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SVENSKA VÄXTGEOGRAFISKA SÄLLSKAPET

The Holocene
History of the Great Alvar
of Öland

By

Lars-König Königsson

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By

Lars-König Königsson

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*This study of a very special forest history
is dedicated to the memory
of past generations of the Königsson family,
farmers and foresters in the woodlands
of north Sweden*

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ABSTRACT

This study presents an outline of the Holocene history of the Great Alvar on the island of Öland in the Baltic. The Great Alvar is an almost tree and bushless area, about 300 km², which has a very thin soil cover or no soil at all upon the bedrock. The description of the area is based upon a physiognomic map, surveyed by the author. A description of soil types and a classification of the morphology and stratigraphy of the fens and Alvar lakes is also given.

By means of pollen analysis the vegetational history is outlined and discussed in comparison with the archaeologic succession on the island. A comparative study of two fens in the deciduous wood area of middle Öland, which also includes notes on these fens' local development is reported on.

The Great Alvar is shown to have had a "forest" period with an open tree/bush wood from the later part of Preboreal to the transition between the At-

lantic and Subboreal periods. In the mentioned zone transition a climatic change has been proved. The continued development of the Alvar shows a very high human influence upon the landscape during the Roman Iron Age, which corresponds to the Roman (Florida) emergence (Fairbridge 1962), and which has been interpreted as a climatic period of increased moisture. Around 500 AD an overgrowth period with decreased human influence is seen on the Alvar. The influence increases again during the later part of the Vendel period or in the Viking Age and the human influence upon the landscape and its variations is considered to be largely due to climatic oscillations.

The establishment of a research team for combined investigations in Archaeology, Human Geography and Pleistocene/Holocene Geology, the *Ölands Stora Alvar* team, is reported on.

PREFACE

I was born on Öland. During my school years at Kalmar most of my spare time was spent on the Great Alvar. It was then quite natural that my investigations should concern Öland, the Great Alvar in particular.

At Uppsala I had Professor Sten Florin as my teacher in Pleistocene Geology. During the thirties he started combined investigations of the Vrå culture of the early Neolithic period. His studies included palaeobotanical investigations of the human influence on the landscape during the Stone Age and also archaeological excavations. He is the pioneer in this type of investigations, and his encouraging interest and helpfulness has followed my work on Öland from the first field summer, through the analysis and laboratory works to the final writing stage.

In Botany my teachers were Professors G. Einar Du Rietz, John Axel Nannfeldt and Nils Fries, in Physical Geography Professor Filip Hjulström and in Archaeology Professors Mårten Stenberger and Bertil Almgren.

When I first came in contact with the pollen analytic method, Professor Magnus Fries was the introducer. He encouraged me to start the investigations on the Great Alvar, and he has followed my continued work with great interest throughout the years. He also suggested that I should try to go to Copenhagen to learn from the modern Danish pollen analytic school. On scholarship from the Danish Ministry of Education I spent half a year with Dr. J. Troels-Smith, head of the Department of Science, Danish National Museum. This period was of greatest importance to me. The continued contact with Dr. J. Troels-Smith has involved innumerable discussion of diagrams, diagram construction, diagram details and diagram interpretation.

The original idea of the investigations of the Alvar lakes and their soils belongs to my dear friend Dr. Anders Martinsson. At any time of the day—or night—by coffee and tea breaks, beer breaks or eve-

nings together with a bottle of wine, or in between, our discussions have concerned the new information about the natural history of the Great Alvar or the diffuse future of the area.

At the Institute of Quaternary Geology at Uppsala, I have had the great advantage of consulting Dr. Maj-Britt Florin on various questions. The discussions with Dr. Florin have always been very interesting.

During my stay at the Danish National Museum I had the most generous guidance of Drs. Svend Jørgensen, Bent Fredskild and Ingrid Sørensen. I have often visited the Department to discuss interpretations and methodical problems with them, and these discussions together with the imaginative comments and suggestions by Dr. H. Tauber have been of great importance to me.

I have also had the opportunity to discuss the Alvar diagrams with Dr. Johs. Iversen, Copenhagen, and with Professor Knut Faegri, Bergen, and their comments have been very valuable for my continued work.

Archaeological background problems have been much discussed with Professor Bertil Almgren, whose interest in the treated problems has been very great and very active. I have also had valuable discussions with Professor Mårten Stenberger, both in the field and in seminars. Very important comments have been obtained from Professor Greta Arwidsson, who also has been very encouraging.

The local "Baltic" problems have been discussed with Professor Bengt Pettersson and Dr. Erik Nylén, both working on the neighbouring island of Gotland, and with Dr. Sölve Göransson.

My U-marked C_{14} analyses were made by Dr. Ingrid U. Olsson. Our cooperation has been very inspiring and most valuable suggestions have been made by Dr. Olsson.

I have had the pleasure of showing my climatology theories to Professor Gösta Liljequist, who has

been very helpful. Some palynologic problems have been discussed with Professor Gunnar Erdtman. Interesting sedimentologic discussions have been had with Dr. John O. Norrman and Mr. Tord Ingmar, FM.

During the Skede Mose investigations I worked in excellent cooperation with Dr. Ulf Erik Hagberg. With the greatest pleasure I recall in memory the wonderful field summers there, sometimes wet, in a sense of real friendship. At this point I also want to mention Miss Margareta Beskow, FK.

In my field works I have been assisted by many helpers directly or indirectly: Mr. Rolf Lind, Mr. Lars-Erik Carlsson, Dr. Sievert Nilsson (Dröstorpe), Mr. Stig Ljungdahl (Möckelmosen), Mr. Eddie Karlsson, Mrs. Lillemor Karlsson, Mr. Verner Danielsson, Mrs. Ebba Stina Königsson, FK, Mrs. Ingrid Themner, Mr. Lage Themner (Stormaren), Drs. Rolf Bergström, Björn Berglund, Bent Fredskild (Gladvattnet), Miss Margareta Beskow, FK, Dr. Ulf Erik Hagberg, Mr. Stig Rydh, FK, Dr. Anders Martinsson, Mr. Elis Johansson, Mr. Paul Ohlsson, Mr. Åke Nilsson (Skede Mose), Dr. Karl Gustaf Pettersson (special collections on the Great Alvar).

In the analysis work I have had the most excellent help by Dr. Ingrid Sørensen, Mr. Thorolf Candolin, FK, Mr. Johan Höijer, FK, and Mr. Ingmar Pålsson, FK.

The drawings have been made by Mrs. Asta Kaljusaar, Mrs. Emma Ballodis, Miss Kjerstin Andersson, Miss Karin Ohlsson, Mr. Harry Holmström and myself.

The language was revised by Mrs. Carolyn Hörner.

The typing of the manuscript was made by Mrs. Ann Margret Ekström and Miss Gunvor Nordenstam. Dr. Werner Hofmann was very helpful at the proof reading.

The photographic laboratory work was made by Mr. Axel Wallner and Mr. Lars Åberg.

The Physiognomic map of the Great Alvar has been made in cooperation with the local government in Kalmar, which has also paid the printing costs for the map. I have had a most pleasant collaboration with Mr. Birger Carle, JK, in this case.

On Öland and in Kalmar many friends have served

to help me during the field summers. First of all I want to mention Mrs. Clara Söderlind and Mr. Eric Oldebrant, but also Mrs. Ingrid Themner and Mr. Lage Themner, Mr. Tore Lundberg, The Börje Beskow family, Mrs. Ingeborg Palm and Mr. Kurt Linde.

At the Institute of Quaternary Geology the good fellowship has been of greatest importance for the work. Many other friends from the neighbouring Institutes, Professor Bengt Collini in particular, have also contributed in this respect, and I want to mention the late evenings and nights and the informal discussions together with some coffee as a very productive scientific environment.

Since 1965 the research team "Ölands Stora Alvar" functions, sponsored by The Tri-Centennial Fund of the Bank of Sweden, and under my leadership. The other team members, Dr. Sölve Göransson, Mr. Ingmar Jansson, FK, Mrs. Ebba Stina Königsson, FK, and Miss Monica Wennersten, FK, have all put much time on discussing both common problems and more special ones. The team work has been very stimulating. The team's collective symbol, a drawing of a silver brooch from the Viking Age found at Ekelunda Alvar Village, vignettes the preface.

Financial support for this work was received from the Funds of the Faculty of Science, University of Uppsala, the Lars Hierta's Memory foundation, the Hierta-Retzius' Foundation, The Funds of the Royal Academy of Sciences, the Rutgers Sernander Foundation, the Knut and Alice Wallenberg Foundation, the Helge Ax:son Johnsson Foundation, Helsingborgsfirmaet Evers & Co Foundation, The Torsten Kreuger Fund. One field summer a house was put to my disposal by Kalmar Läns Fornminnesförening.

To all the persons and institutions, even those not mentioned by name here, who have helped in completing this study, I wish to express my sincere thanks.

Institute of Quaternary Geology
University of Uppsala
August 15th 1968

Lars-König Königsson

INTRODUCTION

"Walls or rudiments of fences, which were signs of large enclosed places on the Alvar, caused us to conclude that this barren Alvar had formerly been more fruitful and thus more cultivated, divided and enclosed . . ." (Linnaeus 1745, p. 92).

Ever since the days of Linnaeus the originality of the Alvar has been discussed. The remarks of Linnaeus, however, were more reflecting his wondering at the human activity that had once taken place in the barren Alvar, rather than a conscious ambition to discuss the development of the landscape. In the discussion after Linnaeus two main opinions have dominated. The first, which has been embraced by most of the discussers, is that the Alvar is a comparatively original landscape with no considerable human influence involved in it. The second opinion looks upon the Alvar as an example of a very extreme cultural landscape. The discussion has mostly been hypothetical and few solid arguments have been available.

The present study may be divided into two main parts: The first part gives a regional description of the Great Alvar. In spite of all botanical and geological activity on Öland since Linne's days, such a description has not been produced before. The Great Alvar's physiognomy, together with the morphology and stratigraphy of the fens and Alvar lakes, is the main subject of the description. At the same time, available botanical information has been added to the described categories.

The second part of the study gives the vegetational history of the area as it is reflected in pollen diagrams from the lakes and fens of the Alvar. The information gained from the pollen analytical investigations is discussed in connection with a map of the whole area, where the distribution of potential tree- and bushgrounds was mapped, and with a summary of the distribution of the antiquities of the area.

This paper is the first contribution to the history of the Great Alvar on southern Öland, which emanates from the research team *Ölands Stora Alvar*, and the additional studies will deal with the human geography and the archaeology of the Alvar as well as with extended studies of the Quaternary

Fig. 1. Map showing Öland's position in the Baltic.

geology. The Tri-Centennial Fund of the Bank of Sweden sponsors the team work, and the ultimate aim of the work is the elucidation of the mechanism of landscape development in general and of the combination of natural and cultural factors in the mechanism. The Great Alvar was chosen for the study because it is a well delimited and very characteristic area, but the methods used and the results will be of use also in less exotic areas.

The results are expected to be very valuable for discussion of the conservation of the Great Alvar and of the future management of the area. As far as is known, this team work is the first conscious attempt of research in this field in Sweden.

GENERAL NATURAL CONDITIONS OF ÖLAND

The Geology of Öland

The bedrock on Öland consists entirely of Cambrian and Ordovician strata, which dip gently towards ESE. As may be seen from special descriptions of Öland's geology, the boundaries between the different strata run roughly along the island (Svedmark 1904, Munthe 1902 *a*, 1902 *b*, Munthe & Hedström 1904, Westergård 1936, Regnéll 1948, Bohlin 1949, 1955 and Jaanusson 1960). The upper surface of the island cuts obliquely across the layers at an even more acute angle than the dip of the layers.

Along the western coast of the island an escarpment, a *klint* (Martinsson, 1958, p. 15) has been formed, which constitutes the geographical "Västra landborgen" (Fig. 4). According to palaeontologic literature and geomorphological studies, the *klint* roughly corresponds to the Cambro-Ordovician boundary. Still more westwards at the present shoreline of the island or in the Kalmarsund another two escarpments form the transition to lower Cambrian strata, pre-Cambrian formations and the sub-Cambrian peneplain (cf. Königsson, 1967 *b*).

The Quaternary geology of Öland was investigated in connection with the geological mapping of the island, which was performed in the last two decades of the nineteenth century. The results were published in 1902 and 1904 and much of it is now out of date, especially in respect to details, and during the last thirty years much new information from gravel pits and hydrogeological investigations has changed the knowledge of the Quaternary geological picture. Still the old geological maps represent the only brief outline of the island's Quaternary geology, which has been published, and the following description refers to a simplified redrawing of these maps (Fig. 2).

The cover of Quaternary deposits on the bedrock is unevenly distributed over the island, and the limestone layers are very often exposed. Along the western coast the *klint* has been formed and is to be found uncovered by soils partly in or very near the

present shoreline, partly on higher altitudes. The *klint* formation goes back to pre-Quaternary times, but the present development of the *klint* is the result of the action of the great land ice in combination with wave action during the postglacial various Baltic stages. Exposed bedrock is most frequent in the inner parts of southern Öland, south of a line between Torslunda and Gårdby, and on the top of the escarpment along the northern parts of the *klint*. On northern Öland the eastward extension of the exposed bedrock shows a certain striped pattern from NW to SE (Königsson, 1967 *a*), which perhaps corresponds to an uneven bedrock surface with NW to SE directed *cuestas* in this particular area.

In many places remarkable soil depths have been recorded outside the shore ridge systems, for instance in Vedborn, parish of Högby (11 m) and in the Skedstad-Kläppinge area in the parish of Bredsättra (9–11 m). The bedrock surface is obviously very uneven and may show interesting morphologic features when it becomes carefully investigated.

According to the geological map, the greater part of the soils on the island have glacial or glaciofluvial origin and are resting on a primary position. De Geer (1910) observed morphological features on the bottom of Kalmarsund, just east and northeast of the city of Kalmar, which he interpreted as terminal moraines. On Öland he considered the ridge forms in the parish of Algutsrum, Törnbottenåsen, Holmetorpsåsen and Jordtorpsåsen as belonging to this system. Dannstedt (1947) investigated the bottom topography of southern Kalmarsund and on the basis of marine charts and on special echograms, he distinguished an additional terminal moraine zone there. Finally Bergdahl made a careful study of the bottom topography between Kalmar and Färjestaden on Öland, and also in parts of northern Kalmarsund, and he confirmed de Geer's theory of the terminal moraines at Kalmar, the Kalmar Line, and besides he followed the eskers from their roughly NW–SE direction on the Swedish mainland down in their

Fig. 2. Geological map of Öland. The map was compiled from the geological maps of the Swedish Geological Survey (Svedmark 1904, Munthe 1902 *a*, 1902 *b*, Munthe & Hedström 1904), and has been simplified in certain details in order to give the general geological situation of the island. Designations: 1. Exposed limestone bedrock. 2. Moraine. 3. Washed moraine. 4. Glaciofluvial deposits. 5. Littoral deposits. 6. Ancyclus ridge. 7. Litorina ridge. 8. Escarpment. 9. Fens.

