam; moderate medium subangular blocky; slightly sticky plastic; reddish brown broken moderately thick clay cutans on ped surfaces; few stones; diffuse smooth boundary.
Bt2	53-110 cm	Yellowish brown (10 YR 5/6) wet, sandy clay loam; moderate to weak medium subangular blocky; slightly sticky plastic; few stones; diffuse smooth boundary.
C	110- cm	Yellowish brown (10 YR 5/4) wet, sandy clay loam; weak medium subangular blocky, slightly sticky plastic; few stones.

Analytical data
Profile No. 6

Analytical data. Profile No. 6

Horizon	Depth cm	Texture, % of humus and calcium carbonate free fine earth									Org. Carbon %	Nitrogen mg/g	C/N
		Sand				Silt				Clay			
		Coarse	Medium	Fine	Total	Coarse	Medium	Fine	Total				
Ah	0- 5	-	-	-	-	-	-	-	-	-	-	-	-
E	5- 23	3.6	25.6	30.1	59.3	15.3	8.8	7.3	31.4	9.3	1.70	-	-
Bt1	23- 53	3.3	23.7	25.2	52.2	9.7	6.9	6.4	23.0	24.8	0.80	-	-
Bt2	53-110	2.4	23.0	26.5	51.9	11.5	7.6	6.4	25.5	22.6	0.25	-	-
C	110-	2.2	24.8	26.0	53.0	10.8	8.1	5.7	24.6	22.4	0.20	-	-

Horizon	Depth cm	pH		Exchangeable cations, meq./kg					CEC pH 8.1 meq./kg	Base-sat. %	$CaCO_3$ %	Phosphorus mg/kg
		H_2O	$CaCl_2$	Ca	K	Mg	Na	H				
Ah	0- 5		-									
E	5- 23		3.8									
Bt1	23- 53		3.8									
Bt2	53-110		3.9									
C	110-		4.0									

Horizon	Depth cm	Bulk Density g/cm^3	Pore volume %	Water content (%) at pF				Fe, mg/g		Al, mg/g	
				0.6	1.8	2.5	4.2	Dithion.	Pyrophos.	Dithion.	Pyrophos.
Ah	0- 5	-	-	-	-	-	-	-	-	-	-
E	5- 23	1.33	50	-	29.3	23.0	7.2	6.21	-	1.54	-
Bt1	23- 53	1.39	48	-	32.2	29.2	14.8	10.14	-	2.25	-
Bt2	53-110	1.68	37	-	31.6	28.3	15.8	7.67	-	1.38	-
C	110-	1.74	34	-	32.6	30.3	16.6	7.88	-	1.15	-

Interpretation:

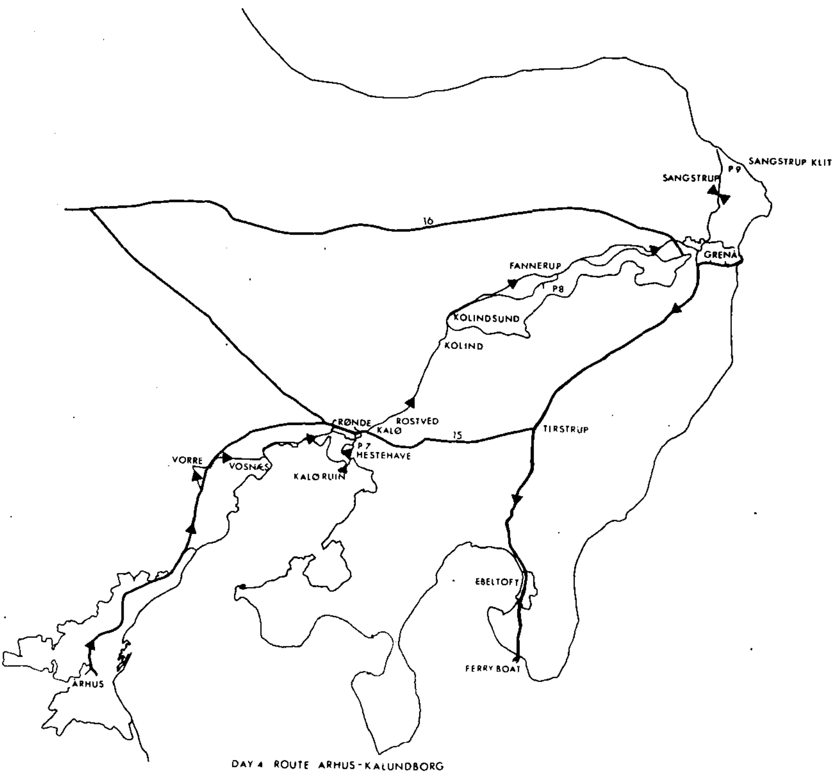
Based on the presence of a textural B horizon, having an elevated clay content compared with the upper horizons and clay cutans, and a low base saturation percentage the soil is classified as an Orthic Acrisol.

This is in contrast to most other Danish soils with clay migration since these have a base saturation high enough to qualify for classification as Luvisols. The reason for this soil development is not clear but it is suggested to be due partly to the fact that the precipitation and accordingly the leaching is rather high, and partly to a rather acid parent material. The Luvisols of the Danish Islands and Eastern Jutland owe their high base saturation percentage in the B horizon to a former content of calcium carbonate in the morainic material. Since profile 6 is located close to the main stationary line of the Weichsel glaciers the parent material could be old Saale deposits translocated by the Weichsel glaciers, but positive evidence to substantiate this suggestion is lacking.

DAY 4

The day will be spent on the peninsula of Djursland which contains within a small area almost the full range of geology, landscapes and soils to be found in Denmark. The bus will leave Århus along route 15. There will be a short stop at the village of Vorre, 15 km to the NE and 110 m above sea level. From here we have a good view over Kalø Vig. The bay is surrounded by the large terminal moraine of the Kalø Vig glacier lobe.

Fig. 14.
Day 4. Route Århus - Kalundborg



DAY 4 ROUTE ARHUS-KALUNDBORG

The next stop will be at the Vosnæs Estate. Here the great change in land-use which resulted from the intense drainage of the wet areas during the last 200 years will be demonstrated. This will be based on the Danish 1844 matrikel map which is a combined cadastral, land-use and fertility survey made of the whole country between 1805 and 1827.

The route will follow the coast to the Hestehaven wood with profile 7 A-C. The wood is just north of the ruin of Kalø Castle. Kalø Castle, which gives its name to the bay, was built in 1320 and was one of the Danish Kings' strongest fortresses in Jutland until it was demolished in 1670.

Lunch

The afternoon will start with a short stop at the present Kalø Estate on top of the terminal moraine. From here there is a good view over the landscape which we will pass through. The route passes over the Tirstrup meltwater plain. During the last 30 years much of this has been planted with coniferous trees because the sandy soils have a low resistance to wind erosion and a poor water holding capasity. The soil type is Entic Haplorthod. The erosion valleys in the meltwater plain have Histosols and gyttja soils which are used for grazing and grain farming. We will pass through Kolind, the old trading centre for central Djursland, and then along the northern boundary canal to Fannerup. Here we come to profiles 8A and B which are dug in the gyttja of the reclaimed Kolindsund.

The last part of the afternoon will be spent at the Rendoll profiles 9 A and B at the north-east coast of Djursland. Here the Danian chalk is close to the surface and exposed in the coastal cliffs. On the way we will pass Grenå, the town which has ferry connections to Sweden and Sealand. Further much of the county's industry with heavy pollution is located here.

After visiting profile 9 A and B the bus will drive to Ebeltoft on the south-east corner of Djursland for the ferry to Sealand. Dinner will be served on the ferry.

Fig. 15.

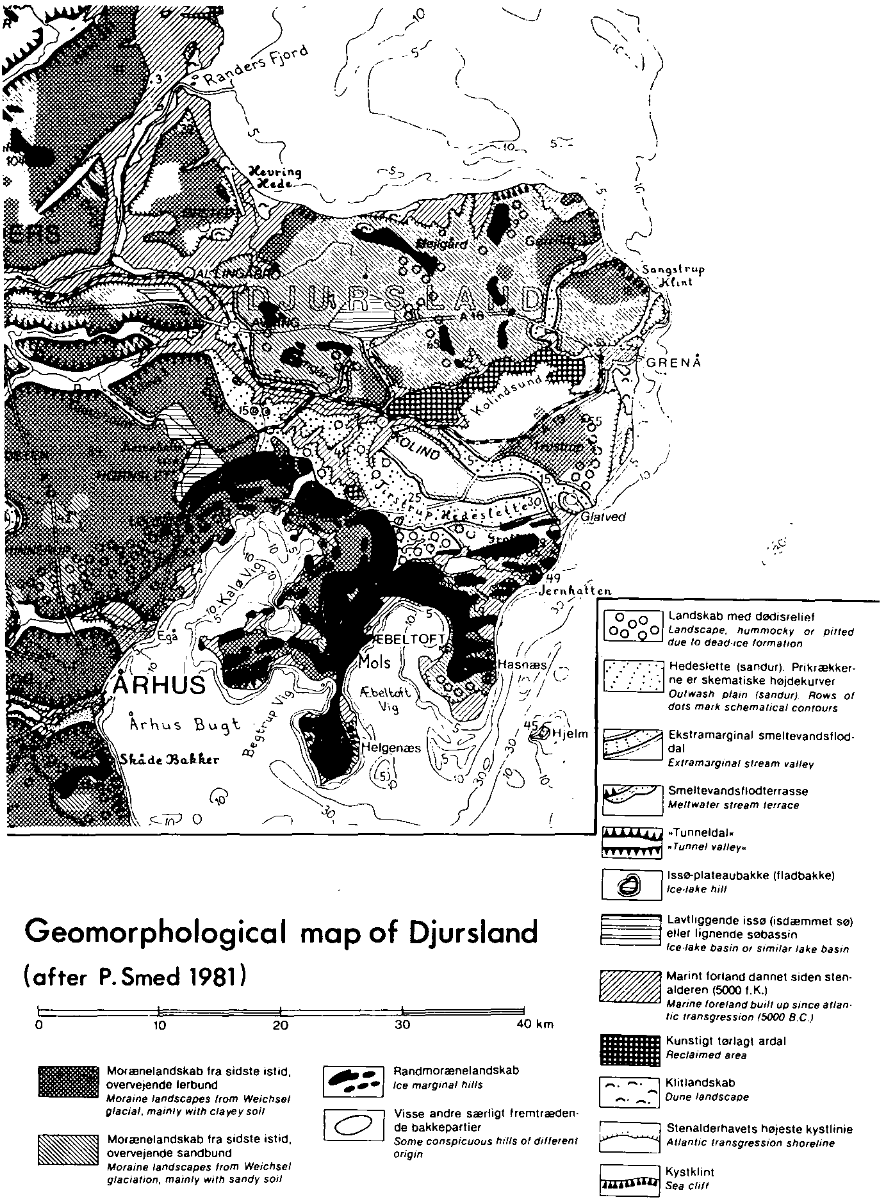

Randers Fjord
Djursland
Sangstrup Klint
GRENÅ
Kolindsund
KOLIND
Glatved
Jernhatten
ÆBELTOFT
Mols
Hasnæs
Æbeltoft Vig
Helgenæs
Hjelm
Kalø Vig
Egå
ÅRHUS
Århus Bugt
Begtrup Vig
Skåde Bakker
Geomorphological map of Djursland
(after P.Smed 1981)
0
10
20
30
40 km
Morænelandskab fra sidste istid, overvejende lerbund
Moraine landscapes from Weichsel glacial, mainly with clayey soil
Morænelandskab fra sidste istid, overvejende sandbund
Moraine landscapes from Weichsel glaciation, mainly with sandy soil
Randmorænelandskab
Ice marginal hills
Visse andre særligt fremtrædende bakkepartier
Some conspicuous hills of different origin
Landskab med dødisrelief
Landscape, hummocky or pitted due to dead-ice formation
Hedeslette (sandur). Prikrækkerne er skematiske højdekurver
Outwash plain (sandur). Rows of dots mark schematical contours
Ekstramarginal smeltevandsfloddal
Extramarginal stream valley
Smeltevandsflodterrasse
Meltwater stream terrace
»Tunneldal«
»Tunnel valley«
Issø-plateaubakke (fladbakke)
Ice-lake hill
Lavtliggende issø (isdæmmet sø) eller lignende søbassin
Ice-lake basin or similar lake basin
Marint forland dannet siden stenalderen (5000 f.K.)
Marine foreland built up since atlantic transgression (5000 B.C.)
Kunstigt tørlagt ardal
Reclaimed area
Klitlandskab
Dune landscape
Stenalderhavets højeste kystlinie
Atlantic transgression shoreline
Kystklint
Sea cliff

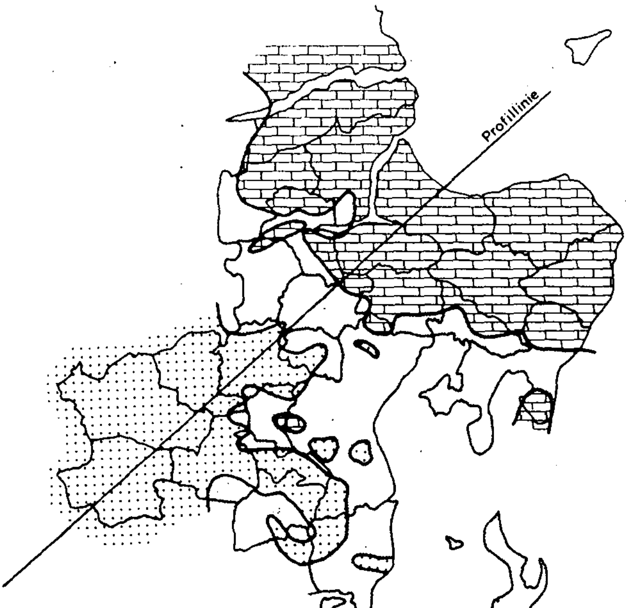
Fig. 16.

The prequaternary surface
in Århus County

Kalk (Ovre Kridt og Danien) Chalk

Fedt ler (Paleocæn Eocæn og nedre Oligocæn) Clay

Sand og ler (Øvre Oligocæn og Miocæn) Sand and clay



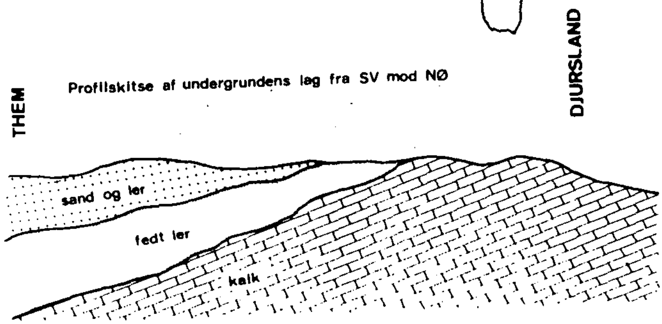
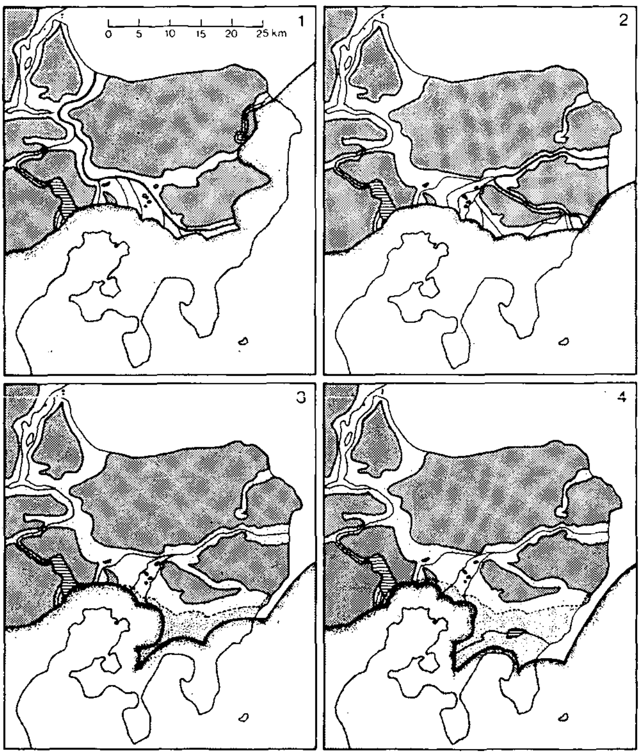


Fig. 17.

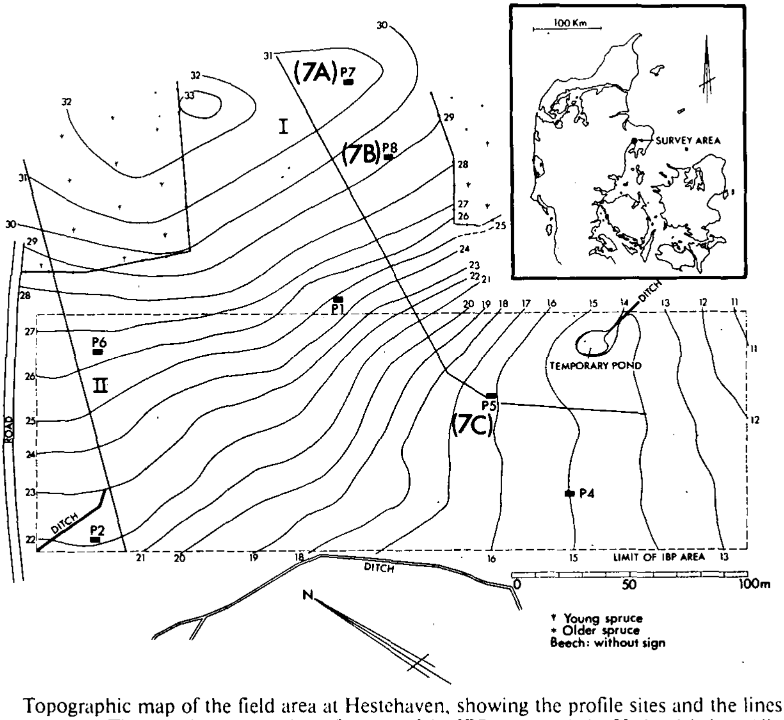
Ice marginal retreat and the pattern of meltwater channels on Djursland
(after Rasmussen 1977)



The Hestehaven wood area
Profile 7 A, B, C

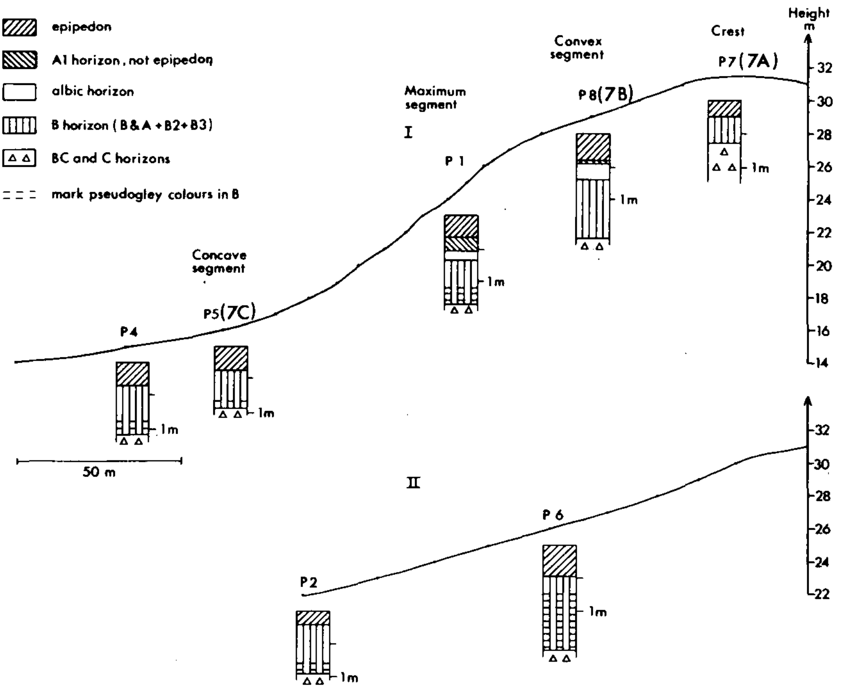
Profile 7 A, B, C in the Hestehaven wood is situated in the field area of the Danish International Biological Program I.B.P. A comprehensive survey was made at much of the physical environment as follow-up of the I.B.P. program. The soil was described by Dalsgaard, Baastrup and Bunting (1981) and the forest microclimate by Rasmussen, Nielsen and Hansen (1982). Since it showed up that a subsurface water flow was found to have played a major role in soil formation this flow was investigated further. On the excursion three profiles showing the influence of lateral water movement on the soils will be demonstrated, together with the main results of the soil-hydrology studies.

Fig. 18.
Topographic map of the field area at Hestehaven



Topographic map of the field area at Hestehaven, showing the profile sites and the lines of the cross sections. The map is an extension of a map of the IBP area made by Hedeselskabet. All unshaded areas occupied by beech wood. Contour heights in metres above O.D.

Fig. 19.
Toposequence
Profile Nos. 7 A - C



The field area is situated within the large terminal moraine of the Kalø Vig Glacier lobe (13000 BP) on the south-facing slope of a ridge made of clayey calcareous till. Hestehaven wood with its old beech oak stands belongs to the Center for Danish Game Reserch. Nothing suggests that the area has ever been ploughed.

The present vegetation is composed of an homogeneous stand of 95 year old beech (Fagus sylvatica L.). Henriksen (1972) showed that the total standing crop was 498 m^3/ha (1971) and it has a high productivity of 12-16 m^3/ha/year (1967-71).

The annual litter fall was studied by Nielsen (1977) during the period 1967-75. The total fall of litter components was 435-535 g dry matter/m^2/year of which leaves constituted 240-300 g. The productivity of the ground flora was investigated by Hughes (1975). The net production above and below ground in the year 1969 was 160 g dry matter/m^2/year. Anemone nemorosa, Asperula odorata, Melica uniflora and Cares sylvatica accounted for 80% of this production.

Profile No. 7A

Mollic Hapludalf or Eutric Glossoboralf, fine loamy, mixed, USDA; Orthic Luvisol, Fao; crest of slope in cross section I (Figs. 18 and 19).

A11/12 0 to 13 cm, dark brown (10YR 3/3 m, 3-5/2 d); very fine to fine sandy loam, few coarse fragments; moderate fine to medium granular; very friable; many roots of all sizes; several wormholes lined with beech leaves; clear smooth to wavy boundary.

A13 13 to 24 cm, brown to dark brown (10YR 4/3 m, 6/4 d), fine sandy loam; some coarse fragments and some roots; moderate strong, very fine to fine angular blocky; firm; clear wavy boundary.

B21t 24 to 45 cm, brown to dark brown (10YR 4/3 m, 5/6 d); sandy clay loam; with dark yellowish brown (10YR 4/4 m) clay skins, few coarse fragments, few fine roots; moderate to strong coarse prismatic breaking into moderate medium angular blocky. Clay skins are seen on almost every ped face, but especially on prism faces; where the root concentration is also highest; firm to friable, clear to gradual wavy boundary.

B22t 45 to 64 cm, yellowish brown (10YR 5/6 m, 6/4 d) sandy clay loam with dark brown (10YR 3/3) clay skins; few fine roots and some coarse mineral fragments; strong very coarse prismatic breaking into moderate fine to medium weak angular blocky structure; firm to friable; clear to gradual wavy boundary.

BC 64 to 104 cm, yellowish brown (10YR 5/7 m, 6/4 d); sandy clay loam with dark yellowish brown (10YR 3/4 m) clay skins, few fine roots; moderate, medium to coarse prismatic structure breaking into moderate medium angular blocky-firm to friable; effervescence with HCl; gradual wavy boundary.

C 104 to 140 cm, light yellowish brown (10YR 6/4 m, 7/3 d); fine sandy loam (including lime); massive structureless; effervescence with HCl.

Micromorphology 10-12 cm. The voids are mostly orthochannels, irregular orthovughs and compound packing voids. Both humus and clay plasma present. Several fecal pellets and an aggrotubule (3 mm Ø). Agglomeroplasmic pattern. Isotic to argillasepic plasmic fabric.

Micromorphology 25-27 cm. Very similar to 10-12 cm. Several aggrotubules and many fecal pellets. Some sesquioxide glaebules, some with sharp, some with diffuse boundaries.

Micromorphology 35-37 cm. The void system consists of skew planes and of channels connected by planes, with linearly-arranged meta-vughs, also orthovughs and vesicles. The largest planes and channels are coated with 25-100 μm thick argillans: the thin planes are orthovoids. Plasma is clay, arranged as argillans, especially as void argillans or as randomly-arranged flakes. A few fecal pellets and diffuse organic or sesquioxidic nodules. Porphyroskelic pattern. Vo-insepic plasmic fabric.

Micromorphology 61-63 cm. Clay plasma with strong birefringence, mostly as thick void argillans, otherwise as unrelated flakes. Several large voids are filled with clay. Some fecal pellets and many diffuse, mostly Mn glaebules. Porphyroskelic pattern. Vo-insepic plasmic fabric.

Micromorphology 81-83 cm. Many irregular metavughs and vesicles. Channels are more irregular than in B22t. The clay plasma is arranged partly as flakes and partly as cutans. The thickest argillans are situated around vesicles. Many diffuse, irregular sesquioxidic nodules and a few fecal pellets. A few lime fragments. Porphyroskelic pattern with tendency to intertextic. Vo-insepic plasmic fabric.

Micromorphology 103-105 cm. Vughs and vesicles appear mostly in those parts with a limey plasma. Two sorts of plasma, clay and lime, both occur, often as cutans. A mixture of the two forms a dense matrix. Many argillans, a few calcitans and sesquans occur. A glaebular halo of iron and some diffuse iron and manganese nodules are present. A few fecal pellets. Agglomeroplasmic to porphyroskelic pattern. Calci-a-vosepic plasmic fabric. Many lime fragments (fossils) are present, several showing dissolution.

Micromorphology 125-127 cm. Fewer argillans. Channels filled with lime. Large lime fragments.

Analytical data profile 7A

Sample depth cm	Horizon	Particle size distribution % of <2 mm >2	2.0-0.6	0.6-0.2	0.2-0.06	0.06-0.02	0.02-0.002	<0.002	Bulk density g/cm^3	Porosity %	Org. C %	C/N	pH H_2O	pH KCl
0-5	A11	2	3.2	14.4	35.4	14.3	17.0	15.7	1.27	49	2.91	13	3.98	3.28
5-9	A12	4	3.1	14.5	35.5	12.8	17.6	16.5	1.11	56	1.70	11	4.07	3.42
14-19	A13	9	5.6	13.1	34.4	12.8	17.7	16.4	1.49	43	0.94	10	4.43	3.53
29-34	B21t	10	3.9	10.8	33.3	8.7	18.7	24.6	1.46	42	0.43		5.07	3.59
55-59	B22t	2	3.2	12.6	30.9	8.3	18.2	27.8	1.55	42	0.33		5.59	3.70
73-77	BC	5	4.3	13.0	32.5	10.6	18.7	20.9	1.44	46			8.21	7.09
104-109	C	6	4.3	11.5	32.6	8.7	22.1	20.8	1.69	36			8.22	7.20
122-127	C	5	5.6	14.4	22.6	13.1	19.6	17.3	1.64	38			8.33	7.33
122-127	Carb. removed		5.6	15.7	30.6	15.6	18.7	13.9						

		Extractabel cations Ca^{+2} pH7 meq/100 g	Mg^{+2}	K^+	Na^+	H^+ pH8	CEC sum	Base sat. %	Fe_2O_3 pyr.	Fe_2O_3 DCB	Al_2O_3 pyr.	Al_2O_3 DCB	Fe+Al pyr/DCB	$CaCO_3$ eqv %	Inorg. P PPM	Org. P PPM
0-5	A11		1.2	0.3	0.3	12.8			0.31	0.79	0.21	0.28	0.46		262	339
5-9	A12	1.7	0.5	0.2	0.3	8.8	11.5	23	0.29	0.80	0.21	0.29	0.44		217	337
14-19	A13	2.1	0.6	0.2	0.3	9.5	12.7	25	0.21	0.81	0.18	0.29	0.34		89	206
29-34	B21t	5.3	1.6	0.2	0.4	5.2	12.7	59	0.15	1.18	0.17	0.38	0.19		69	97
55-59	B22t	7.3	2.1	0.2	0.3	4.1	14.0	71	0.11	1.33	0.12	0.35	0.12		143	-
73-77	BC		1.7	0.2	0.2				0.03	0.85	0.04	0.21	0.06	12.0	331	31
104-109	C								0.02	0.74	0.04	0.18	0.06	20.1	323	.4
122-127	C		1.2	0.2	0.2				0,02	0.75	0.04	0.15	0.06	18.6	335	43

Interpretation

This soil in the crestal position does not exhibit an albic horizon, it has a very well-developed though thin Bt horizon with very thick clay skins. The carbonatic materials is closest to the surface (65 cm) of all the soils studied, despite having the lowest pH of all the A1 horizons analysed. The epipedon is relatively thin and less isotic in thin section. The argillic horizon has the most marked illuviation of clay and, because of more intense root penetration, the organic content of the Bt horizon is significantly greater and its bulk density less than the other argillic horizons studied. The clay plasma is strongly birefringent and the lower BC and C horizons show undifferentiated clayey and limey plasma, the differential leaching of clay and lime being more marked in most of the other soil profiles on the slope sites.

Profile No. 7B

Haplic Glossudalf or Mollic Paleboralf, fine-loamy, mixed, USDA; Eutric Podzoluvisol, FAO; 8% inclination; convex segment of cross section I (Figs. 18 and 19).

A11 0 to 12 cm, very dark grayish brown (10YR 3/2 m, 4/2 d); fine sandy loam; many roots; moderate granular, soft, abrupt wavy boundary.

A12 12 to 26 cm, dark brown (10YR 3/3 m, 4/3 d); fine sandy loam; frequent roots; moderate very fine to fine granular; friable; clear wavy boundary.

A13 26 to 45 cm, dark brown (10YR 3/3 m, 4/4 d); fine sandy loam with many fine roots, few stones; massive, to very weak fine subangular blocky; friable; clear to abrupt wavy boundary.

A2 45 to 71 cm, yellowish brown (10YR 5/4 m, 7/3 d); fine sand with few fine roots; massive, structureless; friable; clear to abrupt, irregular boundary.

B & A 71 to 102 cm, horizon composed of A2 and B2t material, with 5-10 cm wide pockets of A2 material penetrating the B2t horizon. Depth of the pockets is up to 5 cm. Boundary between A2 and B2t material is abrupt.

B2t 102 to 128 cm, yellowish brown (10YR 5/5 m, 6/5 d); sandy clay loam with yellowish brown (10YR 5/6) clay skins; moderate strong to very strong, fine to medium angular blocky; firm; clear to gradual wavy boundary.

B3t 128 to 160 cm, yellowish brown (10YR 5/5 m, 6/4 d); sandy clay loam changing to loam in the lower part of the horizon; moderate medium angular blocky; friable; coarse distinct mottles, brown (10YR 5/3) surrounded by yellowish brown (10YR 5/6).

C > 160 cm, effervescence with HCl, auger sample.
Micromorphology 20-22 cm. Orthochannels, orthovughs and compound packing voids. Several aggrotubules, many fecal pellets and some plant remains. Agllomeroplasmic pattern. Argillasepic to isotic plasmic fabric.

Micromorphology 39-41 cm. Humus plasma and some unrelated clay plasma. A few diffuse sesquioxidic nodules. Some aggrotubules, plant remains and many fecal pellets. Agllomeroplasmic to inter-textic pattern. Plasmic fabric as in A12, but with less plasma.

Micromorphology 55-57 cm. The plasma distribution is very inhomogeneous with areas almost devoid of plasma and other areas containing large clayfilled voids. The plasma-poor part of the plasmic fabric looks like the fabric in A13; in the other part it is in-vosepic. Related distribution patterns are agglomeroplasmic to intertextic and prophyroskelic, respectively. Void argillans are common in the plasma-rich part. Many diffuse sesquioxidic nodules.

Micromorphology 82-84 cm. Chiefly clay plasma, some without birefringence, though most of the clay is present as thick (200 µm) voidcutans. Some fecal pellets and many diffuse, irregular sesquioxidic nodules. Some Mn nodules also. Agglomeroplasmic to porphyroskelic pattern. Vo-insepic plasmic fabric.

Micromorphology 106-108 cm. The metavoids are vesicles, channels and vughs. Clay plasma is dominating and appears mostly as void cutans and weak grain cutans. Some iron stained plasma is observed. The argillans are thin and weakly-oriented. Glaebules as in B1, but fewer. Some pedotubules and fecal pellets. Agglomeroplasmic to porphyroskelic pattern. Skel-in-vosepic plasmic fabric.

Analytical data
profile 7B

Sample depth C122	Horizon	Particle size distribution % of <2mm >2	2.0-0.6	0.6-0.2	0.2-0.06	0.06-0.02	0.02-0.002	<0.002	Bulk density g/cm^3	Porosity %	Org. C %	C/N	pH H_2O	pH KCl
4-6	A11		5.0	16.1	39.9	14.8	14.7	10.4			3.21	13	4.27	3.58
17-21	A12		5.0	16.7	38.5	14.8	14.7	10.3	1.12		1.85	11	4.21	3.40
34-39	A13		6.7	16.9	36.6	15.5	14.7	9.6	1.34	48	0.92	10	4.49	3.69
47-52	A2		9.8	18.6	34.2	18.1	13.0	6.2	1.42	46	0.29		5.21	3.92
70-74	B&A		3.6	14.1	31.9	16.8	12.8	20.8	1.53	42	0.31		5.30	3.63
82-87	B2t		4.0	15.7	34.5	12.2	13.3	20.3	1.62	40	0.24		5.35	3.63
105-110	B2t		3.1	12.9	30.2	12.0	18.7	23.1	1.52	44	0.21		5.59	3.72
122-127	B3t		3.3	11.4	29.5	11.8	18.7	25.3	1.60	40	0.30		6.00	4.19
145-150	B3t		3.3	11.7	32.4	10.8	19.6	22.2	1.65	38			6.68	4.92
163-178	C												8.51	7.43
193-208	C		4.9	12.6	32.1	11.4	18.2	20.8	1.64	38	0.23		8.61	7.52
213-228	C							19.3					8.75	7.53

Sample depth	Horizon	Extractable cations Ca^{+2} (pH7, meq./100 g)	Mg^{+2} (pH7)	K^+ (pH7)	Na^+ (pH7)	H^+ pH8	Base sat. %	$CaCO_3$ eqv. %	Inorg. P PPM	Org. P PPM
4-6	A11	2.3	0.9	0.2	0.4	14.4	21		68	272
17-21	A12	0.9	0.4	0.2	0.3	12.4	13		54	208
34-39	A13	1.1	0.3	0.2	0.2	8.4	18		77	65
47-52	A2	1.2	0.4	0.1	0.1	4.5	29		37	8
70-74	B&A	3.7	2.5	0.2	0.2	8.0	45		85	55
82-87	B2t	7.4	3.0	0.3	0.2	6.3	63		113	49
105-110	B2t	4.8	2.6	0.3	0.3	5.3	60		161	39
122-127	B3t	6.5	2.6	0.5	0.3	5.3	65		266	47
145-150	B3t	7.9	1.4	0.4	0.3	3.4	74		313	11
163-178	C							18.3	-	-
193-208	C		0.9	0.3	0.2			19.8	307	15
213-228	C							20.6	301	23

Micromorphology 135-137cm. Many vughs, several rows of vesicles, but no planes and only a few channels. Plasma as in B2t, but here arranged in thick, strongly-oriented, voidcutans. Some iron-stained plasma in nodules or as cutans inside argillans. Some fecal pellets and many glaebules as in B1. Agglomeroplasmic to porphyroskelic pattern. In-vosepic plasmic fabric.

Interpretation

This profile 7B situated in the upper slope position is the deepest and most strongly-developed of the soils investigated. The lime is leached to a depth of 1.6 m and the clay content of the illuvial horizon is more than twice of that in the eluvial horizon. The deep development is reflected in all the horizons. The profile has the thickest of both eluvial and illuvial horizons, a clear B and A transition horizon and a pronounced albic horizon. The differential precipitation of clay and lime is not observed in the horizons studied, but presumably occurs below 1.7 m. Glaebules are present at 1.3 m depth, but there is no sign of pseudogley polygons, indicating the better drainage condition in this upper slope position.

Profile No. 7C

Typic Argiudoll or typic Argiboroll, fine-loamy, mixed, USDA; Luvic Phaeozem, FAO; concave segment, 5% inclination to south, cross section I. (Figs 18 and 19).

A11 0 to 25 cm, very dark grayish brown (10YR 3/2 m, 4/3 d), fine sandy loam; moderate medium granular; very friable, slightly sticky, slightly plastic; clear smooth boundary.

A12 25 to 37 cm, dark brown (10YR 3/3 m, 5/3 d); fine sandy loam; massive to weak medium subangular blocky; very friable, slightly sticky, slightly plastic; clear wavy boundary.

B21t 37 to 60 cm, dark yellowish brown (10YR 4/4 m, 6/4 d); sandy clay loam to loam; weak fine and medium blocky; sticky, plastic, firm; tongues of A12-material, 5-10 cm wide reach into the B21t, thinning downwards; gradual boundary.

B22t 60 to 83 cm, dark yellowish brown (10YR 4/6 m, 6/4 d); fine sandy loam; coarse prismatic breaking into coarse blocky peds with thin clay skins; sticky, plastic, very firm; gradual wavy boundary.

BC(g) 83-105 cm, mixture of light gray (5Y 6/2 m) and yellowish brown (10YR 5/6 m); fine sandy loam, with a few light brownish gray (10YR 6/2 m) clay skins; moderate coarse blocky; sticky, plastic; clear wavy boundary.

C(g) 105 to > 140 cm, mixture of light gray (5Y 7/2 m) and strong brown-yellowish brown (8.75 YR 5/6); fine sandy loam to loam; structureless, massive, sometimes breaking into moderate medium blocky peds with pale brown surfaces; sticky, plastic; violent effervescence with HCl.

Micromorphology 36-38 cm. The thin section is crossed by transverse 0.5 mm wide weak metaplanes, some vughs, a few chambers and areas of compound packing voids are present. The plasma is of humus and some unrelated clay plasma, also a few weak argillans. Few diffuse sesquioxidic nodules. Some fecal pellets and pedotubules. Agglomeroplasmic to intertextic pattern. Vo-argillasepic to isotic plasmic fabric.

Micromorphology 54-56 cm. The voids are divided into weak metaplanes and channels: many ovoid, irregular metavughs and some vesicles. Clay plasma dominates, arranged partly as argillans though partly unrelated. Few diffuse and some sharp iron nodules. Few pedotubules and fecal pellets. Porphyroskelic pattern. Skel-in-vosepic plasmic fabric.

Micromorphology 70-72 cm. The voids are all lined as meta channels, vesicles, chambers and ovoid vughs. Some voids are filled with clay and sesquioxides, though mainly clay plasma arranged as thick (105-200 μm) strongly-oriented cutans, but some are unrelated. Some cutanic sesquioxidic plasma (ferrans) is seen. Fairly frequent iron nodules. Porphyroskelic pattern. In-vosepic plasmic fabric.

Micromorphology 93-95 cm. The voids are wide though weak metaplanes, vughs and vesicles. Mostly unrelated clay plasma or arranged as a few thin void cutans. Some fecal pellets, a few lime fragments. Porphyroskelic pattern. Vo-insepic plasmic fabric.

Micromorphology 107-109 cm. Mostly unrelated clay plasma or arranged as thin argillans. No sign of calcite crystals or cementation. Some traces of iron-stained plasma. Vo-insepic plasmic fabric.

Analytical data profile 7C

Sample depth cm	Horizon	Particle size distribution % of <2 mm: >2	2.0-0.6	0.6-0.2	0.2-0.06	0.06-0.02	0.02-0.002	<0.002	Bulk density g/cm³	Porosity %	Org C %	C/N	pH H_2O	pH KCl
0-10	A11	5	5.4	15.0	34.3	16.4	14.6	14.3	1.01	61	2.38	11	6.11	4.37
20-30	A12	4	7.4	15.6	33.9	16.8	12.5	13.8	1.50	44	0.76	10	6.78	5.78
35-45	B21t	2	3.9	12.3	31.0	14.4	16.7	21.7	1.65	39	0.34	9	7.52	5.80
55-65	B21/22t	4	3.9	12.4	30.9	14.4	18.3	20.1	1.73	36	0.20		7.72	5.99
70-85	B22t	10	7.7	12.7	30.4	14.2	16.9	18.1	1.66	39	0.17		7.86	6.07
88-96	BC(g)	5	4.8	13.9	33.6	12.7	16.8	18.2	1.66	39			7.82	7.02
108-116	C(g)	12	5.6	14.8	31.6	15.0	19.3	13.7	1.75	36			8.36	7.11

Sample depth cm	Horizon	Extractable cations (meq/100 g): Ca^{+2} pH7	Mg^{+2} pH7	K^{+} pH7	Na^{+} pH7	H^{+} pH8	CEC sum	Base sat. %	Fe_2O_3 pyr. %	Fe_2O_3 DCB %	Al_2O_3 pyr. %	Al_2O_3 DCB %	Fe+Al pyr/DCB	$CaCO_3$ eqv %	Inorg. P PPM	Org. P PPM
0-10	A11	10.7	1.2	0.1	0.5	8.1	20.6	60	0.19	0.65	0.14	0.21	0.35		63	236
20-30	A12	10.0	0.9	0.1	0.6	2.7	14.2	81	0.09	0.73	0,09	0.20	0.18		45	121
35-45	B21t	11.7	1.3	0.2	0.3	1.6	15.1	90	0.05	1.02	0.07	0.28	0.09		49	91
55-65	B21/22t	10.9	1.2	0.2	0.3	1.5	14.1	89	0.04	0.97	0.06	0.23	0.07		263	-
70-85	B22t	11.0	0.9	0.2	0.4	1.3	13.7	91	0.04	0.99	0.07	0.27	0.08		305	75
88-96	BC(g)		1.1	0.2	0.4	1.1			0.04	0.92	0.06	0.24	0,08	3.4	374	61
108-116	C(g)		1.0	0.2	0.4	0.9			0.02	0.73	0.03	0.17	0.05	19.7	316	37

Interpretation

Profile 7C, situated just below the steep slope, is a relatively compact clay enriched profile, with marked humification and nitrification and conforms more closely to a base-enriched lower slope profile with so high a base saturation that the epipedon becomes mollic and the profile meets the criteria of a Mollisol. It is also alkaline below 30 cm depth and hence shows no diagnostic pattern of carbonate-clay interactions.