Fig. 3. Map with known glacial striae on Öland. The information was compiled from the geological maps of the island (Svedmark 1904, Munthe 1902 *a*, 1902 *b*, Munthe & Hedström 1904) together with new observations by Rosengren (1956) and the author. The main directions on southern Öland are N4–10°E,

submarine extension in Kalmarsund, where they alter direction to a more southerly one. This fact had, however, already been noticed by de Geer (1910).

E. Nilsson has recently described the recession of the great land ice from southern Sweden (1958, 1968), and because of two terminal moraine zones he concluded that the Kalmar-line marks an important limit between two stages of the ice recession from the island. South of the Kalmar-line the N–S directed glacial striae dominate, while north of it striae, eskers and the ridges, which cause the jagged shore line on north eastern Öland indicate an ice movement from NW as the ridges have been considered to be morainic ridges (drumlins, radial moraines). The ridges have, however, later been investigated in some places by the author, and they have turned out to be built up by shore material, and it is then not possible to use them as good indicators of any ice movement (cf. Königsson, 1964 *a*, 1964 *b*, 1967 *a*). As related above the eskers have been shown to alter direction from NW–SE to more N–S in the Kalmarsund proper, and only three glacial striae on northern Öland remain to indicate the ice movement. The NW–SE ice movement over Öland in the recession stage is unsatisfactorily proved, and only a systematic search for more glacial striae on Öland may give a more solid basis for further discussion of this problem. The glacial striae which are known from Öland have been collected on Fig. 3.

When the land ice left Öland, moraine and glaciofluvial material covered the bedrock. Very little of the soils have, however, escaped being visibly influenced by wave action during the various stages of the Baltic. Most of the glaciofluvial deposits which are marked on the map have thus been wave-worked and redeposited, and the Lindby–Solberga delta, east of Råpplinge church is the only one of these deposits that to a considerable extent seems to have remained in primary position. In fact also this formation is redeposited in its upper parts, and in the most easterly parts of the delta wave-washed material covers the glaciofluvial material down to two metres below the surface. The Stora Rör area north of Glömminge church is probably a glaciofluvial deposit too, but no exposures are up till now known that prove this. The soil depths are considerable in this area, 29 and 30 metres have been measured, and the drilling records do not contradict the glaciofluvial theory.

N20–24°E. Additionally a number of striae N70–80°E have been recorded and Rosengren also gives one direction (several observations) N12°W. On the northern parts of the island very few observations have been recorded.

Fig. 4. The scarp of *Västra Landborgen* at Södra Bårby, parish of Mörbylånga, seen from the south. Below the scarp is the coastal plain of Cambrian rocks, submerged under the Kalmarsund in the far left background of the picture. Considerable parts of the coastal plain were covered with deciduous woods even in late historical times, and there are still some remnants on the plain along the scarp. The young wood on this picture is dominated by ash. Above the scarp is the Ordovician limestone plateau of the Great Alvar. The cultivated patch in the foreground is within the Iron Age stronghold of Bårby Borg, whose semicircular wall is covered by low bushes just to the right of the isolated spruce tree. At the horizon just to the left of this tree is the church of Resmo, and the city of Kalmar is at the horizon at the left margin of the picture. Anders Martinsson, April 14th, 1968.

Much of the material *in situ*, which is marked on the geological map, is in fact affected by wave action too. The designations for untouched moraine are then too generously used.

On the geological map a difference was made between washed moraine and littoral deposits. This difference does not seem to be very clear in the field.

During the various stages of the Baltic, Öland was repeatedly flooded and left dry. Littoral deposits and shore ridges are consequently found in most places on the island and two main shore ridge systems from the Ancylus Lake and the Litorina Sea completely dominate the landscape on eastern Öland. These shore ridge systems can be followed also along the western coast, but they are less well developed in most places there. Shore ridges are found from ear-

lier as well as later Baltic stages also, and one of the most striking ridges is situated at the top of the *klint*. This ridge system has not yet been definitely dated, but it seems very probable that the system is a meta-chronous formation and that most of it is older than from the Ancylus period. Especially on the Great Alvar and in the area between the Litorina ridge and the present shoreline additional ridges can easily be followed. Nothing or almost nothing is yet known of when they were formed.

THE FEN BASINS OF ÖLAND

The fen basins of Öland are, with few exceptions, shallow and occupy depressions in the upper surface of the island, which are only up to two or three metres deep. The surface of the island slopes slightly to-

Fig. 5. The distribution of the wind frequency in the southern Baltic throughout the year. From Östman (1926, Fig. 4, p. 16).

wards the southeast, and morphologic elements which are more or less transverse to the direction of drainage play an important rôle as damming factors. This is especially true of the great shore ridges on eastern Öland, which run roughly parallel to each other and to the present shoreline.

The sediments in the lower sections of the fens are usually composed of lime gyttjas and detritus gyttjas, with a varying content of algal detritus. Usually the depositional environment can be referred to one facies, rich in lime, of the oligotrophic lake and fen series. In the peat soils overlaying the sediments, the tall *Carex* species, *Cladium mariscus* and *Phragmites communis* play the main rôle within the source communities. The environment of change from lacustrine to thelmatic plant communities shows a considerable amount of *Equisetum fluviatile* and in the limnic phases different species of *Characeae* are characteristic.

REGIONS

Öland differs very markedly from the adjacent areas of the Swedish main land, where the igneous rocks dominate and the landscape is rather hilly, partly because of moraine topography. The highest point on Öland, 57.37 m above sea-level is situated south of Mörbylånga on top of the *klint* at the former gallows-lea near Bårby prehistoric stronghold. Except from the *klint* line on western Öland, not many pregnant landforms are to be found on the island, which is a very flat land. On eastern Öland even stone walls and straw ricks form important differences of altitude, which are widely seen. It is then natural that the higher shore ridges dominate their regions. The following regions are distinguished (see also Bergsten 1948, p. 87, for comparison):

(1) *The klint line and the western coast plain.* Also in this area shore ridges occur, but they never dominate as much as they do on the eastern side of the island. The coast plain is widest at Mörbylånga and becomes narrower towards the south and north. This means that the region only contains the *klint* itself and a very narrow strip of shore west of it north of Köping and south of Degerhamn. The coastal plain is partly covered by boulder clay, which forms one of Sweden's best agricultural areas (Fig. 4).

(2) *The sandy area in the northernmost part of Öland.* In this area drift sand plays an important rôle and in many parts sand dunes occur. Shore ridges and exposed rocks are also found in the area, and the shore ridge area north of Byxelkrok, the fields of Neptunus, is a famous tourist object. In

this area the pine woods on northern Öland have their greatest extension.

(3) *The shore ridge area of northern Öland.* This area is dominated by the NW–SE directed ridges, noted above, which should be interpreted as shore ridges. All over the region exposed bedrock is scattered. The frequency of exposed bedrock is highest in the westerly parts. In the surface littoral deposits dominate within the soils and the fen frequency is low.

(4) *Middle Öland.* Middle Öland is characterized by moraine deposits. Exposed bedrock occurs within the region, but to a minor degree than otherwise on the island, and the fen frequency is higher in this region than in others except for the Alvar areas. The biggest fens on the island belong to this region: Skede Mose, Lindby Mose, Mossberga Mose (Gladvattnet), Jordslåta Mose and Amunds Mose. The only safely determined glaciofluvial deposits of the whole island occur in the Lindby–Solberga area.

(5) *The Great Alvar.* This area is characterized by a remarkable lack of thicker soil. The topography is extremely flat, and shallow shore ridges and scarps dominate the morphology. Karst phenomena occur very frequently and much of the drainage is following the joint systems in the underground. Together with the shore deposits, weathered material and wind-transported soils dominate the Quaternary deposits. The fen frequency is very high.

(6) *The shore ridge area of eastern Öland.* This area is limited westwards by the Ancylus ridge in its northern parts, the Litorina ridge in the southern. The Ancylus ridge runs from Övre Vannborga in the parish of Köping, just north of Borgholm, down to Hulterstad church on southern Öland, and from there and down to the island's southern end the Litorina ridge replaces it. East of this limitation a very flat landscape is found, which is characterized by littoral deposits in its northern parts and where the frequency of exposed bedrock grows higher the more southerly on Öland. Except from the Great Alvar, no other region but this one has higher percentage of exposed bedrock. Littoral deposits are the most common soils together with a thin cover of weathered material in the exposed bedrock areas. The fen frequency is very low.

The Climate

The climate of the island is known from general papers on Swedish climatology, but no thoroughgoing special reports on the conditions of Öland have been published. In his paper on the epiphytic moss

Fig. 6. The wind frequency during the seasons at the southernmost part of Öland. Southwesterly to westerly winds predominate throughout the year. From Östman (1926, Fig. 3, p. 15).

communities in the deciduous woods on Öland, Sjögren has, however, summarized some macroclimatical and microclimatical facts (1961, pp. 9–14).

THE WIND

Because of the air pressure distribution Scandinavia can be expected to be dominated by southerly to southwesterly winds (Ångström 1958, p. 97). According to Östman (1926, p. 16) there is a clear tendency that the dominant winds are roughly parallel to the shorelines in the Baltic, while they are generally perpendicular to it at the Swedish west coast.

In the Baltic NE to E winds dominate in the springtime, while the winds generally blow from SW to WNW in the summer. The more westerly winds are dominating more in the southern areas of the Baltic. During the autumn SW and NE winds dominate together and in wintertime there is a very pronounced maximum for winds from SW to W (Fig. 5). Roughly the same conditions are also true for the southern tongue of Öland (Fig. 6) and this will also be the main wind pattern for the island in general.

As to harder winds, Östman (1926) gives a summary for the years 1907–1916. The maximum for the whole year if the wind forces 7 Beaufort and more is considered has a wind direction from SW

Fig. 7. The hard wind frequency at Ölands southernmost part according to Östman (1926, p. 7). Winds from SW, WSW, and W predominate for winds ≥ 7 Beaufort. Another maximum is shown for winds from N, NNE, and NE. The westerly hard winds are frequent during most periods of the year, while the northerly to northeasterly winds show highest frequency during the winter.

and WSW, and the same directions dominate the still harder winds of 10 Beaufort and more (Fig. 7 and Fig. 8). The wind frequency is not very high, in any case considerably lower than on the Swedish west coast.

Fig. 8. Wind frequency for winds ≥ 10 Beaufort at Öland's southernmost parts, according to Östman (1926, p. 12). The maximum during the year for these winds is for those from SW to WNW.

SUNSHINE

Sunshine and cloudiness in Sweden was investigated for the period 1930–1949 by Lindholm (1955), whose material also involved a measuring station on Öland: its southern tongue. This station, however, had only been functioning during part of the period, and because of this the results may have some uncertainty. The average values of sunshine hours were about 2000 per year for the very northern and southern parts of the island, and slightly less for the rest of it. This is a very high value for Sweden, and it should be compared with 1600 hours per year in parts of south western Sweden and with 1400 hours per year for some regions of western Norway.

PRECIPITATION

Sjögren (1961, pp. 11, 12) gives figures for the precipitation in some stations on Öland compared with the adjacent areas of the Swedish mainland. According to this material Öland can be considered to be in the rain shadow behind the higher elevated western parts of south Sweden. The precipitation per year is lowest in the northern and southern parts, around

460 mm, and slightly higher in the middle part of the island. The average for the summer half year is around 250 mm, which is a critical limit for cultivation without irrigation (Sjögren 1961, p. 11). In Sweden the highest precipitation values are found in the westernmost parts of the country, where in places precipitation figures of between 1500 and 1600 mm per year have been measured. The normal precipitation varies in Sweden between 500 and 1000 mm (Ångström 1958, p. 63).

The number of days with snow cover on the ground is between 60 and 80 on northern Öland and less than 40 in the southern parts of the island (Ångström, 1958, p. 49). Southern Öland belongs to those regions in Sweden which are extremely poor in snow.

TEMPERATURE

Öland belongs to the local maritime east coast region in Sweden (Ångström, 1958, p. 31). The springs are coolish and fairly late, which was already noted by Westerlund (1850, pp. 232, 233), the autumns rather warm, all of which depends on the water temperature in the Baltic. The amplitude of the temperature throughout the year is low.

The average temperature for the year on Öland during the period 1935–1947 was 7.4° centigrades on two measuring stations (Sjögren, 1961, p. 11). The coldest month is February with values between –2° and –1° centigrades and the warmest month July with values between +16° and +17° centigrades (Ångström, 1953, p. 3).

HUMIDITY

De Martonne (1926, p. 450, 451) expressed his "L'indice d'aridité" as $P: (T+10)$, where P was the annual precipitation and T the mean annual temperature. According to this formula Hesselman calculated a humidity degree (for several reasons he disliked de Martonne's name on his index) for Sweden (1932, pp. 530–533). This method was slightly changed and so used by Ångström (1953, pp. 3, 7, 1958, p. 75), and he calculated the degree for the vegetation period only. In both cases Öland gets very low values, less than 30 (Hesselman) and 20–24 (Ångström), which places the island in the sub-arid dry region. This may be compared with the highest Swedish values, which are more than 60, and with the Russian black earth areas, where many places show the same humidity degree as Öland (Sjögren, 1961, p. 12).

The Vegetation of Öland

The vegetation depends greatly on the geology and climatology of the area. This becomes very evident on Öland, where edaphic conditions involve great changes according to soil depth and drainage. The flora list includes many plants which are exotic for this part of the European area and many endemic species occur. The floristic research started with Linnaeus and his journey to the island in 1741. Ever since botanists have been interested in scientific work on Öland, and most Swedish botanists before the present era of intense specialisation have contributed to the floristic knowledge of the island. It even seemed to be *en mode* during the latter part of the nineteenth century for Swedish botanists to make a quick trip to Öland and afterwards to publish some floristic novelties from the island.

THE WOODS

"The road passed through the most beautiful groves you could ever see, which had a beauty exceeding that of all other places in Sweden, and which could compete with all places in Europe; they consisted of lime trees, hazels and oaks, with an even and green soil without stones or mosses; here and there you could find the most marvellous meadows and fields" (Linnaeus, 1745, p. 64).

This description of the idyllic wood landscape on Öland in the middle of the eighteenth century is indeed a good introduction to a description of the wood conditions on Öland today. Linnaei words show the picture of a pastoral landscape, and he does not mention much which can be interpreted as the original vegetational environment, except some information as to the Alvar areas.

The woods on Öland are in fact completely influenced by the activity of Man, and this activity has worked on the landscape and the vegetation for centuries with periodically a greater or lesser intensity.