Kolindsund

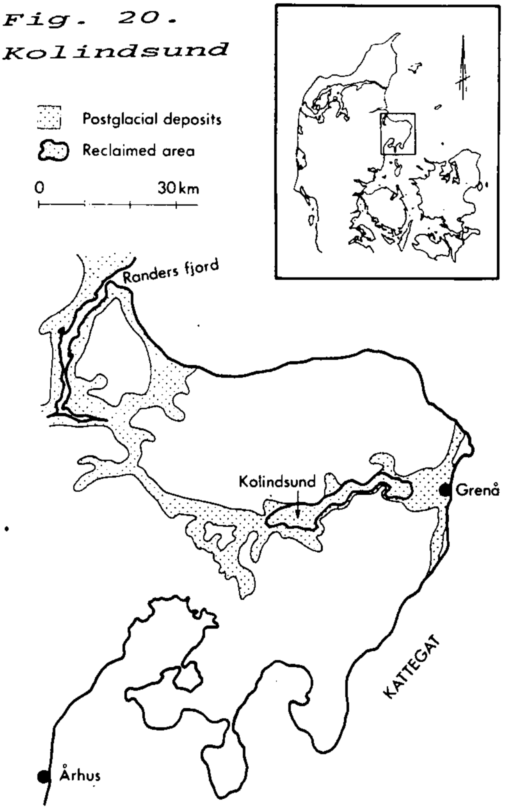
The reclamation of wet lands in Denmark has a long history. In the last half of the 19th century reclamation was intensified with the development of better pumping equipment, and many of the greatest Danish reclamation projects were carried out during this period. The area to be visited, Kolindsund, (fig. 20) is one of the more successful projects, causing only minor agricultural and environmental problems. The soils in Kolindsund are in most instances gyttja soils. In Kolindsund there is a wide variety of gyttja of different geological origin and therefore provides a good opportunity for showing Danish examples in a small area.

The term "gyttja" and its use in the classification of sediments have been discussed at length since Hampus von Post defined the term in 1862. Reviews of this discussion have been given by Hansen (1959) and Grosse-Brauchmann (1961). Since most of the sediments in Kolindsund are not pure gyttjas, but mixtures of gyttja with rather large amounts of silt and clay, the simple classification proposed by Ekström (1927) is adopted for describing the parent materials. Accordingly, the limit between gyttja-mixtured mineral soil and mineral-mixtured gyttja soil is set at 6% organic matter and between the latter and pure gyttja at 40% organic matter. It should be mentioned that the European term gyttja is very close to coprogeneous earth in Soil Taxonomy, but coprogenous earth is restricted to limnic materials. As the main part of the material in Kolindsund is of marine origin, we have maintained the term gyttja.

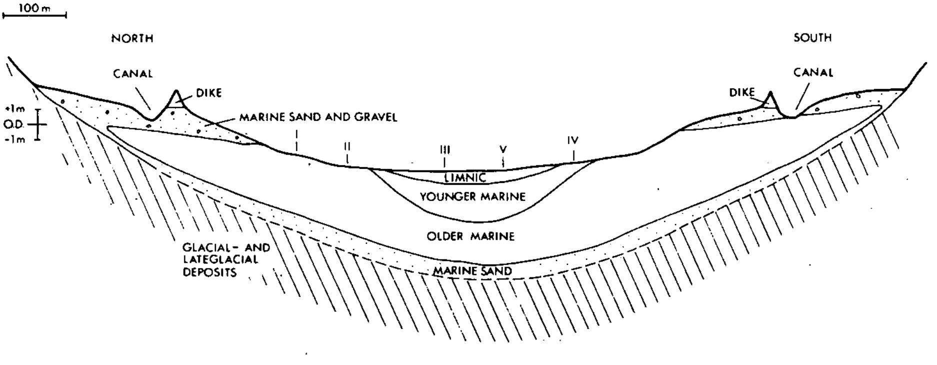
Geological development

Kolindsund is situated in a glacial valley system formed in a prequaternary valley in the eastern part of the Djursland peninsula (Fig. 15). It comprises the reclaimed bottom of a former freshwater lake, originally an old inlet. The main depositional development of the area started when the postglacial Littorina Sea in the Atlantic period transgressed into the valley system (Tapes transgression), rising to a level of 3.5-4.5 m O.D.

Fig. 20.
Kolindsund



The postglacial deposits in the central part of the Djursland peninsula. The location of the investigated area Kolindsund is shown. (After SCHOU 1949).



Sketch profile of the Kolindsund valley showing the situation of the three geological series investigated: The Older marine, The Younger marine and The Limnic series. Approximate location of the profiles is shown.

During the maximum transgression the area was a sound, connecting Randers fjord to the Kattegat at Grenå. Sandy deposits from the transgression phase and from the following period with strong tidal currents are found in borings at the base of the marine series (Fig. 20). Regression combined with sediment transport along the coast caused the connection with the sea at Grenå to be cut off. During this period the 14-16 m thick Older Marine Series (Andersen et al. 1936) of clay and clay-gyttja was deposited (Fig. 4-7). Only a narrow creek supplied the area with water from the open sea, providing ideal conditions for Ostrea and Myttilus along the banks. When sand almost closed the outlet, this creek became filled with a silty clay-gyttja with large amounts of Cardium shells (Younger Marine Series) in places, (Fig. 20). The salinity changed rapidly through brackish towards freshwater conditions. The brackish and freshwater sediments are highly calcareous silty clay-gyttjas with considerable amounts of diatoms. This Limnic Series (max. 1 m) was deposited in the deeper parts of the lake, mainly above the former creek (Fig. 20). Investigations of the content of foraminiferas and diatoms in the youngest sediments show that this final change in environment only comprises the uppermost metre of the geological sequence. Only the upper 30-40 cm kan be considered to be purely limnic. The presence of highly marine diatoms in the Limnic series suggest that from time to time the shallow lake (max. depths 3-4 m) received salt water through the narrow inlet at Grenå.

Reclamation and land use

In 1874-1880 the freshwater lake was reclaimed by means of dikes, canals and pumping stations. The area within the dikes is about 26 km^2. Because of the very thin or missing limnic sediments, the Older Marine Series covers approximately 40 percent of the area, Younger Marine Series 10 percent and Limnic series only 20 percent.Sandy and gravelly beach deposits and postglacial marine sand in the inlet cover the remaining 30 percent (Andersen et al. 1936). In addition there are small areas of peat. Most of Kolindsund lies below sea level, with a minimum elevation of -3 m O.D.

Kolindsund is today a highly fertile agricultural area almost entirely planted in spring-sown crops: wheat, grass for seed, barley, poppy for seed, etc..

Climate and hydrology

The location in a former glacial valley with hills up to 40-60 m O.D. to the north and south gives a typical valley climate with frequent temperature inversions. The mean period without temperatures below zero is only 143 days, compared with 180 or more days in eastern Jutland as a whole (40 year period 1886-1925). The mean annual temperature is 7.3 ^{0}C with maximum 16.2 ^{0}C (July) and minimum -0.3 ^{0}C (February). The mean annual precipitation is 593 mm with maximum 76 mm (August) and minimum 35 mm (February); (Meteorologisk Institut 1933).

The hydrology is also highly influenced by the position in the valley. There is a large in-flow of water into the pumped area. The water pumped out of the diked area is 2.8 times the precipitation. The main hydrological data are shown below.

Table 1.
Main water balance data from Kolindsund (Korkman, 1980)

	Mean (1967-76) mm/year
Precipitation	586
Actual evapotranspiration	422
Inflow of groundwater	1043
Pumping at Fannerup (17.3 km^2)	1207
Pumping at Enslev (9.1 km^2)	2412

The difference between the two pumping stations (2412-1207 mm) = 1200 mm/year is due to seepage of water from the canals through the dikes in the Enslev area. The main reason for the seepage is the location of the canals in the old beach area. The groundwater inflow is mainly in the sandy material below the gyttja forming springs where the gyttja layer is thin. The spring area has been planted with willows once used for making wicker baskets etc.

Profile No. 8A

Aquent USDA; Eutric Gleysol, FAO;

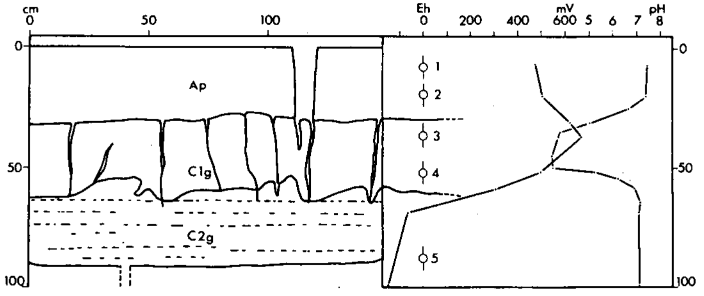
Locality:	Skarnaes, Kolindsund, UTM 32VPH053511.
Vegetation:	Burnt stubble field after spring-sown wheat.
Parent material:	Silty clay-gyttja, brackish and limnic. Cardium found below 64 cm.
Topography:	Level bottom of former lake, 50 m from main channel, approximately -2.7 m O.D.; surface with open cracks.
Remarks:	Profile description September 1973. In August 1976 a 1-2 mm zone of white (10YR 8/1) crystal-clusters of gypsum was found around mottles in C1g.This was not visible in 1973. Water-seepage from cracks below 60 cm (September 1973). Water level in craks at 40 cm in March 1976.

Ap 0-30 cm; pale brown (10YR 6/3, dry) silty clay loam mottled with yellowish red (5YR 5/8, dry);Ap broken by few 10-15cm wide open cracks, extending into polygonal pattern of wedge-shaped cracks in C1g (max. width 2-7 cm); moderate strong structure, both very fine subangular blocky and medium crumb; soft; gradual, smooth boundary.

C1g 30-60 cm; dark greyishbrown -very dark grayish brown (2.5Y 4-3/2) silty clay, highly mottled with yellowish red (5YR 4-5/8) mainly along cracks and around old root-tubes; massive, breaking along horizontal planes; very firm grading into sticky, slightly plastic in C2g; clear, irregular boundary.

C2g 60 cm-; black (5Y 2/2) silty clay loam; massive; sticky and slightly plastic; strong odour of hydrogen sulphide.

Fig. 21.
Profile No. 8A



Analytical data
Profile No. 8A

Sample depth cm	Horizon	Particle size distribution %<2mm (mm) 2-0.05 sand	0.05-0.002 silt	<0.002 clay	Total water 110°C % loss	Density mineral matter	Density solid matter	Bulk density g/cm³	Porosity %	COLS %
3-13	Ap	10.7	55.3	34.0	50.3	2.46	2.26	0.58	74	-
31-41	C1g	6.6	49.2	44.2	116.7	2.41	2.03	0.44	78	22
47-57	C1g	6.3	63.7	30.0	206.6	2.48	2.09	0.36	83	29
83-93	C2g	7.5	62.5	30.0	258.2	2.47	2.23	0.32	86	36

Sample depth cm	Horizon	pH (moist) H_2O	pH (dry)	Eh (moist) mV	$CaCo_3$ eq %	Loss on ign.550°C % (I)	Org C %	C in % on I	C/N	Total sulphur % (S)	Inorg. P ppm	Org. P ppm
3-13	Ap	7.5	7.6	483	1.3	20.1	6.81	34	6.8	0.4	426	432
31-41	C1g	3.8	3.8	675	0.0	30.2	10.11	34	6.5	1.7	293	345
47-57	C1g	4.6	3.8	500	0.0	30.9	14.46	47	9.2	2.7	335	472
83-93	C2g	7.1	7.8	-115	9.4	23.5	10.96	47	7.0	2.4		

Profile No. 8B

Aquent, USDA; Eutric Gleysol, FAO;

Locality:	Gammeldaemning, Kolindsund, UTM 32VPH072528.
Vegetation:	Harrowed field after harvest of grass for seed (Poa pratensis L.).
Parent Material:	Gyttja containing silty clay. Older marine serie. With many fine sandy, calcareous laminae below 60 cm depth. Remnants of leaves, mainly Zostera sp., found between laminae.
Topography:	Level bottom of former lake, approximately -1.6 m O.D.

Remarks: Water sepage from cracks below 110 cm (August 1973).

Ap 0-40 cm; dark brown (10YR 3/3) silty clay with some mixture of aeolian sands; moderate, very fine, subangular blocky structure; very firm; clear, wavy boundary; wedge-shaped cracks (max. width 5-12 cm), partially filled with material from Ap, divide horizons below Ap in a very large polygonal pattern; cracks extending from 40 to approximately 120 cm; crack material and Ap show no effervescence with HCl, contrasting other horizons.

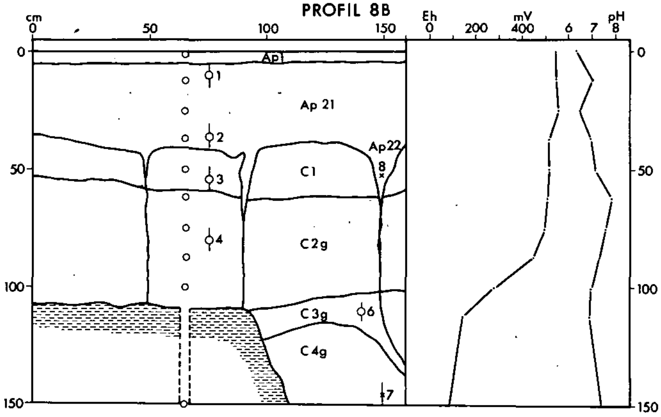
C1 40-60 cm; dark grayish brown (10YR 4/2) silty clay loam, highly mottled with red and yellowish red (2.5 YR 4/6 - 5YR 5/8); massive, firm; gradual wavy boundary.

C2g 60-105 cm; grayish brown (10YR 5/2) silty clay loam with many, light gray (10YR 7/1) fine, sandy laminae showing violent effervescence with HCl; highly mottled with red (2.5YR 4.5/6) mostly along sandy laminae; massive; friable passing into slightly sticky, slightly plastic in lower part; clear, wavy boundary.

C3g 105-120 cm; greenish gray (5YR 5/1) silty clay loam, mottled with yellowish red (5YR 4/6) mostly along cracks and sandy laminae; massive; sticky and pastic; clear, wavy boundary.

C4g 120 cm-; greenish gray (5GY 4/1) silty clay; sandy laminae discernible by strong effervescence; strong odour of hydrogen sulphide; massive; sticky and plastic.

Fig. 22.
Profile 8B



Analytical data
Profile 8B

Sample depth cm	Horizon	Particle size distribution (mm) Carbonate-free %<2mm sand (2-0.05)	silt (0.05-0.002)	clay (<0.002)	Total % water 110°C % loss	Density mineral matter g/cm³	Density solid matter g/cm³	Bulk density g/cm³	Porosity %	COLS %
5-15	Ap	15.8	42.5	41.7	-*)	2.60	2.47	1.08	56	-
31-41	Ap	16.1	45.0	38.9	-	2.59	2.58	1.17	55	-
49-59	C1	11.2	54.8	34.0	40.8	2.63	2.52	1.05	58	6
75-85	C2g	9.9	54.0	36.1	54.6	2.62	2.63	1.04	61	11
107-113	C3g	8.5	57.5	34.0	92.0	2.46	2.64	0.76	71	17
140-150	C4g	7.5	51.8	40.7	-	2.63	-	-	-	-

Sample depth cm	Horizon	pH (moist) 1:1 H_2O	pH (dry)	Eh (moist) mV	$CaCO_3$ equiv. %	Loss on ignition 550°C % (I)	Organic C % (C)	C in % of I	C/N	Total sulphur % (S)	Inorg. P ppm	Org. P ppm
5-15	Ap	7.0	6.9	545	0.0	7.3	2.93	40	10.8	-	404	216
31-41	Ap	6.9	7.0	515	0.1	7.3	2.97	41	10.1	-	-	-
49-59	C1	7.2	8.2	510	3.6	6.0	2.08	35	13.0	-	388	506
75-85	C2g	7.6	8.1	470	7.0	4.5	1.68	37	13.3	0.1	404	502
107-113	C3g	6.9	7.9	160	6.5	5.5	2.04	37	13.6	0.5	-	
140-150	C4g	7.4	7.9	80	10.1	6.0	1.94	33	13.5	0.9	-	

Sangstrup
Profiles 9A and 9B

Soils on chalk

Soils developed over chalk in Denmark have in many places a clay-rich B horizon at the contact with that chalk. This B horizon ranges in thickness from a few mm to about 5 cm. It follows the chalk surface into solution pipes and is commonly thicker at the bottoms of pipes than elsewhere. Similar B horizons have been reported in other countries (Ballagh and Runge, 1970, some formed in residues from the dissolved chalk and others in overlying sediments. What will be presented at this locality are soils which in places have developed a clayrich B horizon in others not.

The parent material and climatic data

The lower Danian bryozoan chalk exposed at Sangstrup Klint was formed as bioherm structures, i.e., limestone mounds of biological origin. Today they are visible in the cliffs as undulating chalk benches with intervening flint layers. The chalk, on average, contains 30% bryozoan fragments in a fine-grained matrix (Thomsen, 1976). The average particle size limit between these two basic textural elements is about 125 µm. Thomsen (1976) shows that the materials from the southeast flanks and from the tops of the bioherms are coarser than the materials on northwest flanks and in the basins.

The sample area is level and lies 11 m above sea level. The drainage conditions are very good. Shortage of water can affect plant growth in summer. The average annual precipitation at Fornaes (4 km to the SE) is 501 mm and mean annual temperature 8.1^{0}C (Lysgaard, 1969).

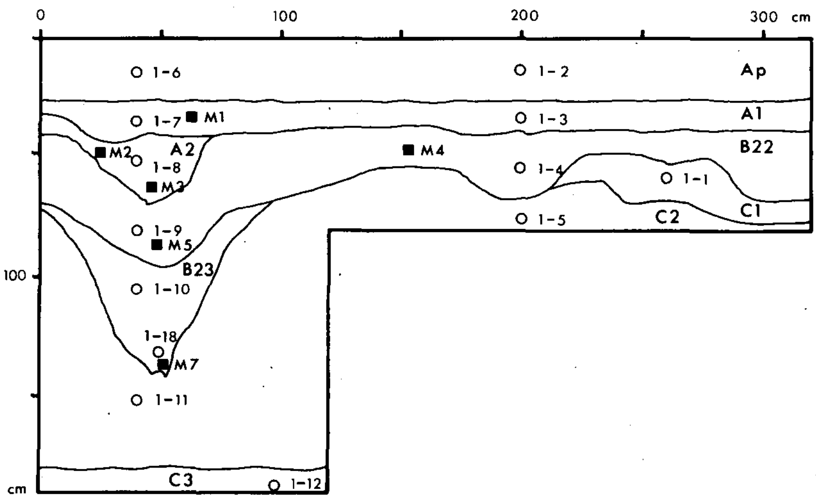
The data for these earlier sampled mollisol profiles will be presented in the following.

Profile descriptions

Profiles 9Aa and 9Ab were exposed on the face of one pit about 3 m long. The pit was dug in a ploughed field after barley. Fig. 23 shows a diagram of the two profiles. Profile 9A is a Typic Argiudoll, USDA and Luvic Phaeozem, FAO.

Fig. 23.
Profile 9Aa and 9Ab

Fig. 23 to show horizons in profiles 9Aa and 9 Ab, the former under 200 cm and the latter under 50 cm mark. Sites of bulk samples are shown by open circles and by black squares for micromorphological samples. Bulk samples are identified by numerals and micromorphological samples by the letter "M" and numbers.



Profile No. 9Aa

Ap 0-26 cm, very dark gray (10YR 3/1); fine sandy loam, many angular gravel-sized fragments of flint, a few of chalk and a few of metamorphic rock; weak medium subangular blocky structure; friable consistence; some undecomposed stubble and many fine roots; abrupt smooth boundary.

A1 26-39 cm, very dark grayish brown (10YR 3/2); distinct fine dark yellowish brown (10YR 4/4) mottles increasing in number with depth; fine sandy loam; many angular gravel-sized fragments of flint, few of chalk and a few cobbles of flint; weak fine angular blocky structure; very friable consistence; many very fine roots; many worm holes, gradual wavy boundary.

B22t 39-55 cm, dark yellowish brown (10YR 4/4) with many dark vertical streaks, 3-6 mm wide; sandy clay loam with a few gravel-sized fragments of chalk and flint; moderate medium angular blocky structure, firm consistence, many fine roots and worm holes; clear wavy boundary.

C1 55-70 cm, light yellowish brown (10YR 6/4) fine sandy loam with many gravel-sized fragments of chalk, a few of flint and a few of metamorphic rock, weak fine angular blocky structure; firm consistence; a few very fine roots; gradual wavy boundary.

C2 70-180 cm, white (10YR 8/2) chalk and flint fragments in a matrix of gravel; a few very fine roots in the upper part of the horizon; gradual wavy boundary.

Profile No. 9Ab

Profile 9Ab is on the face of the same pit as profile 9Aa, 2 m from the latter. It is a Typic Argiudoll USDA, Luvic Phaeozem FAO. The soil has a pipe or conical downward extension of the B horizon which in the upper end is about 1 m wide and extends down into the underlying chalk.

Ap 0-26 cm, very dark gray (10YR 3/1); loam; many angular gravel-sized fragments of flint, a few of chalk and a few of metamorphic rock; weak medium subangular blocky structure; friable consistence; some undecomposed stubble and many fine roots; abrupt smooth boundary.

A1 26-39 cm, very dark grayish brown (10YR 3/2); distinct fine dark yellowish brown (10YR 4/4) mottles increasing in numbers with depth; fine sandy loam; many angular gravel-sized fragments of flint, few of chalk and a few cobbles of flint; weak fine angular blocky structure; very friable consistence; many very fine roots; many worm holes; gradual wavy boundary.

A2 39-65 cm, brown (10YR 5/3) with many dark vertical streaks up to 3-6 mm wide, fine sandy loam with a few gravel-sized flint fragments; very weak fine angular blocky structure; very friable consistence; many very fine roots, gradual wavy boundary.

B22t 65-95 cm, dark yellowish brown (10YR 4/4) with very dark grayish brown (10YR 3/2) coatings on ped surfaces; sandy clay loam with a few gravel-sized fragments of flint and chalk; in the lower part strong medium granular structure; firm consistence; clay skins or thin shiny surfaces of clay and organic material are common; ped surfaces are wet; many worm holes; diffuse broken boundary.

B23 95-140 cm, brown-dark (10YR 4/3) with very dark grayish brown (10YR 3/2) coatings on ped surfaces; clay with many gravels and cobbles of flint and chalk; in the upper part of the horizon strong medium angular blocky structure; in the lower part strong medium granular structure; firm consistence; clay skins or thin shiny surfaces of clay and organic material are common; ped surfaces are wet; many worm holes; diffuse broken boundary.

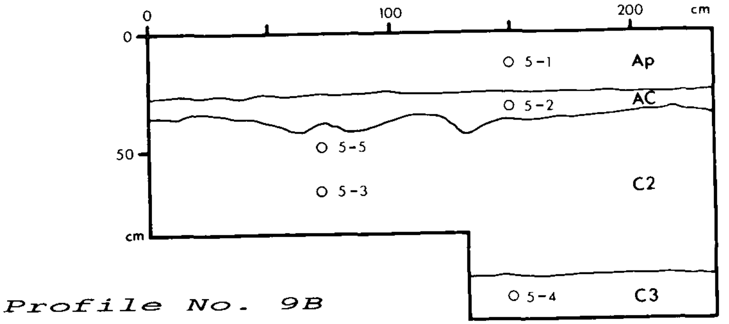
C2 140-180 cm, white (10YR 8/2) chalk and flint fragments in a matrix of gravel; a few very fine roots in the upper part of horizon; gradual wavy boundary.

C3 180- cm, white (10YR 8/2) granular chalk without flint.

Fig. 24.

Horizons in profile 9B

Fig. 24. Diagram to show horizons in profile 9B. Open circles show sites and numbers identify bulk samples.



Profile 9B is developed on top of a bioherm structure and is a Typic Rendoll, USDA, Rendzina, FAO. The pit was dug in a ploughed field after barley.

Ap 0-24 cm, very dark gray (10YR 3/1) loam with many chalk and a few metamorphic rock fragments of gravel and cobble sizes; weak medium subangular blocky structure; friable consistence; some undecomposed stubble and many fine roots, abrupt smooth boundary.

AC 24-40 cm, black (10YR 2.5/1) loam with many fragments of gravel and cobble sizes, most of them chalk, some flint and a few metamorphic rock; the number of chalk fragments increasing with depth; weak medium subangular blocky structure; friable consistence; many very fine roots; many worm holes; gradual wavy boundary.

C1 and C2 40-100 cm. Interfingering masses of various sizes of the two horizons, present especially in the upper part. Bodies of C1 horizon 10 x 20 cm or smaller in lateral cross-section extend down through much of the 40-100 cm depth and consist of light yellowish brown (10YR 6/4) loam with many gravel-sized fragments, mostly of chert but a few of each of flint and metamorphic rocks; very weak fine angular blocky structure; very friable consistence. C2 horizon materials consist of white (10YR 8/2) chalk and flint fragments in a matrix of gravel; horizon becomes progressively more continuous laterally with increasing depth; few very fine roots in upper part; some worm holes throughout.

C3 100- cm, white (10YR 8/2) granular chalk without flint.

Analytical data
Profile No. 9A,B

Physical and chemical data for entire samples.

Horizon (sample)	Depth cm	Particle size distribution (%) 2 mm-250 µm	250-63 µm	63-38 µm	38-2 µm	<2 µm	Particle density g/cm^3	Carbonates as $CaCO_3$ %	pH H_2O	pH KCl	C.E.C. NH_4OAc pH7 (meq/100 g)	Exchangable bases K (meq/100 g)	Exchangable bases Na (meq/100 g)	Organic carbon %	C/N
Profile 9Aa															
Ap(1-2)	14	16.9	32.4	10.8	27.0	12.9	2.52	0.5	7.9	7.2	12.2	0.8	1.4	1.98	10
A1(1-3)	34	16.3	36.8	10.1	25.9	10.9	2.51	0.4	8.3	7.3	12.4	0.4	1.1	0.89	11
B22t(1-4)	54	13.4	36.1	5.9	17.4	27.3	2.56	1.3	8.1	6.9				0.42	9
C1(1-1)	58	14.0	37.5	6.3	24.7	17.3	2.57	28.0	8.6	7.4				0.59	
C2(1-5)	76	18.1	11.6	1.8	20.7	47.7		75.1						0.67	
Profile 9Ab															
Ap(1-6)	14	12.9	30.5	14.0	27.8	14.8	2.54	0.5	7.9	7.2	12.2	1.3	0.9	2.05	
A1(1-7)	35	13.5	35.7	11.1	31.0	8.9	2.57	0.3	8.1	7.1	6.1	0.2	0.5	0.87	
A2(1-8)	51	23.1	43.2	8.6	20.0	5.0	2.54	0.2	8.6	7.8	2.6	0.1	0.7	0.19	
B22t(1-9)	80	12.9	33.3	5.4	18.4	30.1	2.61	0.6	8.0	6.8				0.43	
B23(1-10)	106	9.7	20.0	4.4	15.7	50.2	2.55	0.3	7.6	6.6				0.61	
B23(1-18)	132	6.5	7.8	3.7	21.0	61.1	2.37	10.4	8.0	7.0	43.0	0.5	3.1	1.30	8
C2(1-11)	152	14.9	14.2	4.0	21.2	45.7		80.6						0.47	
C3(1-12)	188	4.0	3.4	1.4	21.7	69.5		87.6						0.61	
Profile 9B															
Ap(5-1)	14	11.6	27.2	14.4	31.4	15.4	2.50	7.3	8.2	7.3	13.0	1.6	1.5	2.49	11
Ac(5-2)	32	9.5	26.6	13.8	35.6	14.3	2.52	15.9	8.4	7.5	9.9	0.8	1.3	1.66	10
C1(5-5)	48	15.0	28.6	9.7	27.3	19.4	2.50	22.4	8.6	7.4	7.8	0.2	1.0	0.53	
C2(5-3)	67	14.3	27.7	8.7	26.8	22.5		58.1						0.67	
C3(5-4)	111	0.6	0.4	0.4	27.4	71.2		91.1						0.55	

Proportions of fine clay, C.E.C., particle density and density separations.

Horizon (sample)	Depth cm	Fine clay <0.2 µm in % of total clay	C.E.C. (NaOAc) pH 8.2 clay fractions meq/100 g 2-0.2µm	C.E.C. <0.2µm	Particle density g/cm^3 light fraction <2.44 2 mm-250µm	light fraction 250-63µm	heavy fraction >2.44 2 mm-63 µm	63-38 µm	38-2 µm	Density separation 2.44 g/cm^3 light frac. in % of total 2 mm-250µm	250-63
Profile 9Aa											
Ap(1-2)	14	42	37.3	70.1			2.59	2.62	2.62	3.8	3.1
B22t(1-4)	54	62	32.1	74.9			2.60	2.64	2.68	1.3	0.9
C1(1-1)	58	35	29.4	66.0				2.66	2.67	0.6	1.8
C2(1-5)	76	44	32.9	63.2	2.18	2.23			2.50	75.0	28.7
Profile 9Ab											
A2(1-8)	51	26	22.9	75.9			2.58	2.65	2.67	1.8	1.7
B22t(1-9)	80	58	31.7	70.4				2.62	2.68	2.1	1.3
B23(1-18)	132	69	50.4	79.5			2.54	2.52	2.52	28.2	12.3
C3(1-12)	188	37	31.9	69.2	2.14	2.23		2.48	2.50	87.2	26.8
Profile 9B											
Ap(5-1)	14	48	39.3	73.5			2.58	2.60	2.61	5.0	2.8
C3(5-4)	111	53	59.6	83.7				2.48	2.50	87.7	72.7

Micromorphology

Descriptions are given in this portion of five thin sections from horizons of profile 9Ab and one from profile 9Aa. Three thin sections represent A horizons, one the B22t horizon, and one the B23 horizon of profile 9Ab. The single thin section from profile 9Aa represents the B22t horizon. Terminology in the descriptions is from Brewer (1976).

M1 (A1 33-35 cm, profile 9Ab).

Voids are mainly simple packing voids plus a few compound ones. Skeleton grains are largely rounded and subrounded; most are quartz but there are some feldspars plus a few chalk, dark mineral and mica grains in the silt. The plasma is dark isotropic humus with some silt. Most of the plasma is concentrated in 15-100 μm agglomerates. The proportions of plasma range from almost zero up to that of the skeleton grains. This is especially evident in the occasional pedotubules. A few partly rounded clay-iron nodules (300 μm in diameter) with embedded quartz grains and one with a clay matrix (700 μm) were found. A few papules composed of pure birefringent clay are seen. The thin section has an agglomeroplasmic-related distribution pattern and an isotic plasmic fabric.

M2 (A2 48-50 cm, profile 9Ab).

Voids, skeleton grains, and plasma are very similar to those of section M1. This also contains a few clay-iron nodules and some iron nodules 100-200 μm in size. The thin section has an intertextic and aggomeroplasmic related distribution pattern and an isotic plasmic fabric.

M3 (A2 61-63 cm, profile 9Ab).

Mostly packing voids with few, irregular 2 mm orthovughs. Skeleton grains are as in M1. Plasma is equally dominated by areas with silt grains and areas with isotropic humus and has smaller areas with birefringent clay. Further, birefringent clay is seen coating some chalk grains. This section contains papules up to 300 μm in size of which some are crushed into discrete smaller parts. There are a few 500 μm ellipsoidal iron nodules and a few spherical iron-clay nodules 150 μm in size. A few plant remains were also noted. The thin section has an intertextic-related distribution pattern and an arg-iso-silasepic plasmic fabric.

M4 (B22t 45-47 cm, profile 9Aa).

Voids are mostly rounded or elongated metavughs up to 300 μm in size. A 1.2 mm orthochannel with 100-200μm pellet-like agglomerates was noted. Skeleton grains are similar to those of the A horizon (M1 and M2). The plasma is yellowish brown clay of which most is weakly oriented and occurs as vugh cutans and grain cutans. Some areas are dominated by an anisotropic weakly oriented clay matrix, and there are few 200 μm iron nodules with sharp boundaries. The thin section has a porphyroskelic-related distribution pattern and a vo-skelsepic plasmic fabric.

M5 (B22t 85-87 cm, profile 9Ab).

Voids of two kinds, many equant metavughs, 100-300 μm in diameter are evident. Craze planes dividing the section probably originated in part from drying of the sample before impregnation. The skeleton grains are very similar to those of the A horizons. The section is dominated by yellowish brown clay-rich plasma, some in the form of vugh cutans and skeletans, but large areas are occupied by weakly oriented clay. Iron nodules up to 300 μm in size are common, some with sharp and others with diffuse boundaries. The thin section has a porphyroskelic-related distribution pattern and a vo-skel-argillasepic plasmic fabric.

M7 (B23 131-133 cm, profile 9Ab).

The two main components are flint and clay. The flint is largely of gravel size. It has inclusions of tridymite crystals. In some of the small 25 μm voids between the flint grains there are thin argillans. The clay is birefringent but very weakly oriented. It has a banded structure which in many places is parallel to the adjacent flint grains. This suggests that clay filled most of the space between the flint grains before the sample was dried. Some small diffuse iron nodules, 10-15 μm in diameter, were seen in the clay matrix. The thin section has a porphyroskelic-related distribution pattern.

Laboratory Methods day 4 - profiles

Particle size distribution:

50 g samples were oxidized by 6% H_2O_2 and $Na_4P_2O_7$ was used as dispersing agent. After removal of the fine fraction by wet sieving, the coarse fraction was dry-sieved 20 minutes using ASTM standard sieves on √2 scale. Sedimentation analysis was carried out with Andreasen pipettes in water bath at 20^0C. At the Mollisol profiles the oxidizing of organic matter and removal of carbonates was made at pH 4.5 before the particle size analysis, for further detail see Nørnberg et al. (1985).

Organic C: by dry combustion and weighing the evolved CO_2.

Organic N: by macro-Kjeldal method after Bremner (1965)

pH: was measured in 1:1 w/w mixture of soil/H_2O and soil/M KCl.

Cation exchange capacity (CEC) was determined with amonium acetate after Chapman (1965), bases by atomic absorption.

Exchange acidity with the barium chloride triethanolamine after Peech (1965).

Calcium carbonate was determined volumetrically according to Allison and Moodie (1965).

Total Sulphur was measured by automatic idometric titration of the SO_2 evolved by heating a sample in a LECO furnace.

Phosphorous was determined by extraction with 0.2 N sulphuric acid. Organic phosphorous is the difference between the content in an ignited (550^0C) and a non ignited sample.

Frie Iron and Aluminium (DCB) was determined by the Dithionite-citrat-natrium-bicarbonate methods (Mehra and Jackson 1960).

Organic bounded Iron and Aluminium was determined with 0,1 M Natrium pyrophosphat at pH 10 (USDA 1972) using AAS after centrifugation at 40.000 g.

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day 4 - profiles

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DAY 5

The excursion starts from Kalundborg* which is located in a bay between two peninsulas which are partly formed as marginal moraines during the later stages of the Weichsel glaciation. The town has developed around a castle built in year 1170. The church, which was built also around 1170, is rather unique with its five towers.

North-East of Kalundborg a rather large artificially reclaimed area, Lammefjorden, is found. This area was passed when travelling from the ferry port at Sjællands Odde to Kalundborg on day 4. The reclamation was started more than 100 years ago and it was completed in several steps. The deepest parts of the reclaimed area are situated 7 m below the present sea level. A number of other areas with Post Glacial marine deposits are also found in the North-Western part of Sealand. At present these areas are above sea level due to isostatic uplift. Some of the areas were passed when travelling to Kalundborg.

From Kalundborg the excursion proceeds East and South. About 15 km from Kalundborg a valley with extremely coarse textured sediments are passed. The valley and its deposits are due to a huge melt water river existing towards the end of the Weichsel glaciation. The river flowed North-West from glaciers covering large areas to the South and East. The reason for this flow direction was that a more Westward course was obstructed by glaciers covering the area which is now Storebælt. The valley system crosses a large part of Sealand, some of it is at a rather low attitude and covered with peat.

On the way across Sealand this valley system as well as a variety of more or less clearly expressed terminal moraines, kettle holes, glacial lake deposits and other glacial features are passed

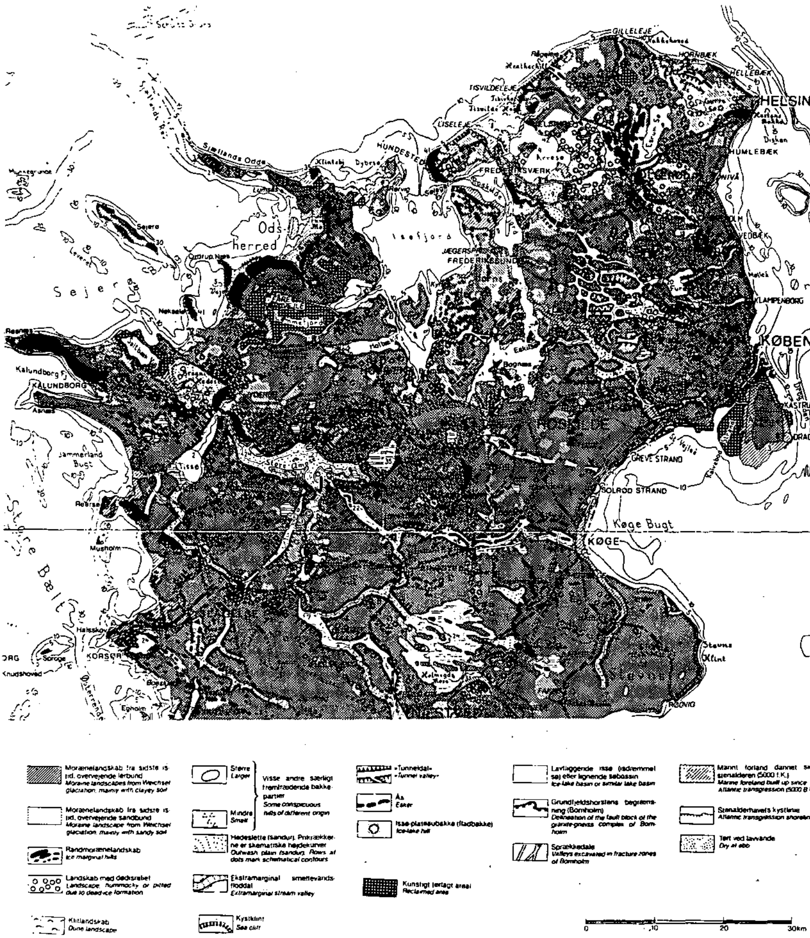
At Munkeskov Forest, Profile No. 10 is studied. It is formed on glacial till deposited rather late in the Weichsel glaciation by a glacier covering the area which is now the Bay of Køge on the East coast of Sealand and the adjoining parts of Sealand. Due to the presence of Senonian and Danian limestone in the area the till was originally calcareous but the lime has since been leached from the upper horizons. The soil is classified as a Dystric Podzoluvisol.

Note: **After finishing the guide book the place of overnight stay was changed to Slagelse.*

**After finishing the guide book the place of overnight stay was changed to Slagelse.*

Fig. 25
Day 5. Route Kalundborg - Helsingør

Fig. 26
Geomorphology of Sealand



After lunch profile No. 11, which is derived from a similar kind of glacial till, is studied. The soil which is cultivated is classified as an Orthic Luvisol. It is situated near Tune Landbo-skole which is an educational institution offering short courses, mainly to staff engaged in agricultural consultancy.

From Tune the excursion proceeds along the Western out-skirts of Copenhagen to Helsingør passing various glacial features. Helsingør is the site of Shakespeare's Hamlet and the well-known castle Kronborg which once, together with its counterpart on the Swedish coast, controlled navigation through the Sound.

From Helsingør a ferry boat takes the excursion to Helsingborg for overnight stay. One of the more reknown sights in Helsingborg is the tower Kärnan which was part of a former castle built about 1200 AD.