The present situation is dynamic. The field pattern on Öland is generally very old-fashioned, and much of it has not changed remarkably since Medieval times. Only the western coastal plain (p. 15) can show ordinary fields, and on much of the rest of the island the fields are still very small, sometimes only some thirty or forty metres wide and one or two hundred metres long and they are surrounded by ditches and stone walls. In our days it is not possible for such small agricultural units to survive actively and where it is not possible to form bigger farms by uniting several older ones, the fields will be left wasted and the trees will quickly immigrate. Old

pasture grounds and meadows have already to a great extent become wooded and the percentage of wooded area on the island is increasing.

This fact is very strikingly shown in the figures for the wooded areas in the two forest valuation surveys which were made in 1923 and 1948. In 1923 the wood productive areas were 13.2% (Riksskogstaxeringsnämnden 1932 *a*, p. 87) and in 1948 17.4% (Arman, 1950, p. 355). The difference, 4.2%, may however be a little too high as the older survey did not take into account smaller stands of trees, which were included in the survey of 1948. The different types of woods in the two surveys (Riksskogstaxeringsnämnden 1932 *b*, pp. 16, 17, Arman, 1950, p. 356) were:

	Pine woods	Spruce woods	Mixed coniferous woods	Mixed coniferous and deciduous woods	Deciduous woods
1948	29.8	3.0	6.9	15.7	44.6
1923	24.1	0.9	15.5	11.8	47.7

These figures show how the woods on Öland up to about 50% are deciduous woods. Only one Swedish province, southern Scania, shows higher values and Gotland had for instance only 2.7% deciduous woods in 1928. The figures also show how the coniferous woods increase their percentual part of the island's woods and that within these the spruce woods show a very marked increase on their part.

The woods on Öland have been described by Danielsson (1918), Sterner (1926, 1938, 1942, 1955 *a*, 1955 *b*, 1955 *c*) and Sjögren (1961, 1964). Danielsson treated the historical aspects of the woods in general, and Sterner described the present conditions on the island, in one case comparing the conditions of certain areas with historical information.

Coniferous woods are found on the well drained, usually sandy or gravelly soils in the northern parts of the island but also north of Glömminge and in the Lindby-Solberga area on glaciofluvial or assumed glaciofluvial formations. During the last years of the nineteenth century and also in the nineteen-twenties the planting of pines was very common in many places, especially on the great shore ridges on eastern Öland, but also on the Great Alvar on some shore ridges there. Solitary pine trees grow spontaneously in most parts of the island.

Mixed deciduous woods are most common on the morainic soils on middle Öland but also on the coastal plains west of the *klint*. A very famous stand of deciduous trees is in the Ottenby lund in the Southernmost part of the island, where *Quercetum mixtum*

is very important. According to Sjögren (1964, pp. 16 et seq. and p. 166) the most common and extensive type of deciduous wood on Öland is the *Quercus robur*-*Betula verrucosa* woods with *Corylus avellana* in the bush layer. There are also drier types of *Quercus robur*-*Betula verrucosa* woods, where *Juniperus communis* replaces *Corylus avellana*. This type is most common on the littoral deposits on or near the Ancylus and Litorina ridges. Additionally there are smaller stands with *Tilia cordata*- and *Carpinus betulus*-woods and on wetter sites *Fraxinus excelsior*- and *Ulmus glabra*-woods dominate. The latter does not cover as big areas on Öland as the birch-oak woods do. *Acer platanoides* and *Ulmus carpiniifolia* are found in the tree layer. In areas with constantly wet conditions *Alnus glutinosa*-*Betula pubescens* woods with *Salix* spp. occur, but this wood type is more seldom found on the island. For a more detailed description of the wood conditions on Öland, see Sterner (1926, 1938) and Sjögren (1964).

On abandoned pasture grounds and on thinner soils birch woods dominate and this type also appears in the border zones of the Alvar areas.

A very special type of wood on Öland is the hazel woods (öl: *hässle*), which in its extreme form shows almost pure stands with *Corylus avellana* (Sterner, 1926, 1955 *a*, 1955 *b*; Martinsson, 1964). They occupy rather big areas on middle Öland (Sterner, 1938, p. 27) and should at least in its greater part be considered as culturally dependent on their existence. They have even been subject to careful treatment in older times so as to yield as big nut crops as possible (Martinsson, 1964, p. 459), when hazel nuts were an important export product from the island.

Sterner (1948) notes the following list of trees and bushes growing on Öland. A few pieces of information from Sterner's book on the flora of Öland (1938) have been added to the list.

Pinus silvestris and *Picea abies* occur spontaneously all over the island.

Taxus baccata grows rarely and only a few bigger stands of trees are known.

Populus tremula is a typical pioneer tree on the abandoned fields and in the border zones of the Alvar.

Single individs may be seen in most woods.

Salix cinerea grows in all parishes on Öland.

Alnus glutinosa is growing on the island, but it is not very common if compared with its frequency in the adjacent areas of the Swedish mainland.

Alnus incana has an isolated stand of trees on the northernmost part of the island.

Betula verrucosa and *Betula pubescens* grow all over the island, the latter on wetter ground.

Quercus robur is very common on Öland and dominates in groves and meadows.

Fraxinus excelsior is considered to be the most common tree on the island. It grows in the woods and in groves and meadows, around fields and along roads. Pure stands of ash are, however, seldom seen and if they appear are not very extensive.

Tilia cordata occurs in meadows and groves as single trees in most parts of the island, and almost pure stands of greater extension are known from a couple of places on northern and middle Öland.

Ulmus carpinifolia is the most important of the elm species of forest trees, but it is rare on northern Öland.

Ulmus laevis belongs to the deciduous woods on the wetter grounds on middle Öland. It is not known to grow in pure stands on the island.

Ulmus glabra is a rather unimportant species in Öland's woods and the most abundant growing place is along the *klint* near the ruined castle of Borgholm.

Acer platanoides is commonly spread over the island.

Sorbus aucuparia is common almost all over the island.

Sorbus intermedia has been found growing in all parishes on the island.

Fagus silvatica. The present individs of this species on Öland are considered not to be spontaneously growing.

Carpinus betulus grows normally as a single tree or smaller stands of trees within the woods. There are also a few bigger stands and one of them at Halltorp just south of Borgholm is thought to be the most extensive *Carpinus* wood in all Sweden (7.5 hectares).

Crataegus oxycantha and *C. monogyna* occur over the island, the former as one of Öland's most common bush species, the latter very often in tree form.

Corylus avellana grows in the groves and meadows as part of the woody vegetation, often together with *Quercus*, *Fraxinus*, *Ulmus* and *Tilia*. It may also very frequently be found in almost pure stands.

Euonymus europaeus and *Cornus sanguinea* are common bushes on Öland and they are especially characteristic of the vegetation, which is connected to the *klint*. The latter may be seen in tree form.

Rhamnus cathartica and *Rh. frangula* are also common bushes on the island, the former most frequent. Both are characteristic for the karst areas on the Alvar where *Rh. cathartica* not seldom occurs in tree form.

Juniperus communis is most common in the Alvar

areas but occurs abundantly all over the island. Juniper in tree form is rarely seen.

Viburnum opulus occurs rather frequently in groves, meadows and bush areas. It has also been seen in the Vickleby karst area.

Sambucus nigra occurs rather commonly on western and southeastern Öland, but is considered not to have spontaneously immigrated to the island.

Among the *Rosa* species *R. majalis* is found mostly on moister grounds or in meadows, *R. rubiginosa* occurs along the west coast of central Öland and *R. villosa* is common all over the island. *Rosa* sp. is characteristic also in many Alvar areas.

Five *Rubus* species are known to grow spontaneously on Öland, mostly as bushes in the under vegetation in some woods.

Prunus spinosa is a characteristic bush from almost all Alvar areas and from the top of the *klint*. It also grows more or less synanthropically in the fields and meadows. *P. padus* is (Sterner, 1938, p. 117) only known to have grown spontaneously in one place, but seems to have grown more abundantly on Öland earlier.

Myrica gale grows in wetter wood types, mostly in connection with fens and most abundantly on northern Öland, where less lime-rich areas are found.

Potentilla fruticosa grows in the southern part of the island very commonly, and has also been subject to protection in older days as the "tok" was used for making brooms.

Finally *Hedera helix* should be mentioned together with the trees and bushes. (*Viscum album* is not known to grow on Öland at the present time.) It grows on Öland in various biotopes, in the pine woods on sandy soils on northern Öland, in birch-oak woods on littoral deposits on middle Öland, along the *klint* and even in the Alvar areas.

THE FLORA

The following description is summarized from Sterner's paper on the flora of the island (1948), which unfortunately was written in Swedish and without an abstract or summary in any congressional language. The description is restricted to the phanerogams and ferns, but a few occasional notes as to the lichens on the Alvar are also given. The systematic names have been controlled and put in conformity with Hylander (1955).

The number of species of Öland's flora is about 1050, and at least 200 of these should be considered as culturally dependent on their existence. Additional species, which are no longer growing on Öland, but which can be proved to have grown there some

time during the last 100 years amount to 16 in number.

The composition of the flora differs remarkably from the adjacent areas of the Swedish mainland. 12 species and 3 subspecies are only known from Öland in all Sweden, and all except two of these are only found outside the Scandinavian floral area except on this island. The latter are *Artemisia laciniata*, *Plantago tenuiflora*, *Orobancha purpurea*, *Ranunculus illyricus*, *Viola alba*, *V. odorata*, *V. elatior*, *Helianthemum oelandicum*, *Helianthemum canum*, *Helianthemum italicum* ssp. *rupifragum*. *Bassia hirsuta* grows in some places in southern Denmark and *Ulmus laevis* in southeastern Finland. The following species are shared with Gotland: *Artemisia rupestris*, *Aster linosyris*, *Globularia vulgaris*, *Galium rotundifolium*, *Veronica praecox*, *Orobancha alba*, *Adonis vernalis*, *Anemone silvestris*, *Sisymbrium supinum*, *Viola pumila*, *Fumana procumbens*, *Potentilla fruticosa*, *Coronilla emerus*, *Ulmus carpinifolia*, *Anacamptis pyramidalis* and *Apera interrupta*. On Öland and in Scania *Peucedanum oreoselinum* and *Carex obtusata* occur. The mentioned species have their normal growing places more to the south in Europe or should be expected to be found still farther away. The following groups of exotic elements in Öland's flora can be distinguished:

1. Siberian Group

Artemisia laciniata is common all over the steppes of southern Siberia. In Europe it is most abundant on Öland and has additionally been found in Austria, Mähren, Thüringen, and Anhalt (Wendelberger, 1959), has shown that *Artemisia oelandica* has been mistaken for *A. laciniata* on Öland). *Artemisia rupestris* is also a common plant in southern Siberia. It has been found on Gotland, in Estonia and in a few places in central Germany. *Potentilla fruticosa* grows extensively in large parts of Siberia and in middle Asia from Persia, the Caucasus and Ural in the west. It also grows in North America in the Rocky mountains and in Canada more to the east. It has been found in a few places on Gotland, in one place in Kurland, it grows relatively abundant in Estonia, it has also been found in a few places in the west Alps, in the eastern parts of the Pyrenees, in northwestern England and on western Ireland. *Carex obtusata* grows over great parts of North America and southern Siberia and has been found in Europe in the neighbourhood of Moscow, in southwestern Russia, in Rumania, near Leipzig, in Brandenburg and in one place in Scania, Sweden. *Oxytropis campestris* grows all over middle Asia and northern

North America and in the central European mountains.

2. Southeastern European Group

In this group one will find *Plantago tenuiflora*, which normally grows in the salt steppes of southern Russia and Hungary and on Öland some 1000 km north of its nearest growing place in Hungary. *Ranunculus illyricus*, which is also found similarly distributed and *Adonis vernalis*, which also belongs to the same area, but which is also rather abundantly growing in central Europe. Additional species of the same southeastern European origin, but not steppe plants, also occur, e.g. *Melampyrum nemorosum*, *Cynanchum vincetoxicum*, *Gypsophila fastigiata*, *Laserpitium latifolium*, *Cnidium dubium*, *Viola tenuifolia*, *Viola elatior* and *Anemone pratensis*. These species grow in open woods, on the Alvar areas, around the fields and in the groves.

3. Southern European Group

These species have their main distribution in southern Europe and they also occur scattered more or less rarely in the central parts of our continent. They have isolated outposts on Öland and on Gotland, whose limestone rocks offer fairly warm growing places: *Viola alba*, *V. odorata*, *Helianthemum canum*, *Fumana procumbens*, *Apera interrupta*, *Veronica praecox*, *Hornungia petraea*, *Holosteum umbellatum*, *Cerastium glutinosum*, *Kohlruschia prolifera*, *Poa bulbosa*, *Coronilla emerus*, *Medicago minima*, *Verbascum thapsiforme*, *Anthericum ramosum*, *A. liliago*, *Galium rotundifolium*, *Gagea pratensis*, *Sisymbrium supinum*, *Erythraea capitata* and *Globularia vulgaris*.

4. Southwestern European Group

There are comparatively few species with special connection to the southwestern European flora on Öland. However, a few species have their northeastern limits on Öland and Gotland as *Teesdalia nudicaulis*, while *Taxus baccata* also reaches the middle Swedish archipelago and southwestern Finland. Other species with southwesterly main distribution are *Hedera helix*, *Myrica gale*, *Baldellia ranunculoides*, *Litorea uniflora*, *Carex arenaria*, *Phleum arenarium* and *Blechnum spicant*.

5. Northern European Group

The most remarkable parts of this group are mountain species. Among the mosses and lichens there are

several such species as *Thamnolia vermicularis*. Among the ferns are *Asplenium viride* and *Polystichum lonchites* and among the phanerogams *Poa alpina* and *Lychnis alpina*.

6. Endemic Group

Helianthemum oelandicum, *Festuca rubra* ssp. *oelandica*, *Crepis tectorum* ssp. *pumila*, *Galium pumilum* ssp. *oelandicum*, *Silene maritima* var. *petraea*, *Allium schoenoprasum* var. *alvarense*, *Viscaria al-*

pina var. *oelandica* and *Plantago tenuiflora* var. *depressa*.

Sterner considered the exotic elements in Öland's flora as relicts from floras during the arctic and warmer periods during the Late Pleistocene and Holocene vegetational and climatic developments. This opinion as to the strange flora elements on the island has long been common among the botanists and e.g. Eriksson (1900, p. 79) counts 70 of around 300 phanerogams and ferns on the Great Alvar (23%) as relicts from the Late Pleistocene period only.

THE INVESTIGATION AREA

The Investigation and its Extent

Originally this study was initiated to investigate an Alvar fen on Öland and the main purpose was to study the stratigraphy and to date the main stratigraphical events by using pollen analysis.