Profile No. 10

UTM:	33U PG 908421
Elevation:	40 m a.s.l.
Temperature:	January -0,2 °C, July 16,9 °C, Year 8,0 °C
Precipitation:	600 mm per year
Parent material:	Glacial till
Vegetation:	Recently planted Picea abies, formerly Fagus sylvatica.
Classification:	USDA: Typic Glossudalf FAO-Unesco: Dystric Podzoluvisol

Description:

Ah	0-9 cm	Very dark grey (10 YR 3/1) moist, sandy loam; weak fine subangular blocky; friable; very frequent coarse, medium and fine roots; clear smooth boundary.
E1	9-24 cm	Dark yellowish brown (10 YR 4/4) moist, sandy loam, weak fine subangular blocky; friable; few stones; common coarse, medium and fine roots; clear smooth boundary.

E2g	24-36 cm	Yellowish brown (10 YR 5/4) moist, sandy loam; few yellowish red (5 YR 5/8) moist, distinct sharp mottles; few small soft knobby nodules; moderate medium granular; friable; few stones; gradual smooth boundary.
E/Bg	36-44 cm	Yellowish brown (10 YR 5/4) moist, and pale brown (10 YR 6/3) moist, sandy loam; common yellowish red (5 YR 5/8) moist, distinct sharp mottles; few small soft knobby nodules; moderate fine angular to subangular blocky and moderate medium granular; firm to friable; few silt cutans; very few stones; few medium roots; gradual smooth boundary.
Btg1	44-70 cm	Dark yellowish brown (10 YR 4/4) moist, sandy clay loam; many brown (7.5 YR 5/4) moist, coarse distinct clear mottles; 15-25% pale brown (10 YR 6/3) moist, tongues; strong medium angular to subangular blocky; friable to firm; continuous moderate thick silt cutans on ped surfaces; very few stones; few fine roots; gradual wavy boundary.
Btg2	70-101 cm	Brown (10 YR 5/3) moist, sandy clay loam; common brown distinct clear mottles; few pale brown tongues in the upper part; moderate medium subangular blocky; friable to firm; few stones; very few fine roots; gradual smooth boundary.

Cg 101- cm Olive grey (5 Y 5/2) wet, sandy clay loam, many yellowish brown (10 YR 5/4) wet, distinct clear mottles, weak medium angular blocky; non sticky plastic; some lime nodules; few stones; very few fine roots.

Analytical data
Profile No. 10

Horizon	Depth cm	Texture, % of humus and calcium carbonate free fine earth: Sand Coarse	Sand Medium	Sand Fine	Sand Total	Silt Coarse	Silt Medium	Silt Fine	Silt Total	Clay	Org. Carbon %	Nitrogen mg/g	C/N
Ah	0- 9	5.1	14.2	38.4	57.7	13.3	7.9	7.1	28.3	14.0	4.45		
E1	9- 24	5.6	20.9	30.7	57.2	15.8	7.9	7.1	30.8	12.0	1.80		
E2	24- 36	7.5	26.9	25.4	59.8	18.2	7.4	3.6	29.2	11.0	-		
E/Bg	36- 44	-	-	-	-	-	-	-	-	-	-		
Btg1	44- 70	3.2	16.8	23.6	43.6	10.4	7.7	7.3	25.4	31.0	-		
Btg2	70-101	3.1	18.9	24.9	46.9	9.1	7.8	8.2	25.1	28.0	-		
Cg	101-	3.9	17.3	24.3	45.5	10.5	9.2	9.8	29.5	25.0	-		

Horizon	Depth cm	pH H_2O	pH $CaCl_2$	Exchangeable cations, meq./kg Ca	K	Mg	Na	H	CEC pH 8.1 meq./kg	Base-sat. %	$CaCO_3$ %	Phosphorus mg/kg
Ah	0- 9		3.2									
E1	9- 24		3.5									
E2	24- 36		4.0									
E/Bg	36- 44		-									
Btg1	44- 70		4.8									
Btg2	70-101		4.9									
Cg	101-		6.6									

Horizon	Depth cm	Bulk Density g/cm^3	Pore volume %	Water content (%) at pF 0.6	1.8	2.5	4.2	Fe, mg/g Dithion.	Fe, mg/g Pyrophos.	Al, mg/g Dithion.	Al, mg/g Pyrophos.
Ah	0- 9	0.94	65	56	33	27	11	4.5	-	1.4	-
E1	9- 24	1.23	54	48	28	23	8	4.5	-	1.4	-
E2	24- 36	1.44	46	40	26	21	7	4.8	-	1.6	-
E/Bg	36- 44	-	-	-	-	-	-	-	-	-	-
Btg1	44- 70	1.70	36	36	34	31	22	5.0	-	1.7	-
Btg2	70-101	-	-	-	-	-	-	6.8	-	0.8	-
Cg	101-	1.81	32	32	30	28	18	4.9	-	0.4	-

Interpretation:

This soil has an argillic B-horizon overlain by an E-horizon. The B-horizon has an irregular upper boundary due to deep tonguing of the E into the B-horizon. The upper part of the B-horizon has a low base saturation percentage. On this basis the soil is classified as a Dystric Podzoluvisols.

The deeper parts of the B-horizon have a higher base saturation percentage and in the C-horizon calcium carbonate may be seen. Calcareous C-horizons are often found in soils developed in the regions of East Denmark which during the Weichsel glaciation were covered by glaciers coming through the present Baltic Sea. Typically, the morainic material deposited by these glaciers was calcareous.

Profile No. 11

UTM:	33U UB 026664
Elevation:	30 m a.s.l.
Temperature:	January -0,2 °C, July 16,9 °C, Year 8,0 °C
Precipitation:	550 mm per year
Parent material:	Calcareous glacial till
Vegetation:	Field crops
Classification:	USDA: Mollic Hapludalf
	FAO-Unesco: Orthic Luvisol

Description:

Ap	0-25 cm	Greyish brown (10 YR 5/2) dry, loam; moderate fine subangular blocky; hard; frequent fine roots; abrupt smooth boundary.
ABtg	25-44 cm	Brown (10 YR 5/3) dry, loam; common yellowish brown (10 YR 5/8) dry, medium to fine distinct clear mottles; strong fine angular blocky; hard; continuous thin clay cutans in root channels and on ped surfaces; common fine roots; clear smooth boundary.

Btg1 44-82 cm Yellowish brown (10 YR 5/4) dry, sandy clay loam; common reddish yellow (7.5 YR 6/8) dry, medium to fine distinct clear mottles; strong medium angular blocky; hard; continous moderately thick clay cutans in root channels and on ped surfaces; very few small soft irregular manganese nodules; common fine roots; gradual smooth boundary.

Btg2 82-107 cm Yellowish brown (10 YR 5/4) moist, loam; common grey (5 Y 5/1) moist, and strong brown (7.5 YR 5/8) moist, medium distinct clear mottles; moderate medium angular blocky; firm; broken thick clay cutans in root channels and on ped surfaces; very few small soft irregular manganese nodules; few fine roots; gradual smooth boundary.

Btg3 107-145 cm Yellowish brown (10 YR 5/6) moist, loam; common grey (5 Y 6/1) moist, medium distinct clear mottles; moderate medium subangular blocky; firm; patchy thick clay cutans in root channels; very few small soft irregular manganese nodules; very few fine roots, abrupt wavy boundary.

CBtg 145- cm Yellowish brown (10 YR 5/4) moist, loam; common light brownish grey (2.5 Y 6/2) moist, and yellowish brown (10 YR 5/8) moist medium distinct clear mottles; moderate medium subangular blocky; firm; strongly calcareous; patchy moderately thick clay cutans in root channels; very few fine roots.

Analytical data
Profile No. 11

Horizon	Depth cm	Texture, % of humus and calcium carbonate free fine earth									Org. Carbon %	Nitrogen mg/g	C/N
		Sand				Silt				Clay			
		Coarse	Medium	Fine	Total	Coarse	Medium	Fine	Total				
Ap	0- 25	3.3	18.3	24.2	45.8	18.1	11.7	8.4	38.2	16.0	1.40	1.44	9.7
ABtg	25- 44	4.2	14.7	21.1	40.0	12.9	11.3	9.9	34.1	25.9	0.35	-	-
Btg1	44- 82	4.3	16.9	21.4	42.6	11.3	9.6	8.7	29.6	27.8	0.23	-	-
Btg2	82-107	3.9	14.0	21.9	39.8	10.1	11.9	12.3	34.3	25.9	0.13	-	-
Btg3	107-145	2.3	16.2	23.5	42.0	10.9	10.4	10.8	32.1	25.9	0.11	-	-
CBtg	145-	2.3	10.3	15.8	28.4	15.5	16.0	15.8	47.3	24.3	0.00	-	-

Horizon	Depth cm	pH		Exchangeable cations, meq./kg					CEC pH 8.1 meq./kg	Base-sat. %	$CaCO_3$ %	Phosphorus mg/kg
		H_2O	$CaCl_2$	Ca	K	Mg	Na	H				
Ap	0- 25	7.2	6.7	136.7	1.8	4.0	0.8	39.5	182.9	78	-	219
ABtg	25- 44	6.3	5.8	112.8	2.1	6.1	1.1	35.9	158.0	77	-	-
Btg1	44- 82	6.6	6.0	129.7	2.5	9.3	1.3	32.5	175.3	81	-	-
Btg2	82-107	6.7	6.1	130.7	2.0	12.5	1.5	18.5	165.4	89	-	-
Btg3	107-145	7.3	6.9	136.7	2.0	10.7	1.8	12.4	163.6	92	-	-
CBtg	145-	8.3	7.7	-	-	-	-	-	148.3	-	16.1	-

Interpretation:

The profile is a typical example of soils developed on calcareous morainic material having a comparatively fine texture. At present, the calcium carbonate has been removed by leaching from the upper layers. Following the removal of calcium carbonate and the subsequent decline in pH a clay migration takes place. The migrating clay particles are deposited near the level where calcium carbonate is still present and where pH accordingly increases.

Soils of this type are rated among the most suitable agricultural soils in Denmark, mainly because of the rather high water holding capacity. With suitable fertiliser applications high yields are obtained.

Laboratory Methods
Day 1-2-3-5 - profiles

Particle size distribution: Dispersion in 0.002 M $Na_4P_2O_7$ followed by sieving and hydrometer measurements.

Organic carbon: Made by dry combustion in a Leco furnace and gravimetric determination of evolved CO_2.

Nitrogen: Made by the Kjeldahl method.

pH_{H_2O} and pH_{CaCl_2}: Measured in suspensions of 10 g soil in 25 ml water or 0.01 M $CaCl_2$, respectively.

Exchangeable Ca, K, Mg and Na: Determined by extraction with 1 M ammonium acetate.

Exchangeable H: Determined by extraction with Ca-m-nitrophenolate buffers at pH 8.1.

CEC and base saturation percentage: Calculated from the determinations of exchangeable Ca, K, Mg, Na and H.

$CaCO_3$: Determined by treatment with hydrochloric acid and titration of carbon dioxide evolved.

Phosphorus: Determined by extraction with 12 N H_2SO_4.

Fe and Al: Determined by extraction with a sodium citrate-dithionite-hydrogen carbonate solution and 0.1 M sodium pyrophosphate, respectively. Fe and Al contents of extracts measured by atomic absorption spectrometry.

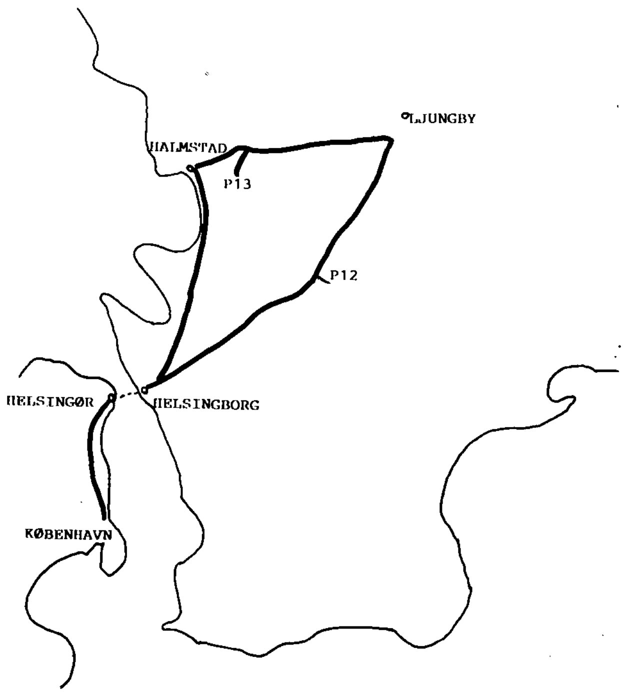
Bulk density and pore volume: By weighing a known volume of undisturbed dry soil, and measurement of particle density using a pyknometer.

Water content at specified pF values: Determined by means of a pressure membrane apparatus on undisturbed samples.

DAY 6

The object of the day is the study of podzol profiles developed on coarse textured morainic material originating directly from the underlying gneiss-granitic rock. Moraines and soils of this type are found North and East of the Fenno-Scandian fault zone.

Fig. 27.
Day 6. Route Helsingborg - Ljungby - Halmstad - København



From Helsingborg* to Profile No. 12 the excursion proceeds along route E 4. Just outside Helsingborg the landscape is developed on Weichselian galcial till similar to that found in Sealand. After 5-10 km the road passes an area with Late and Post Glacial marine sediments. Formerly, the area was a bay from Kattegat but due to the isostatic uplift following the melting of the Weichsel glaciers it is now above sea level. It has a width of about 20 km, but route E 4 proceeds about 20 km further along a narrow side arm with similar sediments. Towards North-East the sediments change from clayey to more sandy.

Just before Ørkeljunga, about 50 km from Helsingborg, the area with gneiss and granite close to the surface is reached. In this area the soils are developped on thin moraines of local origin deposited by glaciers advancing from North and East. Profile No. 12, which is developped on this kind of moraine, is located about 10 km South of Markaryd.

From Profile No. 12 the excursion proceeds to about 10 km South of Ljungby, then towards West to Tönnersjö about 15 km East of Halmstad. South and West of Ljungby an area covered by Late Glacial fresh water sediments is passed. Lunch en-route.

Profiles 13A, 13B and 13C at Tönnersjö are also developed on thin local moraines derived from and resting directly on the country rock.

From Tönnersjö the excursion continues to Halmstad, which is situated on Late Glacial marine deposits, and then South passing an area with similar deposits. About 40 km South of Halmstad a horst, Hallandsåsen, with a NW-SE directin is passed. South of Hallandsåsen the road continues across the areas with marine deposits and moraines which were passed in the morning.

The excursion proceeds with the ferry from Helsingborg to Helsingør and further to Copenhagen where it is terminated.

**The circular route in Sweden will be travelled in the direction opposite to that described.*

GUIDE TO EXCURSION IN SCANIA

Influence of the bedrock on the properties of the soils in Sweden.

The province of Skåne is a landscape strongly influenced by the situation on the border of Fennoscandia and Danish-Polish Trough. The relationship between bedrock, Quaternary deposits, topography and tectonics are extremely conspicous. Topographically significant lines often coincide with bedrock boundaries caused by faulting. Skåne is to a large extent covered by Quaternary deposits with greatly differing thickness. The deepest layers are found in areas with graben structures of the bedrock, e.g. the plains at Ängelholm, Vomb and the Alnarp Valley. The two first are still low lying areas while the Alnarp Valley is filled up with unconsolidated deposits, and not seen in the topography. An especially striking feature in Skåne are the horsts (Fig. A) of crystalline bedrock penetrating the sedimentary surroundings.

Most of the Swedish soils are formed on tills or sediments washed out from the moraine formation. The bedrock (or mineral) component of the soil is transported from its original source, the surface of the pre-Quaternary rocks. In spite of this and the mixing of materials from different sources, there still exists in most parts of Sweden an obvious relationship between the composition of the pre-Quaternary bedrock and the properties of the soil. The reason for this is that the material has been transported only a short distance.

Bedrock geology in Sweden

The bedrock geology of Sweden is dominated by Archaean and Proterozoic igneous and metamorphic rocks (Fig. B). Younger sedimentary beds (about ten restricted areas) are chiefly found in the southern part of Sweden and in the Caledonian belt. Formations from the Cambro-Silurian period comprise the remains of beds that one time were more continuous. They have usually been preserved from denudation by being sunk as a result of faulting (Fig. C). Fig. D shows a simplified bedrock map.

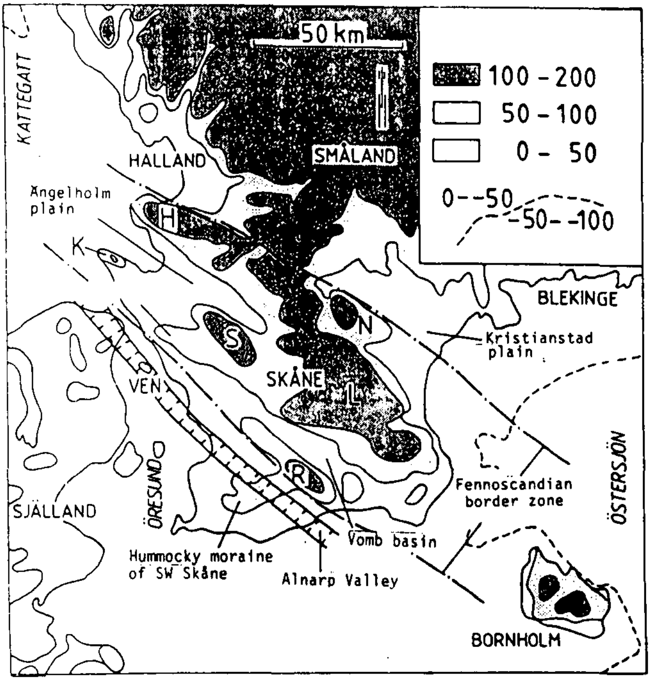
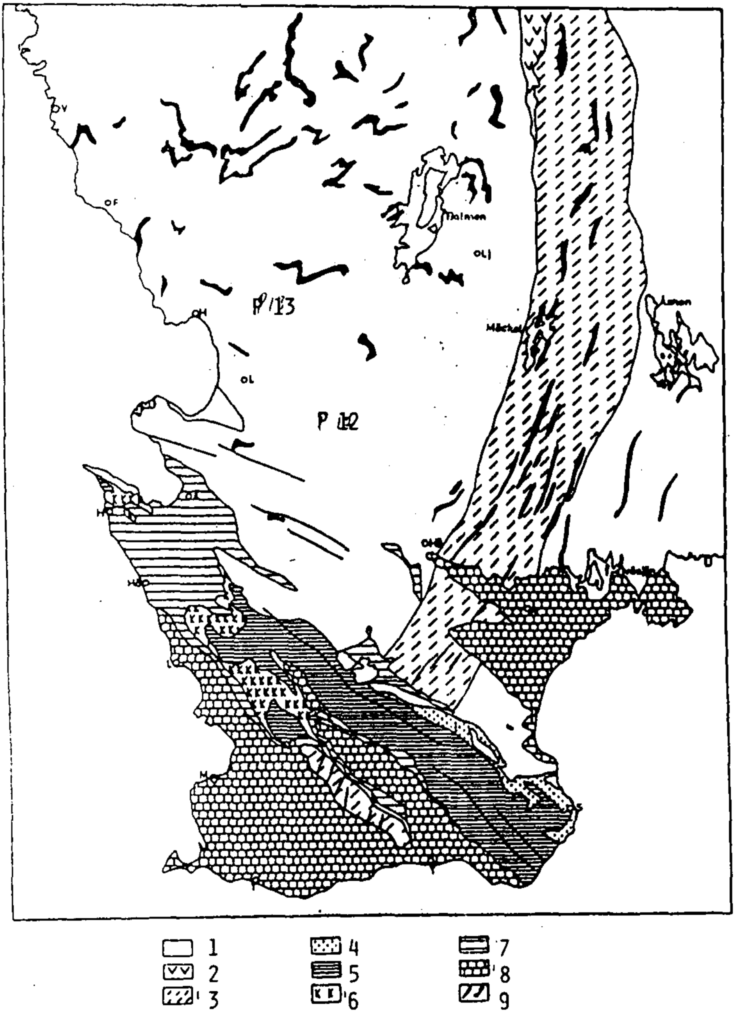


Fig. A. Outline map of topography and morphology in Skåne with adjacent provinces.

The horsts of Skåne are marked, K = Kullaberg, H = Hallandsåsen, S = Söderåsen, N = Nävlingeåsen, L = Linderödsåsen and R = Romeleåsen.

Fig. B. Outline bedrock map.