Dröstorps Mose on the northern part of the Great Alvar (Fig. 47) was chosen for the study, and the results were published in 1962 (Königsson, 1962 *a*, 1962 *b*). Although no detailed modern pollenanalyses were obtained at that time the results still showed

that there were good possibilities for a reconstruction of the landscape history of the Great Alvar if extended investigations of the Alvar lakes and fens and their sediments were made.

In the beginning of the renewed investigations only a study of the Alvar lakes and fens was involved. Later on it became necessary to map the physiognomic conditions of the whole Great Alvar in order to show where eventual woodlike vegetational types could exist and to investigate a couple of fens in the deciduous wood area of middle Öland for comparison.

Fig. 9. Alvar west of Möckelmosen, parish of Resmo, with boulders on a very thin layer of weathered soil upon the bedrock. This type of Alvar with fairly high boulder frequency is rather common, and the boulders are considered to be residuals from a formerly existing soil, rich in boulders. June 1962.

Fig. 10. Air photograph of the southernmost part of Vickelby Storkarst. From the lower left corner a light grey feature runs to the middle of the picture's right margin. This pattern forms part of the Resmo–Ekelunda zone, where a gravelly ridge is situated on the bottom of the groove. The ridge has been examined stratigraphically in one place, where the material turned out to be moraine. In the middle of the photograph an abundant vegetational formation of junipers is found. To the left of this is a darker grey area, which is a temporary pool. In the upper left corner a beach ridge is seen, which belongs to the specific beach ridge type on the Alvar. In several parts of the photograph almost white areas can be seen. These are ephemeral temporary pools. Air photograph by Rikets Allmänna Kartverk 1959. Published by permission of the Swedish Defense Staff.

This paper therefore reports both on the results from the extended Great Alvar studies and on the results from the comparative study on middle Öland.

The Great Alvar of Öland

“One could now see the type and character of the Alvar, which forms the greatest part of Öland and which is a horizontal plateau which is quite dry, bare and sharp, because she only consists of red limestone covered by soil to a finger's thickness or by no soil at all” (Linnaeus, 1745, p. 50).

Linnaei description of his first impressions of the Great Alvar is typical of the impressions of those people, who just travel over the Alvar very quickly,

and for the general opinion of the Alvar's nature (Fig. 9). This is very strikingly shown on the geological maps of Öland (Fig. 2, p. 13), where the Great Alvar indeed is shown as a bare limestone plateau with almost no noteworthy deposits on it.

In order to give the real picture of the distribution of the Quaternary deposits on the Great Alvar, the whole area has been mapped and the result is given on the map in two sheets, which can be found in the plates section of this paper.

The mapping was performed on unrectified air photographs, which means that the map is not quite correct as to the exact position of the landforms. However, the errors do not seem to be very serious, which probably is due to the small differences in altitude over the area, and they have therefore been

Fig. 11. Detail of Fig. 10, showing the area with open joints in the right part of the photo as well as the gravelly ridge mentioned in the text accompanying Fig. 10. It is markedly shown how bushes and smaller trees are restricted to growth in the joints themselves in this area, and how air photographs afford excellent possibilities for extended studies as to the joint directions.

One may also see how the gravelly ridge is very uneven, and how in many places the joint pattern can be traced below the deposit. Air photo: Rikets Allmänna Kartverk 1959. Published by permission of the Swedish Defense Staff.

considered to be of minor importance, as the purpose of the mapping does not demand 100 % exactness.

The mapping was done in the following way. The air photographs were produced in the scale 1 : 5000 (approximately), and some key areas, which were to be examined in detail were chosen. These key areas were all especially well known to me already before

this time. During the key area stadium of the mapping control diggings were performed very frequently. When the key areas had been investigated carefully, the air photos were studied stereoscopically over a greater area, which was also very well known before, and on the basis of the information from the keys a preliminary map was drawn. This was later

Fig. 12. Södra Bårby karst area, parish of Mörbylånga. In this area very well developed open joints occur. The bedrock is covered by various lichen societies, and in the joints one may find *Prunus spinosa*, *Juniperus communis*, *Rosa* sp. and *Rhamnus cathartica* commonly growing. July 1966.

controlled in the field, and predetermined investigation lines were followed. However, extra controls were still made on many patterns on the photos, which for some reason were considered to be uncertain as to their origin, but which were beside the investigation lines.

Later on the same method was extended to the rest of the Great Alvar, and the mapping was carried out during the summers of 1962, 1963 and 1966, when the first map manuscript was completed.

Although the greatest caution has been paid to the

mapping method to make the map as safe as possible, errors may occur. Minor gravelly deposits, especially solitary ones could easily have been overlooked, and for instance small dolines systems may occur, which I have not noticed. The map area is more than 200 km², and because of this it is quite possible that some mistakes may have been made, which however, must be of minor importance for the main geological picture of the Great Alvar, which has been the result of the mapping and which can not be changed except in single details.

Fig. 13. Bedrock Alvar NW of Ekelunda village, parish of Sandby. The joints have become filled up by soil and thus afford growth places for grasses and herbs, which otherwise could not grow within this type of Alvar. The juniper in the foreground also depends on the joint for its existence. August 1966.

THE BEDROCK ON THE GREAT ALVAR AND ITS MORPHOLOGICAL PATTERN

Already in the descriptions of the geological maps of Öland, some notes of the bedrock morphology of the Alvar areas were given (Munthe, 1902 *a*, pp. 33, 34), where the limestone layers were said to be in long "waves" or, more seldom, in low folds. The occurrence of such low folds is also known from the northern part of the island, where they have been described recently (Lindström, 1963), but they are not very pregnant in the field. Instead karst phenomena and erosional features in the limestone layers dominate on the surface, but even these features have rather modest dimensions.

The joint systems in the bedrock are of great importance for the morphological development of the land surface (Fig. 10, Fig. 11). These systems have been studied by Kaufmann (1931) and by Lindström (1963). Kaufmann showed how the joint systems on the island form part of a bigger system, where Öland, Gotland and the adjacent areas of the Swedish mainland on the whole have the same joint

pattern. However, other joint directions than those recorded by Kaufmann may also be seen on Öland, and the Great Alvar is the ideal area for extended joint studies.

The joints are often filled with calcite but weathering has again opened many of the joints, anyhow in the surface layers, and widened them, and much of the drainage on the Great Alvar, perhaps even most of it follows the joint systems (Fig. 12). The vegetation of these areas is rather special and will be described below. On the Alvar the joints are open in the superficial parts in many areas, while they have been filled with soil in others and thus afford possibilities for the growth of herbs, bushes and even trees (Fig. 13). On the map a few vaster areas with open joints have been marked as karst areas, which is an inexact term as really the whole Great Alvar is a karst area. The term refers to the popular name on two of the most famous areas with open joints, the Vickelby Storkarst and the Ekelunda Hasselkarst, but originally coined for similar areas on the island of Stora Karlsö, west of Gotland in the Baltic (cf. Sernander, 1915, Du Rietz, 1921). There are also many

Fig. 14. One of the supposed dolines in the Resmo–Ekelunda zone. The series comprises units of very varying size; this one is one of the biggest. July 1965.

minor areas with open joints, which have not been marked on the map, and a series of such smaller areas may for example be found along both sides of the ridge, which in a northern–southern direction runs from Storåsen (L: 3) on sheet I of the map to Solberga (N–O: 4).

Other karst phenomena have been observed on the Great Alvar. Corbel (1952) treated Swedish karst phenomena in general, and he gives a few notes from Öland. He distinguished two main types of phe-

Fig. 15. Section through one of the supposed dolines in the Resmo group. The section was made by Sydsvenska ingenjörbyrå, SIB, Malmö, for hydrogeological reasons and was kindly put at the authors disposal. The altitude above sealevel is given and the arrow in the left margin shows the ground water surface.

The dimensions of the formation are remarkably large. It seems to be a very interesting fact that features of this range have been able to survive the entire late pleistocene and the holocene climatic successions fairly undisturbed. The formation as shown on the section may perhaps be a doline, but may rather be a sink-hole. Its size may be a consequence of the drainage conditions in

the Resmo–Ekelunda zone, where many springs indicate an abundant water flow, which is very favourable to the formation of dissolution phenomena. The genesis of many of the so called dolines of the Alvar is thus not quite clear.

Fig. 16. The Priest's Pit, one of the supposed dolines in the series NNE of Ekelunda village. Also this formation is connected to a zone with many springs in its very neighbourhood. It is then possible that they should be looked upon as dissolution phenomena of sink hole type. In June 1968 new features have appeared in this area. They will be investigated and reported later on. July 1962.

nomena, the joints and the dolines, which he considered to be very flat ones. He referred to the bigger Alvar fens or Alvar lakes as flat dolines (Möckelmosen, "Ebbelunda mose" (Kritmosen) and Lunda mose). Möckelmosen is not a doline but an accentuated scarp formation with a lake basin dammed by the scarp (cf. pp. 68, 71). This seems to be the case with the Kritmosen too, while it is impossible to say anything accurately about Lunda Mose. Rosengren (1956) found doline-like features in the quarries of Degerhamn and Grönhögen, which he called micro-dolines, and he also described karran weathering from the Great Alvar. Svensson (1963) demonstrated a doline system on the Alvar near Resmo church (Fig. 14, Fig. 15). These were also described by L. Nilsson (1965), who also showed additional dolines in a system SE of Sa Bårby village and some examples of karren weathering. Palmquist (1965) described dôme-like formations from the Alvar south of the Sa Bårby dolines. From Rosengren's report

it is clear that doline-like features may be expected to occur more abundantly than was known earlier, and that below the soils of the Alvar such phenomena appear in many places. The author knows one additional doline system of importance to the two described by Svensson and L. Nilsson, namely the so-called Priest's pit (B: 4) WSW of Skarpa Alby village (Fig. 16). The dôme-like features are rather common and may be found almost over the entire Great Alvar, but they are very varying in size and those reported by Palmquist belong to the largest I have seen. The largest one has been found SSW of Ekelunda village.

There are some saddle-formed ridges on the Great Alvar. One of them was already described by Munthe (1902 *b*) from Mellby (p. 29). Another has been described by Bergsten & Svensson (1963), the so-called Pig's Back (*Svinryggen*) south of Möckelmosen (F: 4), and they mention one additional ridge south of Gösslunda (I: 4) (Fig. 17). Hedström & Wiman

Fig. 17. One of the saddle-formed ridges on the Alvar. This one is the Gösslunda ridge which follows the same direction as one of the supposed tectonic zones marked on the map, Fig. 38.

(1906) discussed the Resmo–Ekelunda zone (Fig. 18), which they call a broken saddle, and Bergsten & Svensson suggested that the saddle-formed ridges may be very closely related to this formation. From the mapping I know one additional saddle-formed ridge, which is situated on the southern “shore” of the Resmo–Ekelunda zone and is quite parallel to this and two minor ridges west of the Pig’s Back. There are, however, many other features on the Great Alvar, which have the same direction as the mentioned ridges and the Resmo–Ekelunda zone which continues further to the northeast and ends in the Norra Vället fen. This pattern and some other interesting similarly directed patterns are drawn on the map, Fig. 38, p. 49.

As the Great Alvar is really a flat land even rather modest height differences mean important mor-

phological features. As said above (p. 12), the surface of the island cuts obliquely across the limestone layers at an even more acute angle than the dip of the layers. As the strike of the layers on the whole follows the length axis of the island, this means that the scarps have developed roughly running in the same direction. The scarps normally face westwards, but residual areas where younger strata remain isolated and surrounded by older layers occur frequently. Some of these residuals are rather extensive and between Möckelmosen and Resmo there is one very big such area. The scarp systems on the Great Alvar are important features (Fig. 19). Along the scarps fens and Alvar lakes have developed in basins formed against them, and the superficial drainage follows the systems to a great extent. Thus they afford possibilities for biological produc-

Fig. 18. Air photograph of the Resmo-Ekelunda zone from NE towards Resmo, parishes of Vickelby and Resmo. The area in the foreground is identical with those on Figs. 10 and 11. The gravelly ridge in the middle of the picture is situated on the bottom of a groove, which normally has a well developed scarp as boundary on both sides of the groove. On the picture is also seen how some shore ridges join the groove ridge. This indicates that the groove ridge's material may contain portions of littoral gravels and sand in places. The only material control which was made up till now has, however, shown unaffected moraine. June 1965. Published by permission of the Swedish Defence Staff.

tion and plant growth, and many of them remain green during the normally rainy years (Fig. 20, Fig. 21). Finally it should be noted that many of the gravelly deposits have been deposited on places where the scarp systems seem to have influenced the localization of the deposition.

Jaanusson (1947) considered that the glacial erosion in northern Estonia had mainly implied breaking up limestone slabs and that a surface with scarps had been produced in this way. The described surface is very reminiscent of that of Öland's Alvar with its

scarp systems. Jaanusson also showed analogies with the glacial erosion in Archaean rocks based partly on his own observations, partly on Ljungner's (1930, p. 257). It seems very probable that the scarp system development is closely connected with the glacial activity, but the joint system may have played an important rôle as to the determination of the scarp's local variations of direction. It is also obvious that tectonic zones have affected the scarp development and that processes during the Holocene have modified the scarp pattern in some areas.

Fig. 19. Scarp east of Gösslunda village, parish of Hulterstad. The strike of the limestone layers on Öland follows the length axis of the island on the whole, and the scarps have developed with this main direction. Many scarps are very accentuated, but most of them are very low features, and the simplest way of mapping the scarps system would be air photographs over the Alvar in autumns after heavier rains or in springs after the snow thawing. June 1966.

Glacial striae have been found in a few places on the Great Alvar. A map with all striae on Öland known up to now is given in Fig. 3. Some of the striae on the Great Alvar are amazingly well-preserved and crossing striae directions occur (Fig. 22). It is, however, very difficult to establish safe interpretations of what directions are older, as the Holocene weathering activity has made the crossings rather diffuse and unclear.

THE VEGETATION OF THE EXPOSED BEDROCK AND THE KARST AREAS

1. The Exposed Bedrocks

Albertson (1950) distinguished the following associations, which are briefly reviewed. For detailed information see Albertson's paper.

A: *Lecanora calcarea* - *Verrucaria nigrescens* - Association (*Lecanoretum calccareae*, p. 282). This association is a terrestrial one with xeric communities. It is best represented within the karst areas. B: *Collema cristatum* - *Collema tunaeforme* - Association (*Collematetum tunaeformis*, p. 283). This association is characteristic of such parts of the exposed bedrock areas where seasonal flooding occurs. It will be again referred to together with the ephemeral swamps below. C: *Sedum album* - *Tortella tortuosa* - Association (*Sedetum tortellosum*, p. 284), where lichen societies form the association together with mosses, succulents and therophytes. This association can be taken as a more advanced pioneer stage of the vegetational development than the first two associations. The *Sedetum tortellosum* is mostly not a closed community (Fig. 23).

Fig. 20. An accentuated scarp north of Ekelunda village. A spring is situated among the stones in the left part of the picture, which supplies the little fen with water. On the hummocks *Potentilla fruticosa* grows, and the bushes upon the scarp are *Corylus avellana*.

The scarp morphology is a very important part of the Alvar's superficial conditions. As their main directions are roughly parallel to the length axis of the island, the drainage is mostly perpendicular to them. This means that most temporary pools have formed in shallow basins towards the scarps. September 1967.

2. The Karst Alvar

These areas show a mosaic of two different vegetation types, namely one with the above-described associations on the exposed bedrocks and another which is restricted to the open joints. In the latter bushes and trees dominate the aspect. In one of the

bigger karst areas, the Ekelunda Hasselkarst, *Corylus avellana* forms greater stands (Fig. 24) and between the bushes one can find *Anemone hepatica*, *Sanícula europaea*, *Hedera helix* and *Coronilla emerus*. Together with *Corylus avellana* *Betula verrucosa* often grows and *Pyrus communis* and *Sorbus inter-*

Fig. 21. Marsh heath (see text) in a basin formed against a scarp between Skarpa Alby village and Drörestorp ruined village not far from the northern limit of the Great Alvar. Parish of Sandby. This scarp is very well developed but is also very weathered. The soil in the marsh heath contains a mixture between weathering material, chemically sedimentated lime and lime gyttja. July 1966.

Fig. 22. Glacial striae north of Eketorp ancient stronghold, parish of Gräsgård. These striae were discovered on the bottom of a ditch, where the soil had been removed. The striae on the Alvar are normally less pregnant. See also Fig. 3. May 1966.

Fig. 21.

Fig. 22.

Fig. 23. *Sedum tortuosum* NE of Nybo, parish of Ventlinge. August 1966.

media occur scattered. In the other karst areas *Corylus avellana* does not grow (but it has recently been observed on the Alvar along the road between Resmo and Stenåsa), and the most common bush is *Rosa caninae* which occurs together with *Cotoneaster integerrimus*, *C. melanocarpus*, *Crataegus* spp., *Juniperus communis*, *Prunus spinosa*, *Rhamnus cathartica*, *Potentilla fruticosa* and *Cornus sanguinea*. Below the bushes xeric mosses grow together with various herbs, among them *Viola hirta*, which is very common, *Hornungia petraea* and *Saxifraga tridactylites*.

The herbs and the ferns of the joints belong to

various types of vegetation and there are some species, which one should not expect to grow on the Alvar e.g. *Convallaria majalis*. Among the ferns *Lastrea thelypteris* grows in the moister joints and commonly all over the Alvar *Asplenium ruta-muraria*, *Asplenium trichomanes* and *Cystopteris fragilis* occur.

THE WEATHERED SOILS

Much of what is shown under light green heading on the map is the bedrock with a thin cover of weathered soil on it. The soils show various degrees of the rock's destruction, which is a complex of frost action

Fig. 24. From Ekleunda Hasselkarst, parish of Gårdby, *Corylus avellana*, *Rosa* sp. and *Juniperus communis* grow very frequently in the joints. *Cynanchum vincetoxicum* is a very common species in this environment. June 1964.

and chemical weathering. The formation of these soils normally starts with frost weathering (Fig. 25). In the soils frost phenomena occur where the drainage is bad and the soil cover is not too thick, and frost polygons are frequently found all over the Alvar (Fig. 26). The polygons are formed extrazonally, which means that they are formed outside the permafrost zones. The bedrock with its bad drainage acts in the same way as the permafrost does (Fig. 27). Already Hesselman drew attention to this fact, and he described frost polygons from Alvar grounds on Gotland (1908, 1915). This was later done also by

Du Rietz (1925). Polygons from Öland were first published by Sterner (1926), and they have since been mentioned in Geological, Botanical and Geographical regional literature (Troll, 1944, J. Lundqvist, 1962, Rapp & Rudberg, 1964). Rydqvist (1962) studied the polygons of the Great Alvar by means of the particle movement in the soils when forming the sorted nets.

In most parts of the Great Alvar so-called marsh heaths occur. Weathered material mixed up with muddy material occurs in shallow basins which are badly or not at all drained. The muddy material is

Fig. 25. Frost weathering is the initial phase of soil formation on the Alvar. The bedrock's surface cracks by the frost effect upon the limestone. This can be best seen in wetter areas. Amosen, parish of Mörbylånga. June 1966.

partly composed of lime, which has been sedimented from lime-saturated water and partly of lime and plant detritus from lime collecting organisms, e.g. blue green algae. The marsh heaths are flooded during part of the year, especially in springtime after the thawing of the snow and in the autumn after heavier rain periods. During the wetter periods of the year the marsh heath soils are very soft and are easily deformed by the tramping of sheep or cattle or being driven over by cars or jeeps. (Fig. 28). During the drier periods the heaths lie hard and white and mud cracks appear in the thin soils. The crack pattern normally follows polygon boundaries where those have developed, or else have formed their own polygon-like patterns (Fig. 29). The particle move-

ment within the soils of the marsh heaths are very strong throughout the year, and the plants which are able to stand this often have parts of their root systems elevated into the air.

THE VEGETATION OF THE WEATHERED SOILS

During the first stage of soil formation (p. 37) the vegetation of the original rock surface persists. In the marsh heaths a subassociation of *Sedum tortuosum* occurs, and more hydrophilous moss species are there added to this association (Aibertsson, 1950, p. 286). In the drier parts and where soil depths are relatively thick, grasses and dwarf bushes domi-

Fig. 26. Repeated freezing and thawing of the thin water saturated soils, which cover the bedrock, results in the formation of sorted polygons. The bedrock has very bad drainage conditions, except very near the open joints, and it acts mechanically in the same way as the permafrost layer does, see also Fig. 27. The soil consists of weathered material, *alvarmo* (a dialectal word from Öland) which means a soil derived from the bedrock by weathering. The term does not pay any attention to the grain size distribution in the soil. Sorted nets are very frequently found all over the Great Alvar. August 1967, Svibo, parish of Ventlinge.

nate the vegetational aspect. The following associations have been described by Albertson (1950). A: *Festuca ovina* - *Festuca rubra* v. *oelandica* - *Tortella tortuosa* - Association (*Festucetum alvarense tortellosum*, p. 289). This association is often fragmentarily developed and mixed with *Helianthemum oelandicum* communities (Fig. 30), often rich in *Tor-*

tella. These components form transitions to the following associations, and are connected to areas with periodically flooded grounds. For detailed descriptions of the various societies within the *Festucetum alvarense tortellosum*, Albertson's publication is referred to (1950, pp. 289–299). B: *Helianthemum oelandicum* - *Festuca ovina* - *Cetraria islandica* - *As-*

Fig. 27.

Fig. 28.

Fig. 29. In the shallowest temporary pools the soil layer is very thin. During the high water periods these basins become flooded, but during the summer they dry up very quickly and some terrestrial plants may find growth places on the bottoms. In this case dry cracks have developed and *Sedum album* grows in the soil. Dry cracks occur in all wetter soil types, and the drying up of these soils causes movements within layers. These movements are important factors for the establishment of a vegetational cover in the same way as the frost action movements are. South of Dröstorps ruined village, parish of Sandby. July 1958.

Fig. 27. As soon as the *alvarmo* layer becomes thick enough to prevent stronger particle movements due to frost action, colonisation by lichens, mosses, grasses and herbs starts. Eketorp, parish of Gräsgård. May 1966.

Fig. 28. On the marsh heaths the soil is a mixture between weathered material, sedimented lime from the water, and lime gyttja. If the soil is water saturated it becomes gruel-like and it is then very sensitive to cattle trampling or jeep driving. In the summer, when the soil dries up, it becomes very hard and non-sensitive to pressure. Mysinge Alvar, parish of Mörbylånga. July 1967.

Fig. 30. *Helianthemum oelandicum* on bedrock Alvar partly covered by *alvarmo*. Some depressions in the bedrock contain enough soil to permit growth of *Festuca ovina* and *Helianthemum oelandicum*. Stenåsa Alvar, parish of Stenåsa. June 1963.

sociation (*Festuceum alvarens cetrariosum*, p. 296). The association is connected to drier areas than the former. The very most important societies are those with *Helianthemum oelandicum* and *Festuca ovina*, rich in lichens. *Thymus serpyllum* is also important and in the southernmost parts of the Great Alvar *Helianthemum canum* and *H. italicum* spp. *rupifragum* are of importance. In *Helianthemum oelandicum* and *Thymus serpyllum* heaths on the north-eastern parts of the Great Alvar *Fumana procumbens* grows, which can also be found on Gotland on similar ground but otherwise in no other place within the Nordic countries. For detailed information see Albertson's paper (1950, pp. 296–300). C: *Sedum rupestre* - *Festuca ovina* - *Rhaconitrium canescens* - Association (*Festucetum alvarens rhaconi-*

triosum, Albertson, 1950, p. 300). This association is dominated by low grass heaths normally dominated by *Festuca ovina* with other grasses as important members together with a very strong representation of lichens (*Cladonia*, *Rhaconitrium*). See also Albertson (1950, pp. 300–303).

THE GRAVELLY DEPOSITS

On the geological maps very little of gravelly deposits is shown. However, the extension of the gravelly deposits is far greater and notes as to this fact have been given by Sterner (1948, p. 17). Svensson (1961, 1963 *b*) and Königsson (1962 *a*). A test mapping was made in 1962 and a fragment of this was published in an article by Martinsson 1965 (Königsson 1965).

As mentioned above some key areas were investigated in detail in connection with the mapping of the area, and on the basis of these studies some information may be given as to the gravelly deposits. An example of the key areas is Fig. 31 and Fig. 32. The area covers an area around the word "Boplat" WSW of Möckelmosen, sheet 2 of the map and Fig. 33. The drawing shows the Quaternary deposits of the area, which can be compared with the photograph. Designation 1 stands for areas with very bad drainage. Vegetationally and sedimentarily this area corresponds to the marsh heath in the description above (pp. 37, 38). After the melting of the snow in the spring or after heavy rains this formation is for some time covered by water, or its soils are water saturated and thus gruel like in their consistency.

This is a type of temporary pool and its morphological conditions will be described below.

Designation 2 stands for another type of temporary pool, which is more persistent than the former. In this category of pool there is water filling in the basin long enough to enable considerable production and sedimentation of lime-gyttja substance with a varying content of plant detritus and minerogene particles. These basins, however, also afford possibilities for a more terrestrial vegetation during the driest parts of the year, and such areas will give a rather characteristic grey shade on the air photographs. Their more terrestrial macrovegetation has been reviewed under marsh heath above, p. 39 and their most hydrophilous facies can be found reviewed under "persistent Alvar swamps" below, pp. 51, 52.

The designation 3 shows gravelly deposits in general. The bigger dots mark the extension of an inner part with a true gravelly material while the smaller dots show a mantle of silty, humus-rich material, which rests upon the original formation and also outside it on the bedrock, and gives this a new contour on the air photograph. When mapping in the field the contour of the whole formation is given as of a gravelly deposit and no attention has been paid to a differentiation of the stratigraphical complex.

In this special area diggings were performed in very many parts to study the inner structure of the deposits. The formation, which has the designation number on it, consists of water-transported and deposited material, well-rounded and stratified. It rests directly on the bedrock. It has been interpreted as a shore ridge. No fossils or datable material have, however, been found in it. On the top one will find a layer rich in humus and very silty, which is 10–40 cm thick. This layer will be further described below. East of this formation a deposit which on the whole is directed west-east is situated. At a 50 cm depth

unaffected moraine has been found and on top of it is a very thin layer of washed material and upon this again the humus-rich silty soil. This formation is a moraine residual and may perhaps be a very small rest of a former existing more extensive moraine cover on the Alvar (Fig. 34). See also p. 157.

The areas on the interpretation figure that have no special designations are exposed bedrock areas or such areas are covered with only very thin weathered, relatively dry soils.

As has been said before three differently directed types of gravelly deposits can be distinguished, namely those which follow a roughly north to south direction, those which run more or less perpendicular to these, and finally two additional systems, which seem to follow tectonic zones within the area.

In the key areas the north-south directed deposits have by all controls turned out to be shore ridges (Fig. 35, Fig. 36, Fig. 37), while the perpendicularly directed deposits were moraines. Enough controls have not yet been made to justify a general statement of most east-west directed gravelly ridges as moraines, and these particular results should therefore still be looked upon as preliminary.

The remaining deposits, which seem to follow tectonic zones on the Alvar (Fig. 10, pp. 30, 31, cf. p. 49) cannot yet be referred to either shore material or moraine material. In the few up till now performed controls in these formations both material types have been found.

The investigations of the gravelly deposits on the Great Alvar are still going on. The continued investigations will try to elucidate the genetical circumstances of these deposits, and will also try to establish a time-table for the formation of the shore ridge systems now mapped (Fig. 38).

THE VEGETATION ON THE GRAVELLY DEPOSITS

Arrhenatherum pratensis (*Avena pratensis*) - *Sesleria coerulea* - *Camptothecium lutescens* - Association (*Avenetum alvarens*, p. 304). Much of the material in the shore ridge systems (which Albertson together with other botanists considered to be of mainly glaciofluvial origin) is relatively poor in lime. During normal summers these deposits are completely dried out to such an extent that the vegetational aspect becomes almost desert-like. In the *Avenetum*, *Helianthemum oelandicum* is still very common. The *Avenetum* societies often occur mosaically together with stands of bushes, where *Juniperus communis* is the most common species. Below the bushes mosses and lichens dominate. *Avene-*

Fig. 31, 32. The described key area. Designation (1) stands for areas with bad drainage, where heavy rains very quickly fill the shallow basins with water. Most of this area belongs to the marsh heaths. Designation (2) stands for a temporary pool of a more hydrophilous character than (1). The areas with no designations at all on them represent bedrock areas with exposed surfaces or with a very thin layer of weathered material on them. The dotted areas are gravelly deposits (3). The bigger dots show the real deposit within the stratigraphical complex, where a top layer of humus-rich silty material is shown under the smaller dots. Air Photo: Rikets Allmänna Kartverk 1959. Published by permission of the Swedish Defence Staff.

tum alvarens comprises a row of societies rich in herbs and has been considered to be very steppe-like because of the great number of continental species involved in it (Albertson, 1950, p. 305). However, no *Stipa* species have been found on Öland. For detailed information as to *Avenetum alvarens*, see Albertson (1950, pp. 304–309).