Legend:
1. Gneiss & Granite
2. Syenite
3. Schistose gneisses & Hyperite-dolerites
4. Sandstone
5. Cambro-Silurian (Shales)
6. Kågeröd-series
7. Rhaetic-Liassic
8. Cretaceous limestones
9. Greenstones

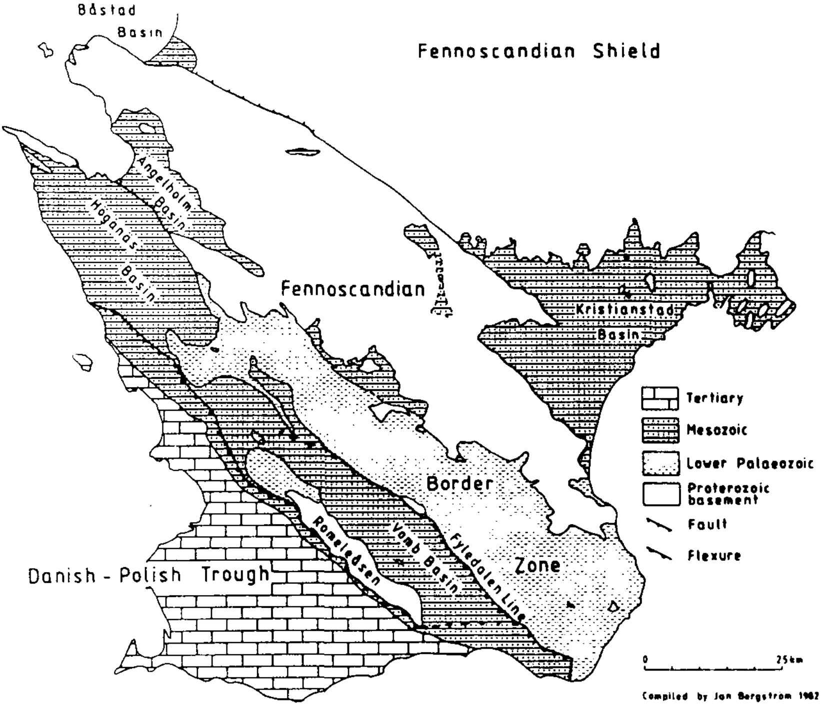


Fig. C. Large tectonic and stratigraphic units of Scania.

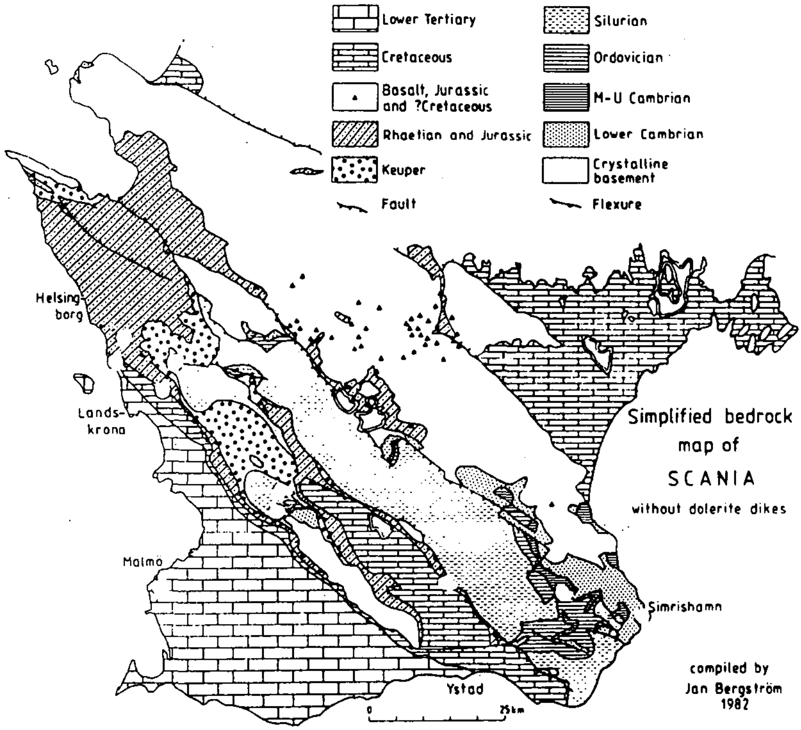


Fig. D. Simplified bedrock map of Scania.

The Cambro-Silurian deposits of Skåne, which are more than 5,000 ft thick (about 2 000 metres), differ from those of other regions in Sweden, in that shales are more predominant while limestones are secondary.

Mesozoic deposits (Figs. E and F) are found only in Skåne and in the bordering parts of the provinces of Halland and Blekinge. They include the motley-coloured sandstones and clays of the Triassic Kågeröd series and also the coal-measures of Skåne. These latter comprise the youngest part of the Triassic and the oldest part of the Jurassic. The petrography is characterized by grey sandstones, shale-clays, fire-clays and secondary layers of coal. Some of the clays are refractory.

During Jurassic-Cretaceous periods, volcanic activity resulted in about 70 small basalt occurrences in northern Skåne.

During the period of regression, which followed upon the deposition of Jura sediments the land area was exposed to deep going chemical weathering. This period continued to the later part of Cretaceous. The feldspars were changed into kaolinite resulting in a smooth and clayey bedrock.

The Cretaceous (Figs. G and H) are the most widely distributed and thickest deposits of the Mesozoic formations of south Sweden. They are supposed to have had a wider distribution, founded on small remains in northern Skåne.

The Cretaceous layers of south-west Skåne are nearly 6,500 ft thick (more than 2,000 metres).

Sediments from the oldest Tertiary period are found only in Skåne, above the Cretaceous rocks.

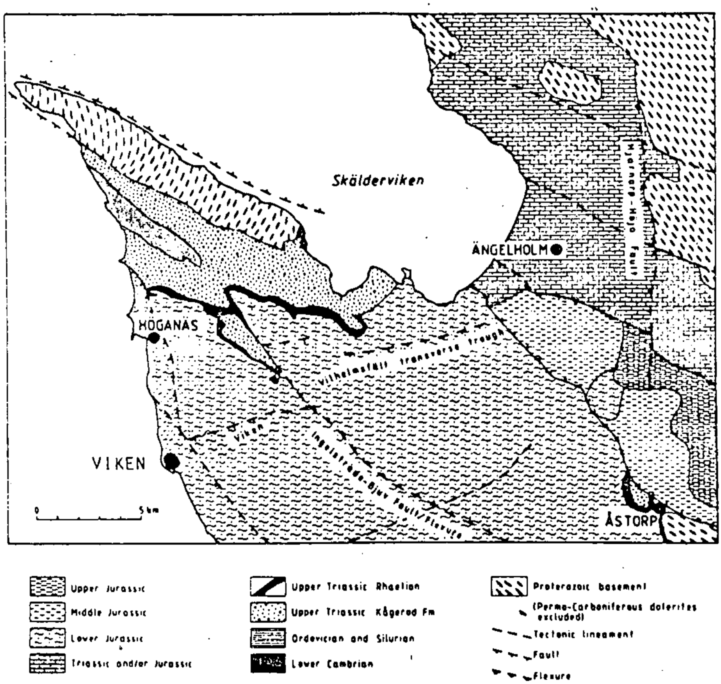


Fig. E. Geological sketch map of NW Scania (After Wikman, Norling, Sivhed & Karis, 1981).

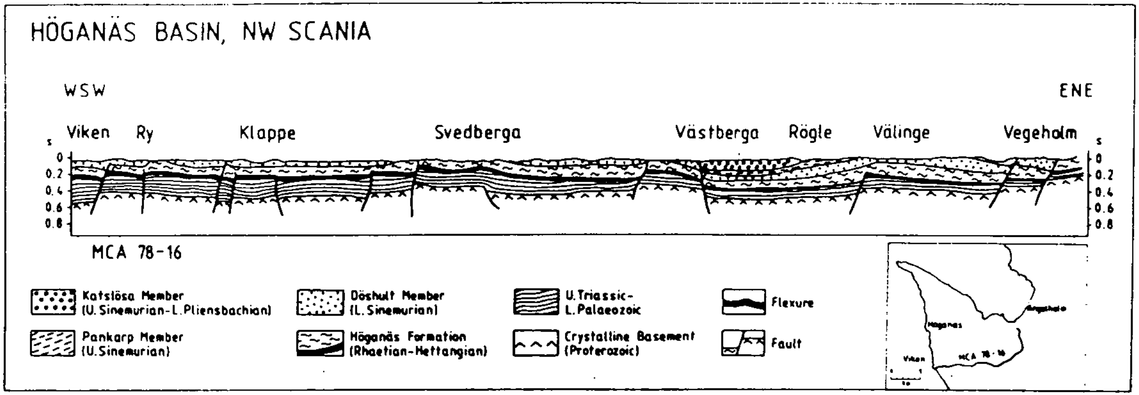


Fig. F. Geological section traversing NW—SE trending Saxonian faults and flexures. Based on reflection seismic profile. Höganäs area, Fennoscandian Border Zone, NW Scania (height scale in seconds two way time).

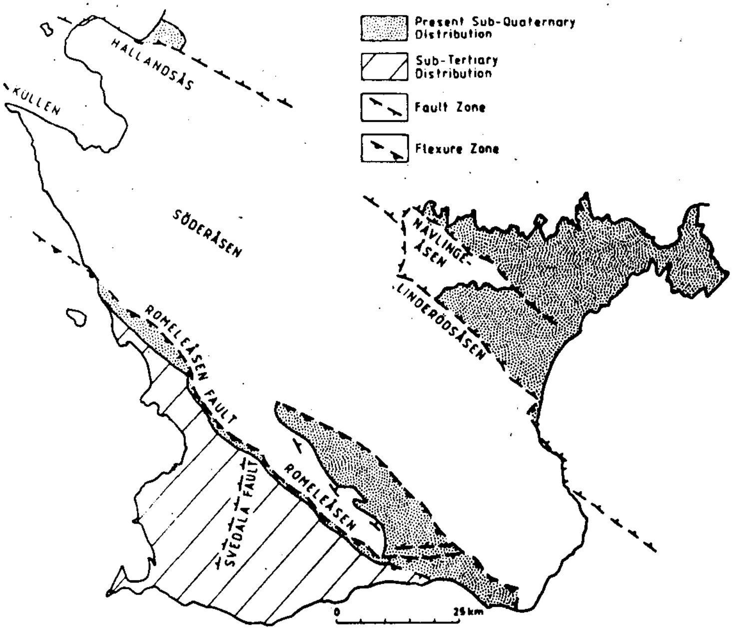


Fig. G. Map of Scania showing distribution of Cretaceous rocks and main Cretaceous tectonic lineaments.

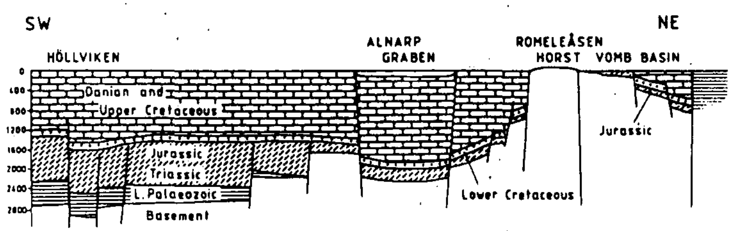


Fig. H. Schematic cross section through the Cretaceous and Danian from the southwestern corner of Scania through the Danish-Polish Trough, the Romeleåsen Horst, and the Vomb Basin in the northeast. The tectonic pattern is simplified.

Quaternary deposits

According to different directions of ice movements during the Weichselian glaciation, the bedrock has given the Quaternary deposits different petrographical composition. Fig. I is a simplified map.

The south-western part of Skåne (Fig. D) is characterized by Phanerozoic sedimentary rocks. The till is often formed as calcareous boulder clay almost stone free with a clay content exceeding 15% (by weight of material less than 20 mm). The content of calcareous material, clay and mineral nutrients, has made these soils to a valuable arable land.

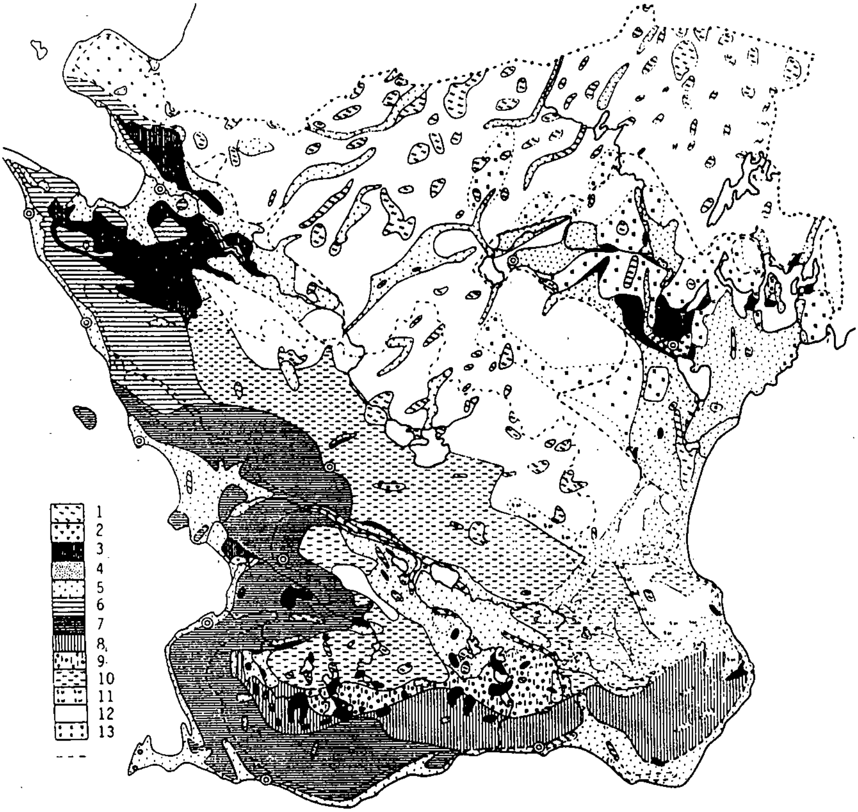
Recent investigations founded on excavation and well drillings, show that different types of till are sandwiched as a result of competition between ice movements. In the lithological stratigraphies, water lain clayey and sandy sediments are also found, resulting from temporarily ice free areas during the Weichselian period.

Different types and stages of deglaciation, result in morphologically different landforms. In areas with areal downwasting icesheet the till deposits form hummocky terrain with coarse textured soils and high boulder frequency in the surface layers. Watersorted sediments are frequently deposited in the depressions. This type of moraine is usually called ablation till, which in genesis is related to flow till in Denmark. Till types in areas characterized by sedimantary rocks, as in Skåne, differ considerably from those normally occurring in Sweden on Crystalline bedrock.

The youngest till in Skåne (Fig. J), the Baltic till (also called SW-moraine), is rich in stones of Danian limestone with its grey coloured flint, white chalk of the Maastrichtian with its black coloured flint, Cambro-Silurian shales and Cambrian sandstone of SE Skåne, and Ordovician-Silurian limestone. Beside these sedimentary rock components there are also crystalline rocks of igneous and metamorphic origin.

As seen in Fig. J, there are areas with calcareous deposits to the NE of the border line between ice movements coming from the Swedish mainland

Fig. 1. Map of Quaternary depostis.



Legend: 1. Peat 2. Alluvial clay 3. Lacustrine clay 4. Fine sand
5. Gravel and sand 6. NW-till 7. SW-till 8. SE-till (Baltic Ice)
9. SE-till, high stone frequence 10. NE-till, shale-crystalline content
11. NE-till, sandstone content 12. NE-till, crystalline content
13. NE-till, calcareous
------- HK, highest coast line

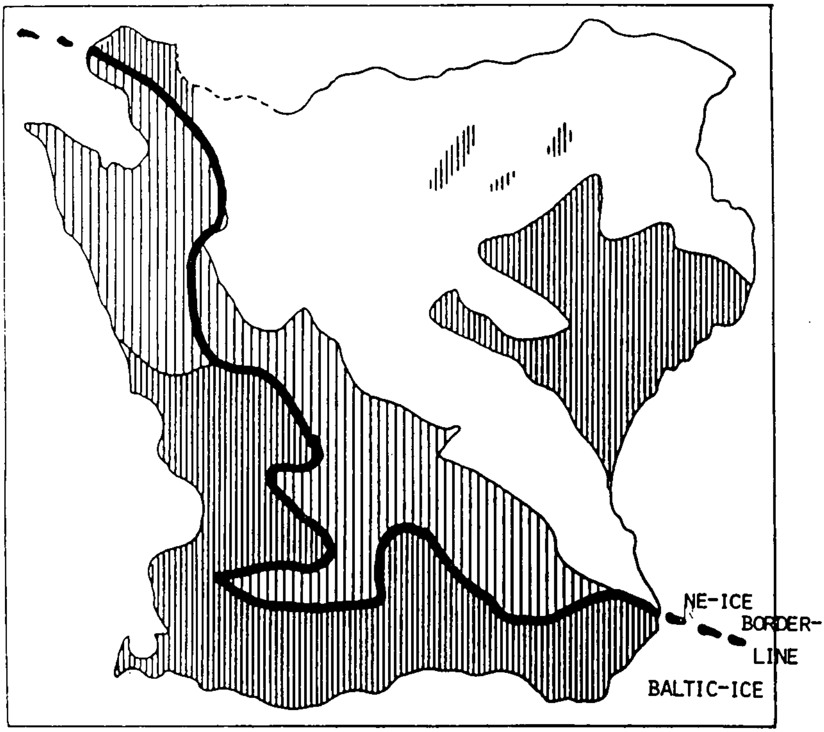


Fig. J. Calcareous Quaternary deposits in Skåne. Densely hatched areas with high and sparse hatched areas with low calcium carbonate content, respectively.

(NE-ice) and from southerly directions (Baltic ice) respectively. This is the immediate result of the local shale and limestonebearing bedrock. When leaving the Skåne area, the soils are characterized by ice movements coming from more northernly directions and a terrain of crystalline bedrock. In the border zone to the South Swedish Upland glaciofluvial deposits become more frequent. Especially esker material are following the valley trains.

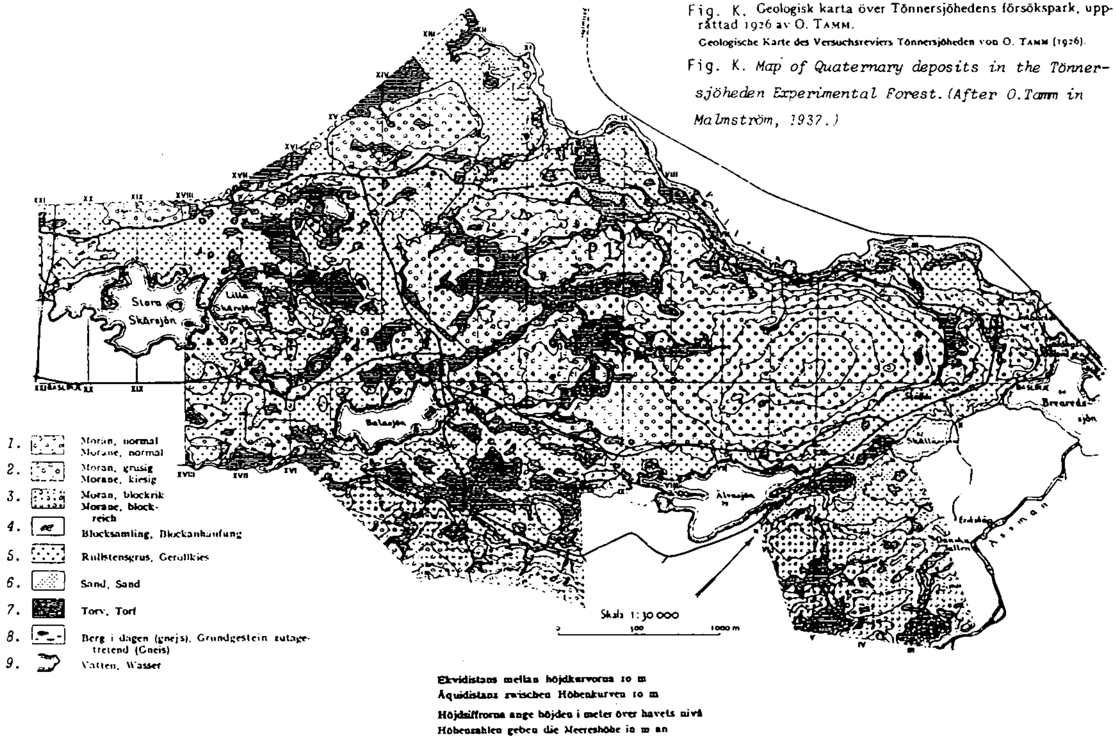
The Tönnersjöheden Experimental Forest (Fig. K) is situated in the border zone to the South Swedish Upland, with a small scale distribution of till, glaciofluvial material, outwash sand and peat areas.

Tills in the northern part of Skåne and most of Sweden, differ considerably from those in areas with sedimentary bedrock. Normal Swedish till has a sandy texture with moderate boulder frequency in the surface. The clay content is low, mostly below 5% by weight and no limestone fragments are present. These tills originate from crystalline bedrock of silica rich igeneous and metamorphic rocks. The petrographical composition is often characterized by gneisses and granites, sometimes with minor amounts of greenstones. In the fine textured fractions the mineralogical compositions is dominated by quartz and feldspars and minor amounts of amphibole, mica, chlorite and apatite. In relation to the quartz content of underlying bedrock, the till often show a considerable enrichment in quartz.