THE TOP LAYERS ON THE GRAVELLY DEPOSITS

On the top of the gravelly deposits a silty layer which is rich in humus is normally found. Its thickness varies and has been observed to be up to 50 cm thick in places. This soil can, however, additionally

Fig. 33. Air photograph of the key area, The photograph was taken from the northwestern limit of the deposit, which carries the designation (3) on it and is directed against SE. The white spotted area corresponds to the persistent alvar swamp (2) on the key map.

On the photograph is also seen how junipers grow on most types of Alvar ground, on the gravelly deposits as well as in the open or soil-filled joints of the bedrock areas. In the central part of the picture a few spontaneous spruces are seen on the fringe of the swamp.

In the lowermost part of the picture an old Alvar settlement from the older iron age is seen. Five house foundations are situated on the ground which is seen between the left margin of the picture and the wing pillar. Mysinge Alvar, parish of Mörbylånga. June 1965. Published by permission of the Swedish Defense Staff.

be found resting upon other formations too, and e.g. the sack-formed area, which is situated south of Södra Kvinneby (F: 5), and which is marked as exposed bedrock on the map, has a very thin layer of windborne material on it.

On the Alvar and on southern Öland in general, wind erosion occurs, and soil transport by winds was noticed already by Hemmendorff (1897). During the

archeological excavation of the prehistoric village SSW of Möckelmosen (the word *Boplats*) the wind transport of particles, especially humus particles, has been watched for three summers now (1965–1967) and the sedimentation of particles within the sheds has been considerable. Cleaning of floor and tables had to be done after almost all windy days.

Sterner (1926, p. 39) considered that the forma-

Fig. 34. One rather extensive deposit is situated around Lundkälla, parish of Resmo, on my map. The abundance of boulders is very striking there, and I look upon this accumulation as a residual from a former existing glaciogene or glaciofluvial deposit. July 1962.

Fig. 35. Shore ridges at Tingstads Flisor, parish of Kastlösa. This picture shows very beautiful shore ridges in a system east of Lunda and Stora Dalby villages. Similar views can be seen in many other parts of the Great Alvar. On the ground there are grave mounds of unknown age and prehistoric monumental stones. The dark line which runs diagonally from the lower right corner is a stone wall. A hundred metres away from the stands of trees to the left on the picture there is a prehistoric settlement with house fundaments. June 1965. Published by permission of the Swedish Defense Staff.

Fig. 34.

Fig. 35.

Fig. 36.

Fig. 37.

tion of hummocks on the Great Alvar involved one phase where wind-blown particles were trapped in the vegetation of the hummock, and that the hummock thus grows bigger every year.

This type of trapping air-borne material in grasses, other herbs, mosses and lichens is general all over the Alvar, and a variably thick layer of this humus-rich silt is very widespread on the Alvar and on almost all types of deposits and grounds. In the ruins of old houses from prehistoric times on various parts of the Alvar, the deposition of this soil is about 20 cm thick in most cases. On the leeward side of the ruins, however, a soil drift has been found, which is up to 50 cm thick (the prevailing winds are westerly, cf. pp. 16–18).

The minerogene component of this soil has been isolated in a few analyses. The bulk of the material is silt with some fine sand in it, but even coarser particles may be found solitarily. Most of the material is quartz, but feldspar also has been observed to occur regularly. The soil is in a dry stage easily eroded when overgrazed, and during the autumn, winter and spring when the soil is water-saturated, tramping and driving may remove the vegetational cover and expose the soil to wind during the drier periods (Fig. 39).

Fig. 38. The shore ridge systems of the physiognomic map diagrammatically shown together with possible tectonic zones on the Great Alvar and with some shore ridges outside the map area. Designations: 1. The ridge which runs on the top of the escarpment, Västra Landborgen. About this ridge nothing is known as to when it was formed. 2. The Ancylus ridge. 3. The Litorina ridge. 4. The shore ridges on the Great Alvar. 5. Possible tectonic zones on the Alvar.

As seen on the map two main directions dominate the ridges, the one roughly parallel to the length axis of the island, and the other crossing them and running from Resmo to Lunda (L), Storåsen (S) and to Gräsgård. This ridge, which is very well developed in most parts, seems to join the top ridge of the Västra landborgen east of Mörbylånga. The top ridge can then be thought to be metachronously formed. It is, however, possible that this particular ridge turns out to be a redeposition of material from a formerly existing ridge on the same place, and that the older ridge may have had glaciofluvial origin. Nothing is yet known about the primary formation, and it is not within the scope of this study to discuss these problems further. It should however be added that investigations, which concern genetic studies and age determinations within the shore ridges of the Great Alvar, already are in progress.

Fig. 36. Shore ridge NNE of Resmo church and north of Lundkälla, parish of Resmo. The ridge is very well developed and it rests directly upon the bedrock. Prospect towards north. July 1964.

Fig. 37. Shore ridges north of Amosen, Södra Bårby Alvar, parish of Mörbylånga. In this area there are as well developed systems of ridges as around Tingstads Flisor. The ridges rest directly upon the bedrock which often is exposed between them. June 1966.

Fig. 39. On the top of the gravelly deposits and in many other areas too, a humus-rich silt is found. These layers are covered by grass-rich plant communities. The grass root layer has, however, proved to be very sensitive to overgrazing, and in many of the present sheep grazing areas wounds like the one which is demonstrated on the picture are found. These wounds are the very beginning of a serious soil erosional activity on the Great Alvar. Södra Bårby Alvar, parish of Mörbylånga, July 1966.

THE ALVAR LAKES AND THE ALVAR FENS

As stated above the superficial drainage follows the scarp systems and many of the fens are situated in connection with bigger scarps or in other depressions in the bedrock. One may divide the wetter Alvar areas very roughly according to their ability to store water, and the terms Alvar lake and Alvar swamp are used. An Alvar lake is then a formation, which during the normal years shows a free water surface all through the year. The Alvar swamps, on the other hand, dry up during normal years.

The Alvar lakes as well as the Alvar swamps can be divided according to the drainage, the Alvar swamps further according to their ability to keep water, which is very important for the sediment production. Each category can additionally be divided according to vegetational aspects. The word Alvar lake (Sw. *alvarsjö*) has first been used in botanical

literature by Sterner (1925, 1926), and the word Alvar swamp (which is the author's translation of *våt*, a dialectal word from Gotland, which means a small and shallow fen there) was first used by Johansson (1897) and later also by Sterner (1925, 1926).

THE ALVAR SWAMPS

The division of the Alvar swamps has been described by Sterner (1925, 1926), Sernander (1941) and Albertson (1946, 1950). The following division can, however, be made.

1. *Ephemeral Alvar Swamps*

The ephemeral Alvar swamps occupy extremely shallow depressions in the bedrock's surface. These depressions are filled with water at the melting of the snow and after rains. The water evaporates

Fig. 40. Ephemeral Alvar swamp on Mysinge Alvar, parish of Resmo. After heavy rains or after snow thawing the very shallow basins become filled by water. Very soon the water becomes drained or evaporated and no considerable sedimentation has been registered in the ephemeral swamps. November 1967.

rather soon, especially in summer and the production of sedimentationable material becomes insignificant (Fig. 40).

2. Persistent Alvar Swamps

These swamps develop in basins where the water is kept long enough to allow persistent production of water-demanding organisms to take place. The greatest of these swamps, temporary Alvar pools (Horn af Ranzien, 1951 *a*, 1951 *b*) are marked on the map in light blue colour, and they have lake-like conditions during the greatest part of the year, but they have a dry period in all normally wet years.

According to the damming conditions the following subdivision is made, which is valid for all Alvar swamps, persistent as well as ephemeral.

- A. Dammed by scarps
- B. Existing in other depressions in the bedrock
- C. Dammed by gravelly ridges (which however very often are combined with scarps).
- D. In depressions within the gravelly deposits.

As to the biological activity of the ephemeral swamps very few details are known—except for the above reviewed lichenologic conditions—and the botanical division of the Alvar swamps is therefore only valid for the persistent Alvar swamps, whose phytosociology was surveyed by Albertson (1950, pp. 313 et sqq.). From the geological point of view there could be a botanical difference between the morphological types A, B and perhaps also C if compared with D, as the latter can be expected to have diverging conditions as to the lime richness. No signifi-

Fig. 41. Persistent Alvar swamp of category D. The swamp is situated NW of Lundkälla, parish of Resmo. The swamp occupies a depression within a gravelly deposit. July 1965.

cant phytosociological corresponding differences seem to have been observed.

1. *Agrostis stolonifera* - *Alopecurus geniculatus* - *Scorpidium turgescens* - Association.
2. *Taraxacum limnanthes* - *Carex panicea* - *Scorpidium turgescens* - Association.
3. *Carex oederi* - *Scirpus palustris* - *Scorpidium scorpioides* - Association.

In most hydrophilous swamps *Characeae* is very important. The persistent Alvar swamps' distribution may be seen from the map where, as has already been noted, the temporary pools have been marked with a light blue colour and the meadow-like swamps with green. Almost all over the exposed bedrocks the ephemeral swamps occur.

THE ALVAR LAKES

The Alvar lakes may be further divided according to their damming conditions.

1. Depending on depressions in the bedrock's surface.
2. In the basin between the Alvar surface and a damming gravelly formation, which may be combined with a scarp, or which may be illusive as the deposit rests upon a damming bedrock feature.

The botanical division is more complicated than the corresponding division of the swamps. This is due to the fact that the Alvar lake in its periphery always transits in some swamp community.

The Alvar lakes are physiognomically characterized by a central fen community with a surrounding free water zone (Fig. 42). In the central fen *Carex elata* tussocks dominate the macrovegetational aspect (Fig. 43) and minor stands of *Scirpus Tabernaemontani*, *Phragmites communis* and *Typha latifolia* occur. *Equisetum fluviatile* plays an important rôle both as a plant between the *Carex elata* tussocks and as a reed-forming plant around the central fen. In the surrounding free water zone *Chara*

Fig. 42. Stormaren, parish of Södra Möckleby. An Alvar lake shows a free water surface all through the year if this has normal precipitation conditions. Physiognomically the Alvar lake is characterized by a central fen community which is surrounded by a free water zone. June 1965. Published by permission by the Swedish Defence Staff.

contraria and *Chara aspera* occur and the Alvar lakes have been characterized as strongly typical *Chara* lakes (Albertson, 1950, p. 320, cf. Almquist, 1929, p. 92). Some nympheids and elodeids occur, e.g. *Potamogeton natans* and *Potamogeton gramineus*, *Polygonum amphibium*, *Glyceria fluitans*, *Myriophyllum alterniflorum*, *Potamogeton pectinatus* and *P. filiformis*. In the central fen *Menyanthes trifoliata* and *Sparganium erectum* are important members of the plant community. In a few places *Cladium mariscus* is reed-forming together with *Phragmites communis*. In the shallow free water zone *Littorella uniflora* is a very important plant, often forming very dense carpets.

A very good description of the vegetation in the Alvar lakes was published by Horn af Ranzien (1951 *a*, 1951 *b*). The following papers are also referred to: Hemmendorff (1897), Sterner (1926, 1938), Königsson (1962 *b*), where general surveys are given.

Shorter vegetational notes are given in Westerlund (1852), Sjöstrand (1863), G. Lundqvist (1928), Sterner (1925, 1950) and Albertson (1940, 1950). For comparison and as a basis for the understanding of the pollen diagrams the vegetational sketch maps from Möckelmosen and Stormaren (Sterner, 1926) and Dröstorps Mose (Königsson, 1962 *b*) have been redrawn and in this paper will accompany the descriptions of the morphology and the sediments of these Alvar lakes.

THE SOILS OF THE ALVAR LAKES AND FENS

Peats, gyttjas and lake marl are found in the fens and Alvar lakes of the Great Alvar. A special description of the sediments is given for each lake or fen, whose stratigraphy has been investigated in detail.

Fig. 43. In the central fen *Carex elata* dominates and *Menyanthes trifoliata* is an important plant which grows between the tussocks. Edging the central fen *Equisetum fluviatile* is reed forming. Västerstads Träsk, parish of Kastlösa. July 1966.

MORPHOLOGIC NOTES FROM THE ALVAR LAKES, FENS AND SWAMPS

Ice-pressed walls have been observed in many of the Alvar lakes on their eastern shores (cf. Königsson, 1962 *b*, p. 97). Very pregnant walls have been profiled in Dröstorps mose and Rosenkärret.

Hummocks occur in most wet areas on the Great Alvar (Fig. 44). They are considered partly to be frost phenomena.

THE HYDROGRAPHY OF THE GREAT ALVAR

As has already been stated the dip of the island's surface brings in a drainage which is directed mainly to the southeast. The scarp systems, which on the whole run perpendicular to this direction do not change this picture but may locally cause variations in the pattern.

The bulk of the drainage seems to follow the joint

Fig. 44. Hummocks occur in most wet areas of the Great Alvar. They are considered partly to be frost phenomena. Segerstad's Alvar parish of Segerstad. August 1966.

Fig. 45. This unnamed fen is situated within the Resmo-Ekelunda zone, south of Ekelunda village, parish of Sandby. It is tributed by a couple of springs, one of which is very productive. Photograph by Rikets Allmänna Kartverk. Published by permission by the Swedish Defence Staff.

Fig. 44.

Fig. 45.

Fig. 46. The most productive of the springs, mentioned together with the air photograph, Fig. 45. The picture was photographed July 1963, when a very dry period reduced the spring's outflow considerably. As is seen, the spring has developed in a very well-defined scarp, the northern limit of the Resmo-Ekelunda groove in this place. The Resmo-Ekelunda zone has many springs along its course, starting with the Resmo Källa in its southwestern end.

Unfortunately this idyllic spot has been completely destroyed by blasting, which was done by a sheep farmer in order to create a pond for the sheep's water demand.

systems and other subterranean water ways as very few superficial streams bring water to the Baltic from the Great Alvar. During the summer time the following condition has been repeatedly observed in the temporary pool east of the "*Boplats*", the designation 3 on the key map, described above: After a dry period some days of rain follow. So the rain stops and the morning afterwards the pool, which was quite dry before has become filled with water during

the night. Next morning again the water content which was around half a metre deep, has disappeared again. Evidently the precipitation fills the joint system west of this pool and a subterranean flow of water southeastwards starts. The flow collects subsidiaries from a certain area, and it seems probable that a narrowing of the flowing area appears west of the pool and that the system opens out in the pool. Drainage eastwards must then follow a similar pat-

tern, and the volume of this outlet allows a quick drainage of the pool. This type of subterranean drainage seems to play an important rôle in the drainage of the Great Alvar.

The real streams of the Great Alvar are few and in many cases strong subterranean continuations have been observed. During the high water periods it is not very unusual to walk over very dry exposed bedrock areas, where one can hear the sound of streaming water below. Two such very pregnant streams follow the outflow of the Dröstorps Mose in its continuation west of Ekelunda and the Penåsa stream. On the other hand springs occur, which con-

tinue in superficial streams, and the biggest of these is situated southwest of the Ekelunda village, following the tectonized zone between Resmo and Ekelunda northeastwards (Fig. 45, Fig. 46). Other important examples are the subsidiary to the Möckelmosen in its southwestern parts and the streams north of Stora Dalby village.

The notes of the hydrography of the Great Alvar have been given to offer a general aspect of the hydrographical conditions. They have therefore the character of occasional notes and do not claim to give the whole hydrographical picture.

THE INVESTIGATED LAKES, ALVAR LAKES AND FENS

The Investigated Fens and Alvar Lakes on the Great Alvar

This section contains a description of the stratigraphy and morphology of the investigated fens and Alvar lakes. The composition of the soils is also shown as drawn in the soil columns of the pollen diagrams, thus giving detailed descriptions of soil types within the area. When describing soils Troels-Smith's system, nomenclature and designations has been followed (1955). The upper limit of a soil layer is noted as *lim.* 0–4 (p. 56).

The position of those Alvar lakes and fens, which have been investigated or else mentioned, is shown on the map, Fig. 47 a.

The soils of the fens and Alvar lakes on the Great Alvar have been treated before by Hemmendorff (1897), Haglund (1914), Lundqvist (1928) and Königsson (1962 b).

Hemmendorff described the stratigraphy of Hulterstadsmosen (p. 43) where he distinguished a highly humified peat, which rests on sand, and of Lunda Mose, where he described two special sections. In the upper parts he found (A) *Phragmites*- and *Cladium*-peat. In the uppermost parts of the peat layer he recognized leaves of *Quercus robur* and in the lower parts needles, twigs and cones of *Pinus silvestris*. (B) Lime gyttja with *Pinus silvestris* in the upper parts, leaves and fruits from *Betula pubescens* and leaves from *Populus tremula*. (C) Sand and clay layers with numerous finds of *Salix polaris* leaves and occasional finds of *Dryas octopetala* leaves.

Haglund's investigations were stipulated for economical reasons, and he paid most interest to the fens' potential as agricultural lands or for peat cutting. In a general and regional survey, however, some of his notes should be included.

Lenstads Mose was already at that time cultivated, but *Cladium mariscus* was found growing along the ditches. 0.1–0.5 m peat was found upon lake marl, boulder clay or gravels. South of Lenstad another fen was mentioned, which obviously is what has been marked on my map as Lenstads Mose. Ac-

cording to Haglund's review *Carex flacca* and *Sesleria coerulea* transits into *Caltha palustris* and *Carex nigra* communities, in the wettest parts with *Carex flacca*, *Equisetum fluviatile* and *Carex elata*. The soil is said to be humus upon gravels.

Kastlösakärret seems to be the same fen as Hemmendorff's Lunda mose. In the southern parts the soils were found to be humus and *Carex-Phragmites* peat (1 m) upon some shell gyttja and sand, in the northern parts humus, *Phragmites* peat and yellowish-brown gyttja, which contains shells (1 m); in certain parts 0.3 m "pure shell gyttja" upon sand was found. The area was cultivated at that time.

Brunneby Moses on both sides of the eastern road are totally cultivated. The soils were 0.2–0.3 m highly humified *Cladium* peat upon lake marl or clay.

Slagerstads Mose. 0.1–0.4 m humus upon sand. It is doubtful if Slagerstads Mose is identical with Torpmosen or if some temporary pool in the area between Slagerstad and Ebbelunda is meant, which, however, seems most probable.

Ebbelunda Moses are cultivated in their northern parts while their southern parts were shallow lakes. Haglund found *Carex panicea*, *C. flacca* and *Sesleria coerulea* growing there. The southern shallow lakes are here considered to be identical with Torpmosen and Kritmosen.

Möckelmosen is surrounded by exposed bedrocks and was found to have a free water zone. In the water reeds and stands of *Phragmites communis* and *Carex elata* were observed.

Triberga Mose, "west of the hostelry", was cultivated and had 0.2 m gyttja upon 0.1 m lake marl, clay and stones. In the southern parts of the fen is a pool where Haglund observed much *Menyanthes trifoliata* and rather extensive and dense *Carex elata* stands.

G. Lundqvist described the fens of the island (1928), and he made a few notes from the Great Alvar. However, his available field investigation time did not allow him to make any detailed studies of the Alvar areas, as the shallow basins and their de-

Fig. 47 a. The position of the fens, Alvar lakes and other localities which have been treated in this paper, or which have otherwise been discussed. For the position of localities mentioned by G. Lundqvist the map, Fig. 1, p. 5, in his paper (1928) is referred to.

Fig. 47 b. Map showing the parishes on Öland.

Fig. 48. Map showing the scarp morphology in the environment of Drörestorp Mose. The figure shows how intimately the contours and situation of the Alvar lake in the field are dependant on the morphologic details of the Alvar plain. Legend: See Fig. 57.

posits on the Alvar could not be expected to yield any big peat quantities and his works were included in the Swedish peat inventory.

Stenåsa Mose is situated on the eastern fringe of the Alvar near Stenåsa church. It seems very probable that this fen is a continuation of what Haglund called the Brunneby Moses, and the stratigraphy should therefore be expected to be similar to each other. G. Lundqvist investigated his samples microscopically, and he therefore knows much more about his material than Haglund did. G. Lundqvist identified what he called Fen dy (which will be further discussed below), which was sandy and seemed to be highly destructed although the fossil pollen content was very well preserved. Below the dy he distinguished lime gyttja with peaty to dy-like fine detritus, downwards with increasing sand content.

Möckelmosen. In the central fen area, Lundqvist found the following stratigraphy: (A) Fen peat. (B) Fen dy. (C) Lake marl with sand in it. In the deepest parts of the free water zone, the sediment is a lime gyttja, rich in peat detritus and with "grey-detritus". Macroscopically the gyttja is said to be very similar to clay gyttja.

Lunda Mose. Hemmendorff's description was repeated by Lundqvist, who also verified it except for

the description of the upper peat layer as a *Phragmites* peat. This was instead characterized as an almost pure *Cladium* peat with no considerable amounts of *Phragmites* in it.

Lenstads Mose. G. Lundqvist has taken his investigation series in the bigger fen, which is situated north of the Alvar limit. His stratigraphical remarks were the following: (A) Fen peat. (B) Lake marl. (C) Lime gyttja. (D) Sand. (E) Moraine.

Finally the present author has described the stratigraphy of Drörestorps Mose (1962 *b*), and this investigation will be reviewed again below.

DRÖRESTORPS MOSE

Drörestorps Mose is one of the biggest Alvar lakes and is situated some 2 km south of the edge of the Mittland areas of deciduous woods on the northernmost part of the Alvar. Its size varies with the seasons, and in the spring after the snow thawing it reaches its greatest extension. When mapped in June 1957 it was hardly 1100 m long and rather more than 350 m broad.

The Alvar Lake's morphologic conditions are shown on Fig. 48, where the gravelly deposits and the scarps of the surroundings have been mapped.

Fig. 49. Dröstorps Mose. Morphology of the Alvar lake basin.

Fig. 50. Vegetational sketch map of Dröstorps Mose. Designations: 1. *Salix cinerea*, 2. *Carex elata*, 3. *Typha latifolia*, 4. *Spartanium erectum*, 5. *Menyanthes trifoliata*, 6. *Eriophorum angustifolium*, 7. *Phragmites communis*, 8. *Carex lasiocarpa*, 9. *Equisetum fluviatile*, 10. *Polygonum amphibium*, 11. *Chara* sp. (*Ch. contraria* in the border zone, *Ch. aspera* in the middle.)

Fig. 51. Air photograph of Drörestorps Mose from NW. The physiognomy of the Alvar lake is demonstrated. The *Carex elata* dominated central fen community with its stands of *Salix cinerea* has developed where the basin is deepest. Very little of its plants can be found in the free water zone, and it is possible that this is due both to the dryness in this area in the summer, and to the ice erosion during late autumn, winter and early spring. The air photograph was made early in June 1965, when the spring high water period still lasted. Published by permission of the Swedish Defence Staff.

The nature of the gravelly deposits around the ruins of Drörestorp's village is not known, but it seems probable that wave-washed material covers a nucleus of untouched moraine. In its periphery this mantle of washed material has developed shore ridges, especially in the southern extension of the deposits, and the ridges follow the scarps to a certain degree. The length axis of the Alvar Lake is also well-adapted to the scarp system and in the depth contours for the bottom of the basin below the sediments the same adaptation is traced (Fig. 49).

It is then evident that Drörestorps Mose has developed in a basin, which has been formed as an accentuated depression against a scarp.

On the contour map the eastern shore line is relatively even while the western is very lobate. This is due to the fact that the eastern shore line is higher and that because of this it shows a more stable configuration when the water level of the basin rises or sinks, while the lower and flatter western shore changes its configuration remarkably even when very small alterations in water stand occur.

The physiognomic aspect on the vegetational arrangement is shown on Fig. 50. The central fen community was surveyed briefly and a map was constructed (Königsson, 1962 *b*, pp. 104, 105). Apart from a study of the *Characeae* vegetation no systematic investigation was made in the free water zone. A list of identified species, including the vegetation of the free water zone and also the diatoms in this was given in Königsson 1962 *b* (pp. 104, 105).

As can be seen from a comparison between the vegetational sketch map and the contour map, the central fen with its by *Carex elata* and *Salix cinerea* dominated aspect has developed where the basin is deepest. Very little of its plants can be found in the free water zone, and it is possible that this is due to the dryness of this area in the summers and to the ice erosion during late autumns, winters and early springs (Fig. 51).

The stratigraphy of the Alvar lake may be roughly divided into two main groups. They comprise two main phases in the history of sedimentation; an early lake stage and a later fen stage. The sediments of the free water zone comprise a third group, which will be treated separately.

The Lake Stage

In the lowest parts of the fen a thin layer of grey calcareous gyttja has been deposited. Molluscs and fragments of molluscs are scarce in the layer, which also includes sand and remains of plants, mainly *Characeae*.

The grey sediment is covered by a yellowish-white lake marl, where the amount of sand is considerably less or absent; the mollusc frequency is greater, and the total amount of plant fragments is judged smaller.

The Fen Stage

Within the central area, which comprises a *Carex elata*-dominated fen, there is a thick layer of fen sediments over the lake marl, which upwards passes over from a gyttja, rich in peat detritus to *Carex* peat within the tussocks proper without well-defined boundary. This layer is highly decomposed, and it is very hard to judge its source. It was named *Fen dy* in the Dröstorps paper (Königsson, 1962 *b*, p. 99) but that was given with much doubt and very much because of G. Lundqvist's determination of the stratigraphy in Möckelmosen, where he named the upper soils *Fen peat* and *Fen dy*.

In older literature the difference in colour for dried dy and gyttja has been assumed to be safe characteristics of the two soils, namely black for the dy and grey for the gyttja. However, dy in its pure form is a relatively rare soil, and it mostly occurs

Fig. 52. Longitudinal sections through Dröstorps Mose. Legend: See Fig. 81.

Fig. 53. Cross sections through Dröstorps Mose. Legend: See Fig. 81.

mixed with gyttja particles and detritus. Thus the referred way of distinguishing them is a bit unsafe. Additionally there may be difficulties in distinguishing a totally decomposed peat from highly humified gyttja or from dy.

By microscopical analyses, e.g. in connection with pollen analysis there should be a good possibility of tracing the original soil-forming environment, and this way is considered to be the simplest method to determine the genetics of these soils.

By later controls in the Dröstorps material new information was collected. As is the case in Möckelmosen, which will be shown later, the sediment is a gyttja with coarser and finer plant detritus and molluscs in it, and in the microscope *Pediastrum* sp. has been identified in all performed controls. The detritus is, however, highly decomposed and has degree *humo* 4 *sensu* Troels-Smith (1955, p. 57).

Half a metre down in the gyttja a black, compact layer is found. Its structure is very homogenous and no separate parts of plants have been found in it. A similar layer has been found in several of the lakes and fens on the Great Alvar, and because of its pollen content it has been interpreted as a totally decomposed peat layer there. It also seems to derive from a by *Cyperaceae* dominated source community. According to Troels-Smiths' system it has been classified as *Substantia humosa* (1955, p. 17). In Dröstorps this layer was not continuous over greater parts of the Alvar lake and it was therefore not included in the sections.

The Sediments of the Free Water Zone

Within this zone a calcareous sediment has been deposited, which, if the corresponding part of Möckelmosen is concerned, has been defined by G. Lundqvist as a calcareous mud rich in peat detritus and with "grey-detritus" (1928, p. 32). He pointed out that macroscopically it is reminiscent of clayey ooze or mud.

The sediments of this zone must be considered a calcareous mud mixed up with allochthonous detritus from the central fen as well as from the adjacent Alvar and its temporary pools. It is typical that the structure has been entirely destroyed by long pasture in the area during which the animals, as the water level has sunk, have had to go even further in the Alvar lake in order to get water and thereby effectively kneaded the mud.

The Extension of the Sediments

The extension of the sediments within the fen may be seen in Figs. 52 and 53. These figures represent a compilation of data collected during 112 samplings

along 9 longitudinal sections (Fig. 54). These samplings also form the basis for the construction of the basin's topography below the sediment, which has already been treated (p. 62).

The connection between the depth conditions and the extension of the sediments as well as the connection between the basin's development and the position of the central fen may be seen in the sections. The somewhat larger extension of the fen in earlier time may also be seen.

One may see how the boundaries within the older sediments dip towards the east and how, consequently, the younger parts of the strata are better represented in the eastern parts of the basin.

This has earlier been demonstrated from Lina Myr on the island of Gotland by G. Lundqvist (1928, p. 10) and is said to be due to currents "which are caused by the dominating, strong wind during the ice-free part of the year". G. Lundqvist has also shown (1927) how this is true of large lakes in general.

The dominating winds on Öland are westerly (see also pp. 16–18). This is also seen in the sorbs and ashes in the nearby, deserted village of Drörestorp, which have been bent towards ENE, and which stretch their branches in that direction.

The Stratigraphy

Drörestorps Mose, DM 1

Calcareous mud (the lowest part of the soil column): *Nig.* 1, *strf.* 1, *elas.* 1, *sicc.* 2, *color* grey, *struc.* base substance homogeneous, *composition* Ga, Lc, Th, *test.* (moll), *lim.* 1, *humo.* 1, *Formula* Lc 4, Ga + Th¹ +, *test.* (moll) (+). Lake marl: *Nig.* 1, *strf.* 1, *elas.* 1–2, *sicc.* 2, *color* yellowish-white, *struc.* base substance homogeneous, *composition* Lc, Th, *test.* (moll), *molluscs.* *humo.* 1, *lim.* 1, *Formula* Lc 4, Th¹ (+), *test.* (moll) +.