Much of the land was immersed below the water surface following the iceborder retreatment from low lying parts of Sweden. In the South Swedish Upland, even ice dammed lakes was formed, and sandy sediments were deposited. The changing balance between isostatic uplift and eustatic sea level change, resulted in raised beaches and dislocated coast lines. The highest line to which a sealevel has reached after the deglaciation is usually called the highest coast line (HK) and is a metachronous line, met at different heights in Sweden. This depends on what stage of sea or lake, forming the beach line. Depending on the drainage pattern and connection between the Baltic and the Atlantic, there have been alternating periods with fresh water and brackish water in the Baltic basin. Lithologically this has resulted in varved glacial clays formed in fresh water and non-varved post-glacial clays.

Fig. K. Geologisk karta över Tönnersjöhedens försökspark, upprättad 1926 av O. TAMM.
Geologische Karte des Versuchsreviers Tönnersjöheden von O. TAMM (1926).

Fig. K. *Map of Quaternary deposits in the Tönnersjöheden Experimental Forest. (After O.Tamm in Malmström, 1937.)*



LEGEND: 1. *Till, sandy*, 2. *Till, gravelly*, 3. *Till, high boulderfrequency*, 4. *Boulder field*, 5. *Glaciofluvial gravel*, 6. *Sand deposit*, 7. *Peat*, 8. *Bedrock outcrops*, 9. *Lake and river.*

After the investigation of clay minerals in agricultural soils, initiated by professor Wiklander in the 1960's, little work has been done on this subject in Sweden.

In general, illite is the dominating type of clay minerals in marine and lacustrine clay deposits. Depending on the size fraction, more or less quartz and feldspars accompany the clay minerals.

Tills in Skåne, with different petrographical composition, are also dominated by illite. Dependent of the soil horizon sampled, there are variations in amount of chlorite, kaolinite, vermiculite and smectite (earlier called montmorillonite). Especially the glacier coming from the Baltic basin, carried appreciable amounts of smectite, which was deposited with the SW-till. In spite of deeply kaolintized bedrock in Skåne, there are astonishing low content of kaolinite in the till.

References:

Bergström, J., Holland, B., Larsson, K., Norling, E. and Sivhed, U. 1982. Guide to excursions in Scania. SGU Ca 54. 95 pp.

Climate

In contrast to Denmark the climate differs drastically between various parts of southern Sweden. This is mainly due to differences in altitude and differences in atlantic influence. In South-western Sweden the westerly winds drop their water content as the altitude gradually increases. On the other hand; Southeast Sweden is in rain shadow. This could be examplified by the precipitation which at Halmstad on the west coast amounts to 800 mm. At Simlångsdalen at an altitude of about 80-150 m a. s. l. the annual precipitation is 1000-1100 mm while it at Kalmar and the east coast amounts to 480 mm. In general July and August has highest precipitation and early spring is the driest season.

Also the temperature fluctuates between different parts. In general temperature decreases with an increase in elevation. In addition the atlantic influence results in mild winters especially on the west coast with -0.7°C as mean temperature in February in Helsingborg while the inland mean temperature is about -3.0°C. The warmest month is July with temperature within a range from 17.5°C at low altitudes to 15.5°C at higher altitudes. The annual mean temperature is 6.5°C-8.5°C.

Land use

The original forests of the provinces of Skåne and Halland were mainly composed of decidous trees. At wet or fertile sites ash occurred frequently. As a result of an increased human population these forests were replaced by different kinds of land use such as pasture meadows, coppice, arable land and cultivation. Woodland was used for pasture resulting in bad forest conditions and a vegetation type rich in Calluna. To improve the pasture, ground vegetation was repeatedly burnt, resulting in low humus contents of the soils. A Calluna-heath landscape developed on the glacial tills in southwestern Sweden.

In 1850 only minor parts of the province of Halland were covered by forests. During the last part of that century great agricultural changes took place and one also became aware of the economic value of the forests. This greatly affected the extension of the heath landscape. The cultivated soils were more intensively utilized due to the use of fertilizers.

Lay plants were grown, decreasing the demands on woodlands pasture or pasture meadows. The burning ceased and conifer stands were established especially during the 1890's. Today the boulder clays and the fine textured water sediments are used as arable land for production of wheat, sugar beet and soil plants. The annual production of wheat grains amounts to about 6 000-8 000 kg per ha. The glacial till, composed mainly of crystalline rock fragments, as well as outwash sand are forested. Although beech forests still occur in the province of Skåne, conifers (mainly spruces) predominate. In general the annual production approximately amounts to 5-15 m^3 per ha. Clear-felling of the stands is performed after about 80 years.

Soils

The soils developed on boulder clay in South and West Scania are rather similar to the soils in eastern Denmark. In similarity, the soil originally had a considerable calcium carbonate content, that is approximately 20-25 %. The lime limit was originally defined by Tamm (1914). He postulated that the leaching of calcium carbonate is due to percolating water and distinguished three horizons in the profile. In the upper all calcium carbonate is lost whereas in the middle the leaching process is going on and calcium carbonate is only partially lost. In the lower horizon no leaching has occurred. In a fine textured calcareous soil the middle horizon is assumed to be shallow. The limit between the upper and the middle horizons is designated as the lime limit. Lime limit occurs at an average depth of 0.5 m. Although clay illuviation might have occurred at some places it does not generally qualify the B horizons as Bt. Small increases in clay content between 40 and 50 cm have been reported by some authors. This concentration of clay might, however, be caused by processes connected with the deposition of the till. Thus, Euthric Cambisols predominate in boulder clays as well as in marine and lacustrine clays. At lower places with high ground water table Gleysols and Histosol (frequently cultivated) occur. See soil map in Fig. L.

The sandy lacustrine, marine or eolian sediments in central part of the province of Skåne (Vomb-basin) and north-eastern province of Skåne originally contained lime but through intensive leaching the lime limit occurs at a depth of two metres. These soils are mainly podzolized. Although they today are forested, 50-100 years ago they were used for agriculture whereby only weakly developed E-horizons are discernable.

In Central and Northern Skåne the till is characterised by its content of gneisses and Cambro-Silurian sandstones and shales. In this area the soil type varies because of spatial differences in mineralogy and texture. Thus although Dystric Cambisols predominate also Euthric Cambisols as well as Podzols occur.

The glacial till on the crystalline bedrock are characterized by Podzols. This is due to minerals with high content of silica and the coarse texture with only a few per cent of clay. An important fact is the high precipitation which increases gradually as the elevation increases from the coast to the inland. The soils are also heavily affected by the previous land use (cultivation of potatoes, rye and barley). The cultivation started by burning woodland followed by the growing of potatoes and cereals. The final step was pasture woodland maintained by repeated burning. Less than 100 years ago the western part of the area was covered by an extended Calluna-heath from which only a minor remnant is preserved until today. Thus the forests we will see during the journey from Skånes Värsjö to Tönnersjö and to Halmstad mainly are first or second generations. The influences of the coniferous forests on the soil processes are by this reason quite weak and soil properties are inherited from forests older than 1500-centurary or from the period with repeated burning and cultivation or pasture cultivation/burn-beating. Consequently the E-horizons frequently are weakly developed although they are underlaid by distinct Bs horizons. At Skånes Värsjö the E horizons commonly exceeds 6 cm whereas they westwards as well as eastwards mainly are thinner than 6 cm.

Finally, the high humidity has resulted in an extreme high frequencey of Dystric Histosols, sometimes as high as 30 %, in the area. Humic Podzols and Gleysols are common.

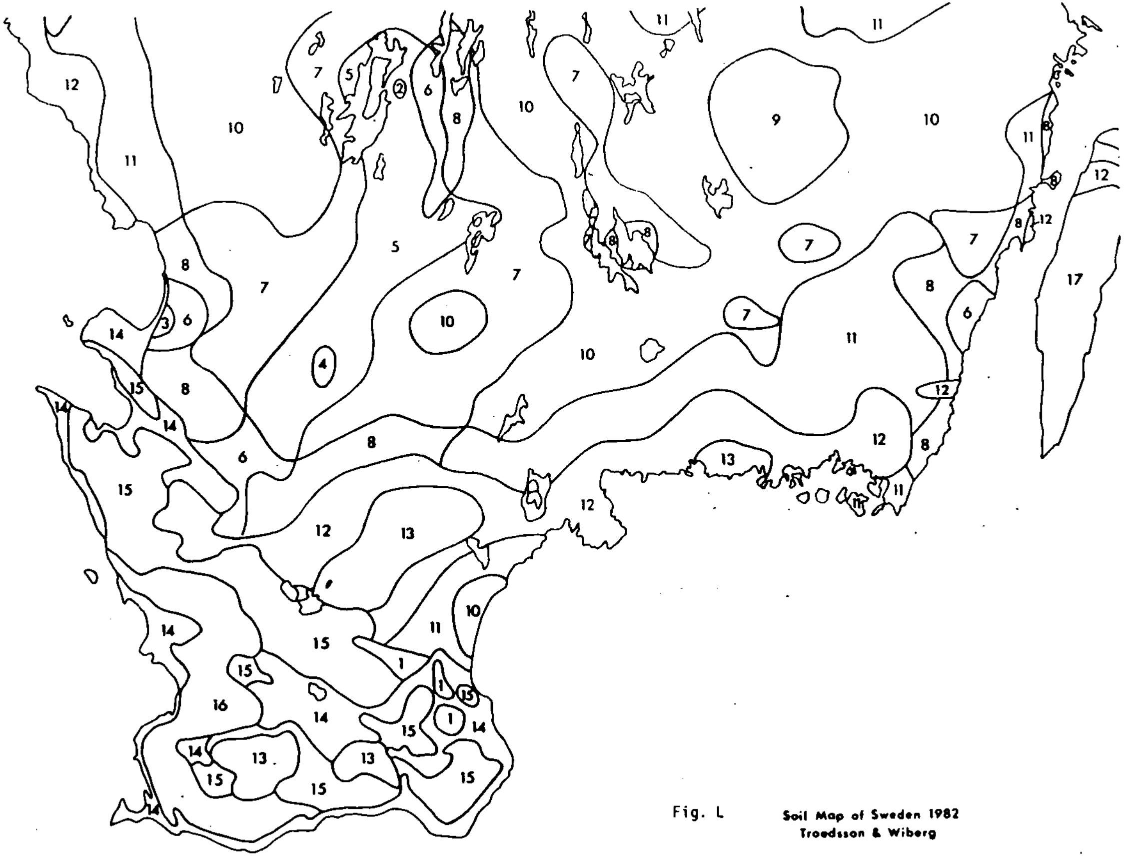


Fig. L Soil Map of Sweden 1982
Troedsson & Wiberg

Fig. L. Legend

1. Orthic Podzols
ass. Gleyic Podzols } A2 > 6cm: 70 - 100% (of tot. freq. of podzols)
ass. Humic Podzols

2. Orthic Podzols
ass. Gleyic Podzols } A2 > 6cm: 70 - 100% (of tot. freq. of podzols)
ass. Humic Podzols
ass. or incl. Dystric Cambisols 10 - 30% (of tot. soils)

3. Orthic Podzols
ass. Gleyic Podzols } A2 > 6cm: 70 - 100% (of tot. freq. of podzols)
ass. Humic Podzols
ass. Dystric Cambisols 30 - 50% (of tot. soils)

4. Orthic Podzols
ass. Gleyic Podzols } A2 > 6cm: 50 - 70% (of tot. freq. of podzols)
ass. Humic Podzols

5. Orthic Podzols
ass. Gleyic Podsols } A2 > 6cm: 50 - 70% (of tot. freq. of podzols)
ass. Humic Podsols
ass. or incl. Dystric Cambisols 10 - 30% (of tot. soils)

6. Orthic Podzols
ass. Gleyic Podsols } A2 > 6cm: 50 - 70% (of tot. freq. of podzols)
ass. Humic Podzols
ass. Dystric Cambisols 30 - 50% (of tot. soils)

7. Orthic Podzols
ass. Gleyic Podzols } A2 > 6cm: 30 - 50% (of tot. freq. of podzols)
ass. Humic Podzols
ass. or incl. Dystric Cambisols 10 - 30% (of tot. soils)

8. Orthic Podzols
ass. Gleyic Podzols } A2 > 6cm: 30 - 50% (of tot. freq. of podzols)
ass. Humic Podzols
ass. Dystric Cambisols 30 - 50% (of tot. soils)

9. Orthic Podzols
ass. Gleyic Podzols } A2 > 6cm: 0 - 30% (of tot. freq. of podzols)
ass. Humic Podzols
incl. Dystric Cambisols < 10% (of tot. soils)

10. Orthic Podzols
ass. Gleyic Podzols } A2 > 6cm: 0 - 30% (of tot. freq. of podzols)
ass. Humic Podzols
ass. or incl. Dystric Cambisols 10 - 30% (of tot. soils)

11. Orthic Podzols
ass. Gleyic Podzols } A2 > 6cm: 0 - 30% (of tot. freq. of podzols)
ass. Humic Podzols
ass. Dystric Cambisols 30 - 50% (of tot. soils)

12. Dystric Cambisols
ass. Orthic Podzols } 50 - 70% Cambisols
incl. Eutric Cambisols

13. Eutric Cambisols
ass. Dystric Cambisols } 70 - 100%
ass. or incl. Orthic Podzols

14. Dystric Cambisols
incl. Orthic Podzols
incl. Eutric Cambisols

15. Eutric Cambisols
ass. Dystric Cambisols
incl. Vertic Cambisols

16. Eutric Cambisols
ass. Vertic Cambisols
incl. Calcic Cambisols
incl. Orthic Luvisols

17. Rendzinas
incl. Eutric Cambisols

Profile No. 12
Skånes Värsjö, Southern Sweden

Long:	E13°30'
Lat:	N56°40'
Altitude:	135 m a.s.l.
Mean annual temp.	+6,5C
Mean annual prec.	725 mm
Vegetationperiod (>5,0°C)	230 days
Prec. vegetation period	425 mm
Humidity	400 mm
Snow cover	65 days

Stand: 80 years old spruce (Picea abies).
Parent material: Glacial till, granitic-gneissic material.
Soil profile U.S. Dept. of Agri., Soil taxonomy: Typic Haplorthod.
"- FAO-Unesco, Soil map of the world: Orthic Podzol.
Groundwater table at least 2,0 m below soil surface.

Description:

01	0-3,5 cm	More or less fragmentated needle litter. The original form of most vegetative matter is visible to the naked eye. Single grain structure, nonsticky and nonplastic. Loose when moist.
02	3,5-8,0 cm	10R 2,5/1. The original form of most plant or animal matter cannot be recognized with the naked eye. Weak developed fine granular structure. Slightly sticky and plastic when wet. Very friable consistence when moist.

Ah	8-9 cm	5 YR 2,5/2. Single grain structure. Some granules and coated grains. Slightly sticky and plastic when wet. Very friable consistence when moist.
E	9-14 cm	5 YR 4/3. Single grain structure. Nonsticky, nonplastic. Very friable when moist.
B/A	14-19 cm	2,5 YR 3/4. Weak medium to coarse angular blocky. Nonsticky and nonplastic. Very friable consistence when moist.
Bs1	19-30 cm	2,5 YR 3/6. Weak medium to coarse angular blocky. Nonsticky, nonplastic. Very friable when moist.
Bs2	30-45 cm	5 YR 4/6. Weak medium to coarse angular blocky. Nonsticky, nonplastic. Very friable when moist.
Bs3	45-60 cm	7,5 YR 4/4. Single grain structure. Nonsticky, nonplastic. Very friable when moist.
C1	60-80 cm	10 YR 5/3. Moderate very coarse platy structure. Nonsticky and nonplastic. Friable when moist.
C2	80-100 cm	10 YR 5/3. Moderate very coarse platy structure. Nonsticky and nonplastic. Friable when moist.
C3	100-160 cm	10 YR 5/3. Moderate very coarse platy structure. Nonsticky and nonplastic. Friable when moist.
C4	160-210 cm	10 YR 5/3. Moderate very coarse platy structure. Nonsticky and nonplastic. Friable when moist.

Analytical data
Profile No. 12

Horizon	Depth cm	Texture, % of humus and calcium carbonate free fine earth: Sand Coarse	Sand Medium	Sand Fine	Sand Total	Silt Coarse	Silt Medium	Silt Fine	Silt Total	Clay	Org. Carbon %	Nitrogen mg/g	C/N
01	0-3,5	-	-	-	-	-	-	-	-	-	40.2	16.1	25.0
02	3,5-8,0	-	-	-	-	-	-	-	-	-	26.8	17.3	15.4
Ah	8- 9	-	-	-	-	-	-	-	-	-	8.1	4.3	18.7
E	9- 14	8	35	35	78	-	-	-	20	2	1.6	0.92	16.8
B/A	14- 19	-	-	-	-	-	-	-	-	-	1.9	0.11	18.1
Bs1	19- 30	13	28	32	73	-	-	-	25	2	2.2	0.13	17.8
Bs2	30- 45	-	-	-	-	-	-	-	-	-	1.4	0.84	16.5
Bs3	45- 60	-	-	-	-	-	-	-	-	-	0.71	0.44	16.1
C1	60- 80	-	-	-	-	-	-	-	-	-	0.41	0.24	17.1
C2	80-120	-	-	-	-	-	-	-	-	-	0.24	0.21	11.4
C3	120-210	15	35	25	75	-	-	-	24	1	0.06	0.10	6.0

Horizon	Depth cm	pH H_2O	pH KCl	Exchangeable cations, meq./kg: Ca	K	Mg	Na	H	CEC pH 8.1 meq./kg	Base-sat. %	$CaCO_3$ %	Phosphorus mg/kg
01	0-3,5	4.51	3.71	124.9	7.7	40.3	2.6	526.6	718.6	26.72	0.0	-
02	3,5-8,0	3.98	2.94	29.3	6.0	27.6	3.0	684.5	753.3	9.13	0.0	-
Ah	8- 9	3.97	2.98	1.0	2.0	2.8	1.2	161.0	168.1	4.24	0.0	-
E	9- 14	4.32	3.35	0.20	0.59	0.51	0.31	46.2	47.8	3.39	0.0	-
B/A	14- 19	4.23	3.54	0.17	0.43	0.45	0.32	77.6	79.0	1.77	0.0	-
Bs1	19- 30	4.90	4.36	0.19	0.35	0.23	0.21	61.7	62.7	1.61	0.0	-
Bs2	30- 45	4.90	4.65	0.06	0.17	0.09	0.19	35.9	36.4	1.43	0.0	-
Bs3	45- 60	4.94	4.71	0.05	0.11	0.06	0.17	22.4	22.8	1.75	0.0	-
C1	60- 80	5.06	4.73	0.04	0.08	0.02	0.13	13.1	13.4	2.09	0.0	-
C2	80-120	4.98	4.72	0.07	0.09	0.05	0.10	11.0	11.3	3.01	0.0	-
C3	120-210	4.80	4.72	0.05	0.06	0.02	0.09	4.7	5.0	4.63	0.0	-

Horizon	Depth cm	Bulk Density g/cm^3	Pore volume %	Water content (%) at pF 0.6	1.8	2.5	4.2	Fe, mg/g Dithion.	Fe, mg/g Pyrophos.	Al, mg/g Dithion.	Al, mg/g Pyrophos.
01	0-3,5	0.12	90	-	-	-	-	1.5	0.1	0.5	0.2
02	3,5-8,0	0.22	86	-	-	-	-	2.1	0.7	1.3	1.2
Ah	8- 9	0.61	72	-	-	-	-	2.0	0.4	0.7	0.7
E	9- 14	1.22	52	-	-	-	-	2.0	0.5	0.3	0.3
B/A	14- 19	1.05	58	-	-	-	-	6.0	4.1	1.1	1.5
Bs1	19- 30		57	-	-	-	-	10.2	5.2	8.2	5.6
Bs2	30- 45	1.20	53	-	-	-	-	4.6	2.0	8.0	4.6
Bs3	45- 60	1.29	50	-	-	-	-	2.5	0.8	5.1	2.8
C1	60- 80	1.44	45	-	-	-	-	1.2	0.3	1.7	1.3
C2	80-120	1.51	43	-	-	-	-	1.2	0.3	1.1	1.0
C3	120-210	-	-	-	-	-	-	1.0	0.1	0.4	0.2

Petrographical determination of the stone fraction at profile No. 12. Skånes Värsjö

Mica schist	0.5
Greenstones	0.5
Grey gneisses	43.6
Red gneisses	3.4
Granite, red, fine to medium grained.	32.0
Granite, red, coarse grained	20.0
	100.0 %

Interpretation

The profile is a rather well developed Orthic Podzol in a sandy glacial till above highest shore line. Thus the till is not water washed and is rather homogenous throughout the profile. The mineralogy is poor with only 1% greenstones and mica shists.

As this profile is situated above the highest shore line it has been exposed to aerobic biochemical processes since the ice left the area, for approximately 13 000 years. We consider that the brownish B/A horizon which is relatively rich in organic matter is caused by former human mixing of the soil. Accordidng to local old authorities a large part of this area was potatoe fields 80-100 years ago. The Bs horizon was formed still earlier but the rather weakly developed E-horizon is a new formation connected to the shift in land use.

An important question is wheather the increased forest productivity (twice as high as in the 1930's) will increase acidity of soil and result in chemical changes of the Bs horizon.

Profile No. 13A Tönnersjöheden Experimental Forest, Southern Sweden. Spruce Stand.

Long:	E13°10'
Lat:	N56°40'
Altitude:	80 m a.s.l.
Mean annual temp.	+6,5°C
Mean annual prec,	1045 mm
Vegation period (>5,0°C)	230 days
Prec. vegetation period	675 mm
Humidity	625 mm
Snow cover	65 days

Stand: 62 years old spruce (Picea abies).
Parent material: Glacial till, granitic-gneissic material.
Soil profile U.S. Dept. of Agri., Soil taxonomy: Typic Haplorthod.
"- FAO-Unesco, Soil map of the world: Orthic Podzol.
Groundwater table at least 2,0 m below soil surface.

Description:

01	0-1,5 cm	More or less fragmentated needle litter. The original form of most vegetative matter is visible to the naked eye. Single grain structure, nonsticky and nonplastic. Loose when moist.
02	1,5-4,0 cm	The original form of most plant or animal matter cannot be recognized with the naked eye. Weak developed fine granular structure. Slightly sticky and plastic when wet. Very friable consistence when moist.
Ah	4,0-6,5 cm	Single grain structure. Some granules and coated grains. Slightly sticky and plastic when wet. Very friable consistence when moist.

E	6,5-9,5 cm	Single grain structure. Nonsticky, nonplastic. Very friable when moist.
B/A	9,5-12 cm	Weak medium to coarse angular blocky. Nonsticky and nonplastic. Very friable consistence when moist.
Bs1	12-31 cm	Weak medium to coarse angular blocky. Nonsticky, nonplastic. Very friable when moist.
Bs2	31-45 cm	Weak medium to coarse angular blocky. Nonsticky, nonplastic. Very friable when moist.
Bs3	45-61 cm	Single grain structure. Nonsticky, nonplastic. Very friable when moist.
C1	61-80 cm	Moderate very coarse platy structure. Nonsticky and nonplastic. Friable when moist.
C2	80-100 cm	Moderate very coarse platy structure. Nonsticky and nonplastic. Friable when moist.
C3	100-120 cm	Moderate very coarse platy structure. Nonsticky and nonplastic. Friable when moist.
C4	120-140 cm	Moderate very coarse platy structure. Nonsticky and nonplastic. Friable when moist.

Analytical data
Profile No. 13A

Horizon	Depth cm	Texture, % of humus and calcium carbonate free fine earth: Sand Coarse	Sand Medium	Sand Fine	Sand Total	Silt Coarse	Silt Medium	Silt Fine	Silt Total	Clay	Org. Carbon %	Nitrogen mg/g	C/N
01	0-1,5	-	-	-	-	-	-	-	-	-	44.3	20.6	21.5
02	1,5-4,0	-	-	-	-	-	-	-	-	-	41.4	17.1	24.2
Ah	4,0-6,5	-	-	-	-	-	-	-	-	-	8.2	3.3	24.8
E	6,5-9,5	17	36	24	77	-	-	-	21	2	3.1	0.90	34.4
B/A	9,5- 12	-	-	-	-	-	-	-	-	-	6.9	0.98	70.4
Bs1	12- 31	15	32	28	75	-	-	-	22	3	2.2	1.0	22.0
Bs2	31- 45	-	-	-	-	-	-	-	-	-	1.4	0.88	15.9
Bs3	45- 61	-	-	-	-	-	-	-	-	-	0.85	0.52	16.3
C1	61- 80	-	-	-	-	-	-	-	-	-	0.17	0.18	9.4
C2	80-100	-	-	-	-	-	-	-	-	-	0.10	0.15	6.7
C3	100-120	-	-	-	-	-	-	-	-	-	0.06	0.12	5.0
C4	120-140	14	33	33	80	-	-	-	18	2	0.07	0.12	5.8

Horizon	Depth cm	pH H_2O	pH KCl	Exchangeable cations, meq./kg: Ca	K	Mg	Na	H	CEC pH 8.1 meq./kg	Base-sat. %	$CaCO_3$ %	Phosphorus mg/kg
01	0-1,5	4.26	3.37	392.6	11.2	8.7	5.1	542.9	1093.3	50.34	0.0	-
02	1,5-4,0	4.16	2.83	53.4	5.5	3.7	5.5	875.2	1236.3	29.21	0.0	-
Ah	4,0-6,5	4.10	2.89	28.6	1.1	0.4	1.0	156.0	214.6	27.31	0.0	-
E	6,5-9,5	4.09	3.18	1.0	0.4	0.1	0.4	49.1	52.1	5.76	0.0	-
B/A	9,5- 12	4.27	3.57	0.2	0.3	0.1	0.3	68.2	69.6	2.01	0.0	-
Bs1	12- 31	4.52	4.29	0.1	0.2	0	0.3	55.3	56.1	1.43	0.0	-
Bs2	31- 45	4.54	4.58	0	0.1	0	0.2	32.4	32.8	1.22	0.0	-
Bs3	45- 61	4.58	4.63	0.1	0.1	0	0.2	21.9	22.4	2.23	0.0	-
C1	61- 80	4.73	4.73	0.1	0.1	0	0.1	8.3	8.6	3.44	0.0	-
C2	80-100	5.07	4.76	0.1	0.1	0	0.1	7.6	7.9	3.80	0.0	-
C3	100-120	5.35	4.81	0.1	0.1	0	0.1	6.8	7.1	4.23	0.0	-
C4	120-140	5.23	4.81	0.1	0.1	0	0.1	6.7	7.0	4.29	0.0	-

Horizon	Depth cm	Bulk Density g/cm^3	Pore volume %	Water content (%) at pF 0.6	1.8	2.5	4.2	Fe, mg/g Dithion.	Fe, mg/g Pyrophos.	Al, mg/g Dithion.	Al, mg/g Pyrophos.
01	0-1,5							0.8	0.0	0.4	0.2
02	1,5-4,0							1.8	0.5	0.8	0.7
Ah	4,0-6,5							2.3	0.7	0.4	0.4
E	6,5-9,5							2.3	0.7	0.2	0.2
B/A	9,5- 12							11.2	7.4	1.2	1.6
Bs1	12- 31							10.8	6.9	5.5	4.7
Bs2	31- 45							5.2	1.5	8.0	3.7
Bs3	45- 61							2.6	0.7	4.4	2.3
C1	61- 80							1.2	0.2	1.1	1.0
C2	80-100							1.1	0.2	0.8	0.8
C3	100-120							1.1	0.1	0.7	0.6
C4	120-140							1.0	0.1	0.6	0.6

Interpretation

The profile is a rather well developed Orthic Podzol similar to profile no 12. The brownish B/A horizon is considered to be of desicive importance showing the shift in land use. Before the present spruce stand the area was covered by beeches. Probably also burning has occurred. Plenty of charcoal remains occur in the upper mineral soil. This profile will be compared to 13B and 13C developed in similar parent material but with different land use.

Profile No. 13B
Tönnersjöheden Experimental Area, Southern Sweden, Birch Stand

Long:	E13°10´
Lat:	N56°40´
Altitude:	80 m a.s.l.

Mean annual temp.	+6,5°C
Mean annual prec,	1045 mm
Vegation period (>5,0°C)	230 days
Prec. vegetation period	675 mm
Humidity	625 mm
Snow cover	65 days

Stand: 63 years old birch (Betula verrucosa).
Parent material: Glacial till, granitic-gneissic material.
Soil profile U.S. Dept. of Agri., Soil taxonomy: Typic Haplorthod.
"- FAO-Unesco, Soil map of the world: Orthic Podzol.
Groundwater table at least 2,0 m below soil surface.

Description:

01	0-1 cm	More or less fragmentated litter. The original form of most vegetative matter is visible to the naked eye. Single grain structure, nonsticky and nonplastic. Loose when moist. Occasional medium, sized porous peds (earthworm excrements) of organic matter and/or mineral grains.
02	1,0-3,0 cm	A combination of medium crumb structure with moderate grade and single grain structure. The latter depends on a rather rich occurrence of fragmentated plant remnants with visible tissues. Slightly sticky and slightly plastic. When moist friable.
Ah	3-6,0 cm	Single grain structure. Some granules and coated grains. Slightly sticky and plastic when wet. Very friable consistence when moist.
B/A	6-8 cm	Weak medium to coarse angular blocky. Nonsticky and nonplastic. Very friable consistence when moist.
Bs1	8-25 cm	Weak medium to coarse angular blocky. Nonsticky, nonplastic. Very friable when moist.
Bs2	25-50 cm	Weak medium to coarse angular blocky. Nonsticky, nonplastic. Very friable when moist.
Bs3	50-65 cm	Single grain structure. Nonsticky, nonplastic. Very friable when moist.
C1	65-130 cm	Moderate very coarse platy structure. Nonsticky and nonplastic. Friable when moist.
C2	130-150 cm	Moderate very coarse platy structure. Nonsticky and nonplastic. Friable when moist.

Analytical data
Profile No. 13B

Horizon	Depth cm	Texture, % of humus and calcium carbonate free fine earth: Sand Coarse	Sand Medium	Sand Fine	Sand Total	Silt Coarse	Silt Medium	Silt Fine	Silt Total	Clay	Org. Carbon %	Nitrogen mg/g	C/N
01	0- 1	-	-	-	-	-	-	-	-	-	42.84	23.8	18.0
02	1- 3	-	-	-	-	-	-	-	-	-	21.48	7.7	27.9
Ah	3- 6	-	-	-	-	-	-	-	-	-	6.17	3.5	17.6
E	6- 8	28	25	17	70	-	-	-	25	5	2.99	2.2	13.6
Bs1	8- 25	13	27	36	70	-	-	-	28	2	1.93	1.1	17.5
Bs2	25- 50	-	-	-	-	-	-	-	-	-	1.26	0.76	16.6
Bs3	50- 65	-	-	-	-	-	-	-	-	-	0.36	0.26	13.8
C1	65-130	-	-	-	-	-	-	-	-	-	0.08	0.12	6.7
C2	130-150	10	30	40	80	-	-	-	19	1	0.08	0.10	8.0

Horizon	Depth cm	pH H_2O	pH KCl	Exchangeable cations, meq./kg Ca	K	Mg	Na	H	CEC pH 8.1 meq./kg	Base-sat. %	$CaCO_3$ %	Phosphorus mg/kg
01	0- 1	4.63	3.98	127.9	30.6	42.7	8.0	509.0	752.0	32.31	0.0	-
02	1- 3	4.33	3.29	22.4	7.6	12.8	2.1	299.2	346.7	13.70	0.0	-
Ah	3- 6	4.23	3.36	2.7	2.1	2.7	0.5	142.2	150.5	5.51	0.0	-
E	6- 8	4.69	4.04	0.6	0.8	0.8	0.4	88.2	91.0	3.08	0.0	-
Bs1	8- 25	4.82	4.46	0.2	0.3	0.2	0.2	48.1	49.0	1.84	0.0	-
Bs2	25- 50	4.67	4.58	0.2	0.2	0.1	0.2	32.2	32.9	2.13	0.0	-
Bs3	50- 65	4.79	4.63	0.1	0.1	0	0.1	15.6	15.9	1.89	0.0	-
C1	65-130	5.23	4.75	0.1	0.1	0	0.1	5.6	5.9	5.08	0.0	-
C2	130-150	5.50	4.78	0.1	0.1	0	0.1	5.5	5.9	6.78	0.0	-

Horizon	Depth cm	Bulk Density g/cm³	Pore volume %	Water content (%) at pF 0.6	1.8	2.5	4.2	Fe, mg/g Dithion.	Fe, mg/g Pyrophos.	Al, mg/g Dithion.	Al, mg/g Pyrophos.
01	0- 1							0.5	0.1	0.2	0.2
02	1- 3							3.2	0.7	0.4	0.3
Ah	3- 6							8.0	3.8	1.1	1.0
E	6- 8							13.4	9.2	4.8	4.3
Bs1	8- 25							8.2	4.5	7.0	5.4
Bs2	25- 50							8.3	3.0	6.0	3.5
Bs3	50- 65							1.8	0.7	1.6	1.7
C1	65-130							0.7	0.1	0.7	0.7
C2	130-150							1.0	0.1	0.6	0.6

Interpretation

This profile is an Orthic Podzol with a well developed Bs horizon. The present birch stand has affected soil biology and changed the humusform from mor to mull-like moder which is reflected by the chemical analyses. Thus, the A and E horizons have a relatively high concentration of organic carbon and extractable Fe and Al (compared to profile 13A). The C:N-ratio is more narrow and pH is approximately 0.3 unit higher, even in the C horizon.

Profile No. 13C
Tönnersjöheden Experimental Area, Southern Sweden, Oak Stand

Long:	E13°10´
Lat:	N56°40´
Altitude:	135 m a.s.l.
Mean annual temp.	+6,5°C
Mean annual prec.	1045 mm
Vegetationperiod (>5,0°C)	230 days
Prec. vegetation period	675 mm
Humidity	625 mm
Snow cover	65 days

Stand: 60 years old oak (Quercus robur) and beech (Fagus silvatica).
Parent material: Glacial till, granitic-gneissic material.
Soil profile U.S. Dept. of Agri., Soil taxonomy: Typic Haplorthod.
"- FAO-Unesco, Soil map of the world: Orthic Podzol.
Groundwater table at least 2,0 m below soil surface.

Description:

01	0-6 cm	7,5 R 2/2. More or less fragmentated leaf litter. The original form of most vegetative matter is visible to the naked eye. Single grain, nonsticky and nonplastic. Loose when moist.
02	6-12 cm	7,5 R 2/1. The original form of most plant or animal matter cannot be recognized with the naked eye. Weak developed fine granular structure. Slightly sticky and plastic when wet. Very friable consistence when moist.
Ah	12-15 cm	7,5 R 2/2. Single grain structure. Some granules and coated grains. Slightly sticky and plastic when wet. Very friable consistence when moist.
E	15-23 cm	5 YR 5/2. Single grain structure. Nonsticky, nonplastic. Very friable when moist.
B/A	23-31 cm	5 YR 3/6. Weak medium to coarse angular blocky. Nonsticky and nonplastic. Very friable consistence when moist.
Bs1	31-40 cm	7,5 YR 5/8cm. Weak medium to coarse angular blocky. Nonsticky, nonplastic. Very friable when moist.
Bs2	40-50 cm	7,5 YR 5/6. Weak medium to coarse angular blocky. Nonsticky, nonplastic. Very friable when moist.
B/C	50-100 cm	10 YR 5/6. Single grain structure. Nonsticky, nonplastic. Very friable when moist.
C1	100-140 cm	10 YR 5/4. Weak very coarse platy structure. Nonsticky and nonplastic. Friable when moist.
C2	140-180 cm	10 YR 6/3. Weak very coarse platy structure. Nonsticky and nonplastic. Friable when moist.
C3	180-230 cm	10 YR 6/3. Weak very coarse platy structure. Nonsticky and nonplastic. Friable when moist.

Analytical data
Profile No. 13C

Horizon	Depth cm	Texture, % of humus and calcium carbonate free fine earth									Org. Carbon %	Nitrogen mg/g	C/N
		Sand				Silt				Clay			
		Coarse	Medium	Fine	Total	Coarse	Medium	Fine	Total				
01	0- 6	-	-	-	-	-	-	-	-	-	41.7	20.0	20.9
02	6- 12	-	-	-	-	-	-	-	-	-	41.2	20.8	19.8
Ah	12- 15	-	-	-	-	-	-	-	-	-	19.4	-	-
E	15- 23	18	42	22	82	-	-	-	16	2	2.5	1.2	20.8
B/A	23- 31	-	-	-	-	-	-	-	-	-	4.3	2.3	18.7
Bs1	31- 40	20	35	27	82	-	-	-	16	2	1.8	1.1	16.4
Bs2	40- 50	-	-	-	-	-	-	-	-	-	0.42	0.29	14.5
Bs3	50-100	-	-	-	-	-	-	-	-	-	0.10	0.10	10.0
C1	100-140	-	-	-	-	-	-	-	-	-	0.03	0.05	6.0
C2	140-180	-	-	-	-	-	-	-	-	-	0.00	0.02	-
C3	180-230	14	38	30	82	-	-	-	17	1	0.01	0.02	5.0

Horizon	Depth cm	pH		Exchangeable cations, meq./kg					CEC pH 8.1 meq./kg	Base-sat. %	$CaCO_3$ %	Phosphorus mg/kg
		H_2O	KCl	Ca	K	Mg	Na	H				
01	0- 6	4.13	3.40	83.6	25.4	36.1	7.3	678.1	838.1	19.09	0.0	-
02	6- 12	3.71	2.84	48.6	11.8	47.9	3.8	966.0	1078.6	10.44	0.0	-
Ah	12- 15	3.78	2.77	4.4	3.9	19.9	2.4	411.4	442.1	6.94	0.0	-
E	15- 23	4.15	3.21	0.3	0.8	1.2	0.4	60.2	62.9	4.29	0.0	-
B/A	23- 31	4.75	4.25	0.2	0.6	0.4	0.3	113.2	114.7	1.31	0.0	-
Bs1	31- 40	4.78	4.61	0	0.3	0.1	0.1	41.0	41.5	1.20	0.0	-
Bs2	40- 50	4.78	4.77	0	0.2	0.1	0.1	17.6	18.0	2.20	0.0	-
Bs3	50-100	4.95	4.80	0	0.1	0	0.1	8.7	8.9	2.25	0.0	-
C1	100-140	5.28	4.87	0.1	0.1	0.1	0.1	5.8	6.2	6.45	0.0	-
C2	140-180	5.39	4.89	0	0.1	0.1	0.1	4.8	5.1	5.88	0.0	
C3	180-230	5.29	4.86	0.1	0.1	0.1	0.1	4.8	5.2	7.69	0.0	-

Horizon	Depth cm	Bulk Density g/cm^3	Pore volume %	Water content (%) at pF				Fe, mg/g		Al, mg/g	
				0.6	1.8	2.5	4.2	Dithion.	Pyrophos.	Dithion.	Pyrophos.
01	0- 6	-	-	-	-	-	-	1.3	0.3	0.4	0.2
02	6- 12	-	-	-	-	-	-	1.5	0.5	0.7	3.1
Ah	12- 15	-	-	-	-	-	-	1.8	0.4	0.8	0.8
E	15- 23	-	-	-	-	-	-	1.9	0.5	0.3	0.3
B/A	23- 31	-	-	-	-	-	-	12.4	5.0	9.8	8.1
Bs1	31- 40	-	-	-	-	-	-	7.4	0.9	9.4	3.6
Bs2	40- 50	-	-	-	-	-	-	3.1	0.2	2.9	1.4
Bs3	50-100	-	-	-	-	-	-	1.1	0.2	1.0	0.8
C1	100-140	-	-	-	-	-	-	0.9	0.1	0.5	0.4
C2	140-180	-	-	-	-	-	-	0.9	0.1	0.4	0.4
C3	180-230	-	-	-	-	-	-	1.3	0.1	0.2	0.3

Interpretation

The profile is an Orthic Podzol which in similarity with profiles no 12 and 13A has a B/A horizon as a result of previously different land use. This profile is in many respects similar to 12 and 13A. The oakstand has not been able to cause significant changes in soil properties. In conclusion, oak will not prevent the podzolization in case of coarse textured acid till soils in a humid climate.

Laboratory Methods
Day 6 - profiles

N_{org} Kjeldahl

C_{org} Wet combustion and titration of evolved CO_2, Nômmik 1971. Soil Sci. 111:5, 330-336).

CEC 1M ammoniumacetate extraction at pH 7.0; determination of titratable acidity and atomic spectroscopic determination of base cations. (Brown 1943. Soil Sci. 43. 353-357).

Free Fe & Al Extracted by sodium dithionite-citrate. Soil Survey laboratory Methods and Procedures for collecting soil samples (Also: Holmgren 1967. Soil Sci. Soc. Amer. Proc. 210-211).

Organic bounded Fe & Al Extracted by sodium pyrophosphate. Soil Survey laboratory Methods and Procedures for collecting soil sample. (Also: Bascomb 1968. Journal of Soil Sci. 19, 251-268).

pH 5 g mineral soil (2 g humus) in 25 ml H_2O/0.1 M KCl.

Particle size distribution:

Organic matter and sesquioxides were removed by H_2O_2 and Tamm´s solution. Analyses by sieving and hydrometer determinations (Gandahl 1952. GFF 74).