Gyttja: *Nig.* 4, *strf.* 0, *elas.* 0, *sicc.* 1–2, *color* blackish-brown, *struc.* homogeneous, *composition* Ld (the amount Th is quite impossible to determine), *test.* (moll). In the upper parts, the peat part of the sediment is better preserved and the composition may then be Ld³, Th³, *test.* (moll), *humo.* 4, *lim.* 1, *Formula* Ld¹ 4, *test.* (moll) +. Or Ld³ 3, Th³ 1, *test.* (moll) (+).

Peat: The interior of the *Carex elata* tussocks consists of *Magnocaricetum* peat. This will be treated again as the Möckelmosen material is described. *Nig.* 2–3, *strf.* 0, *elas.* 0 (increases upwards), *sicc.* 2, within the tussocks *sicc.* 3, *color* brown, darkening downwards, *struc.* heterogeneous, *composition* Th, *part. test.* (moll), *humo.* 2–3, *lim.* 0, *Formula* Th^{2–3} 4, *test.* (moll) (+).

TRANEKÄRR

Tranekärr is situated west of Drörestorps Mose, and is a typical representative for the larger temporary pools of the Great Alvar. It is relatively large, some 700 m long and has a gravelly ridge along most

Fig. 54. Drörestorps Mose, index map of the sections.

of its eastern shoreline. This ridge is not, however, the only damming factor, which instead is constituted by the ridge in combination with a scarp. In the

Fig. 56. Linträsk, parish of Vickleby. Linträsk belongs to the Alvar lakes as it shows a free water surface all normal wet years. It is probably dammed by a gravelly ridge, but it has not been possible to state if the ridge rests upon a scarp, which seems to be very probable. The water supply is during the spring time due to a tributary stream which flows from the north. Additionally spring water supply seems to exist as even during the extremely dry year 1959, a free water surface could be found within the basin.

western parts of the basin an accentuated cavity has been found with up to 61 cm thick sediments in it. Tranekärr dries up all normal years.

The scarp systems around this pool are of very great interest as the localization of the gravelly deposits in the vicinity of Tranekärr seems to be influenced by the scarps to a very high degree. This is especially true for the deposits east of the pool.

No mapping of the basin morphology of Tranekärr has been made, but the sediments have been

controlled by digging in two points in the above-mentioned western part of the pool.

The Stratigraphy

Tranekärr, TK 1

All soils in Tranekärr belong to the gyttja series and even those layers, which macroscopically were noted as peat layers in the field turned out to consist of dominating gyttja substance when investigated in the laboratory.

1. Limestone.
2. Gyttja with lime gyttja substance. *Nig.* 1–2, *strf.* 0, *elas.* 3,

Fig. 55. Air photograph of Ekelunda Alvar village, parish of Sandby, and its surroundings. The agricultural area of this village occupies one of the more extensive gravelly deposits on the Great Alvar, which consists of dominating morainic material. NW of the cultivated area Ekelunda Mose is situated. This is a rather shallow fen with lake marl in its lower stratigraphical parts and with calcareous gyttja underlying the lake marl. To the northwest of the fen a gravelly ridge, probably a shore ridge, continues further north. The little stream which can be seen along the upper half of the right margin of the picture is situated in a little groove which has developed on both sides of the stream along part of its course. Photograph by Rikets Allmänna Kartverk 1959. Published by permission of the Swedish Defence Staff.

Fig. 57. The morphological situation of Möckelmosen, Frösslunda Mose, Kritmosen and Torpmosen. The adaption of the configuration of the basins to the scarp system is striking. Legend. 1. Alvar lake. 2. Scarp. 3. Gravelly deposit.

sicc. 2, *color* grey to brownish-grey, *struc.* heterogeneous, granular, *composition* Lc, Ld, Ag, *humo.* 2, *lim.* 1, *Formula* Lc 2, Ld² 2, Ag (+).

3. Peaty gyttja with lime gyttja substance. *Nig.* 2, *strf.* 0, *elas.* 3, *sicc.* 2, *color* brown to brownish-grey, *struc.* heterogeneous, *composition* Lc, Ld, Th, Ag, *humo.* 3, *lim.* 1, *Formula* Lc 1, Ld³ 1, Th³ 3, Ag (+).

4. Gyttja with lime gyttja substance. *Nig.* 1–2, *strf.* 0, *elas.* 2–3, *sicc.* 2, *color* grey to olive grey, *struc.* heterogeneous, *composition* Lc, Ld, Th, Ag, *humo.* 3, *lim.* 1, *Formula* Lc 1, Ld³ 2, Th³ 1, Ag (+).

5. Peaty gyttja. *Nig.* 2–3, *strf.* 0, *elas.* 3, *sicc.* 2, *color* brown to dark brown, *struc.* heterogeneous, *composition* Ld, Th, *humo.* 1, *lim.* 1, *Formula* Ld¹ 2, Th¹ 2.

6. Lime gyttja. As layer 3.
7. Peaty gyttja with lime gyttja substance. *Nig.* 3, *strf.* 0, *elas.* 2–3, *sicc.* 2, *color* dark brown, *struc.* heterogeneous, *composition* Lc, Ld, Th, *humo.* 3, *lim.* 1, *Formula* Lc 1, *Ld*³ 1, *Th*³ 2.
8. Peaty lime gyttja with gyttja substance. *Nig.* 1–2, *strf.* 2, *elas.* 3, *sicc.* 2, *color* yellowish-white, *struc.* heterogeneous, *composition* Lc, Ld, Th, Ag, *humo.* 2, *Formula* Lc 2, *Ld*² 1, *Th*² 1.

EKELUNDA MOSE

Ekelunda Mose is situated WNW of Ekelunda village (Fig. 55). It is formed in a basin, which is dammed against the gravelly deposits of Ekelunda, and is rather a temporary pool than an Alvar lake. No special mappings have been made in this area, and the stratigraphy has only been controlled in a couple of diggings.

The Stratigraphy

Ekelunda Mose, EM 1

1. Limestone.
2. Silty lime gyttja with gyttja substance. *Nig.* 2, *strf.* 0, *elas.* 3, *sicc.* 2, *color* grey to olive-grey, *struc.* heterogeneous, *composition* Lc, Ld, Ga, *humo.* 2, *Formula* Lc 2, Ga 1, *Ld*² 1.
3. Gyttja with lime gyttja substance. *Nig.* 1, *strf.* 1, *elas.* 2, *sicc.* 2, *color* greyish-white to yellowish-grey, *struc.* heterogeneous, *composition* Lc, Ld, Ga, *humo.* 1, *lim.* 1, *Formula* Lc 2, *Ld*¹ 2, Ga (+).
4. Lake marl. *Nig.* 0, *strf.* 1, *elas.* 3, *sicc.* 2, *color* white to yellowish-white, *struc.* homogeneous, granular, *composition* Lc, *humo.* 1, *lim.* 1, *Formula* Lc 4.
5. Gyttja with lime gyttja substance. *Nig.* 2, *strf.* 0, *elas.* 2, *sicc.* 2, *color* brownish to olive greenish-grey, *struc.* homogeneous, *composition* Lc, Ld, *humo.* 2, *lim.* 1, *Formula* Lc 2, *Ld*² 2.
6. Peaty gyttja with lime gyttja substance. *Nig.* 3, *strf.* 0, *elas.* 2, *sicc.* 2, *color* brown, *struc.* heterogeneous, *composition* Lc, Ld, Th, *humo.* 3, *lim.* 1, *Formula* Lc 1, *Ld*³ 2, *Th*³ 2.
7. Peaty gyttja with lime gyttja substance. *Nig.* 3, *strf.* 0, *elas.* 2, *sicc.* 2, *struc.* heterogeneous, *color* brown, *composition* Lc, Ld, Th, *humo.* 2, *Formula* Lc 1, *Ld*² 1, *Th*² 2.

LINTRÄSK

Linträsk belongs to the Alvar lakes. This, however, seems to depend on additional water supply due to springs as the basin is very shallow and the tributary stream dries up very quickly in the spring. Even during the extremely dry summer in 1959, when e.g. Dröstorps Mose and Möckelmosen were dry, Linträsk had a small remaining water table in its central part (Fig. 56).

The vegetation is typical for the most hydrophilous in the temporary pools series, and was described in detail by Albertson (1950).

Morphologically Linträsk has been formed in a basin between the Alvar surface and a marked strand

Fig. 58. Index map of Möckelmosen, showing the position of the sections.

ridge along the lake's eastern shore, but most of its bottom below the very thin soils is bedrock. In the northern parts of the basin, gravels, sands and silt

Fig. 59. Möckelmosen. Longitudinal sections. Legend: See Fig. 81.

Fig. 60. Möckelmosen. Cross sections. Legend: See Fig. 81.

Fig. 61. Möckelmosen. Contour map of the basin's morphology.

Fig. 62. Sketch map of the vegetational environment of Möckelmosen. Redrawn after Sterner (1926). Designations: 1. *Salix cinerea*, 2. *Carex elata*, 5. *Menyanthes trifoliata*, 7. *Phragmites communis*, 9. *Equisetum fluviatile*, 11. *Molinia coerulea*, *Carex panicea*, *C. hostiana*, *C. Oederi*, 12. *Littorella uniflora*, 14. *Potamogeton natans*, *P. gramineus*, 15. *Chara* sp., 16. *Glyceria fluitans*, 17. *Scirpus lacustris*, 18. *Agrostis stolonifera*. The dashed shoreline indicates that it is somewhat diffuse.

underlay the gyttjas, and in this part the most abundant sediment layer has been found. No systematical investigation has, however, been made, but the stratigraphy described below is representative of the control diggings which were made in several parts of the northern basin.

The Stratigraphy

Linträsk, LT 1.

1. Sandy silt. *Nig.* 1, *strf.* 2, *elas.* 1, *sicc.* 2, *color* grey to blue-grey, *struc.* heterogeneous, *composition* *Ga*, *Ag*, *humo.* 0, *lim.* 1, *Formula* *Ga* 1, *Ag* 3.

2. Silty gyttja. *Nig.* 3, *strf.* 2, *elas.* 1, *sicc.* 1–2, *color* olive-grey, *struc.* heterogeneous, *composition* *Ld*, *Ga*, *humo.* 2, *lim.* 2, *Formula* *Ld*³ 3, *Ga* 1.

3. Peaty gyttja. *Nig.* 3, *strf.* 1, *elas.* 1, *sicc.* 1–2, *color* dark brown, *struc.* heterogeneous, *composition* *Ld*, *Th*, *humo.* 2, *lim.* 0, *Formula* *Ld*² 3, *Th*² 1.

4. Peat with gyttja substance. *Nig.* 4, *strf.* 0, *elas.* 1, *sicc.* 2, *color* blackish-brown, *struc.* heterogeneous, *composition* *Ld*, *Th*, *humo.* 3, *Formula* *Ld*³ 1, *Th*³ 3.

MÖCKELMOSEN

The morphological situation of Möckelmosen, Frösslunda Mose, Kritmosen, and Torpmosen is shown on the map, Fig. 57, where the investigated scarps' pattern is drawn together with the extension of the gravelly deposits. A detailed study of Möckelmosen was completed in 1958, and the results of 157 control stations (Fig. 58) within the Alvar lake have been summarized in the map of the basin topography below the soils and in the diagrammatical sections through these (Figs. 59, 60, 61).

Sterner's vegetational sketch map from 1926 has been redrawn and is shown for comparison with the Dröstorps material and to enable an understanding of the physiognomy of the Alvar lake (Fig. 62).

The map with the basin topography should be compared with the cross sections. Along most of the lake's eastern shore a scarp runs (Fig. 57). Its continuation downwards in the depth contours and in the cross sections is even more evident than in Dröstorps Mose, and the adaptation to the scarp system

of the adjoining area is very striking. The western shoreline is very lobate as is the case also in Dröstorps Mose. This is because of the very even Alvar surface which dips towards the scarp very smoothly. Very small alterations in water depth will then cause great changes of the western shoreline pattern. Möckelmosen is thus a very typical exponent for the basin topography, which has developed in accentuated depressions formed against scarps.

The scarp pattern east of Möckelmosen also shows other interesting features. East of Möckelmosen two furrows can be distinguished, one of them with the present outlet of the Alvar lake in it. It has been formed by breaking through the scarps, but it is hard to say if the formation mainly took place during the Holocene or if any glacial or glaciofluvial processes have been involved in the development. Because of the furrows' rather modest dimensions it seems most probable that the formation should be placed mainly in Holocene time.

The northern furrow first follows the original scarps direction and then changes direction more easterly. It finally reaches Frösslunda Mose as a tributary stream to this Alvar lake. The southern furrow is not normally filled with water as an outlet to Möckelmosen, but during extreme high water periods some water can be expected to take this way from Möckelmosen eastwards. In much of the furrow, and in its eastern half in particular, rather hydrophilous temporary pools with *Potentilla fruticosa* fill it up, thus giving it a diverging landscape colour from the surrounding dry bedrocks.

Möckelmosen is the greatest Alvar lake. It was almost 2000 m long when the mapping was completed. During its high-water periods the area of the Alvar lake is more than doubled.

As in Dröstorps Mose the deepest parts of the basin have been filled up with sediments and then colonized by fen communities, forming the central fen part, which is surrounded by a free water zone (Fig. 58, Fig. 63). The same basic sedimentational situation exists as in Dröstorps Mose, and the free

Fig. 63. Air photograph of Möckelmosen, parishes of Mörbylånga, Resmo and Stenåsa. The fairly even shoreline along the Alvar lake's eastern side is well demonstrated on the photograph together with the lobate configuration of the western shore. The physiognomy of Möckelmosen with its central fen should be compared with the map of the bottom morphology, Fig. 61, where the deepest parts of the basin correspond to the extension of the fen area in the middle of the Alvar lake.

It is also very clearly seen how the exposed bedrock occupies most of the photographed area, and how the joint systems can be followed everywhere outside the swamp and Alvar lake areas.

Möckelmosen is partly supplied by spring water. This is seen in the lower left corner, where a couple of springs occur.

In the upper left part of the photograph there is a persistent Alvar swamp, which belongs to my category C, where along most of the eastern shore a shallow gravelly ridge, probably a shore ridge, is situated.

The outlet of Möckelmosen to Frösslunda Mose is seen in the northernmost parts of the photograph, and the beginning of the southern furrow, mentioned in the text is filled by water and there are persistent swamps in their most hydrophilous facies. Air photograph by Rikets Allmänna Kartverk 1959. Published by permission of the Swedish Defence Staff.

Fig. 64. Frösslunda Mose, parish of Stenåsa. Frösslunda Mose is an Alvar lake, which has formed in a basin towards the extensive morainic deposits, which constitute the agricultural area of Frösslunda village. This Alvar lake also shows the same physiognomic conditions as in Dröstorps Mose and in Möckelmosen, and its central fen community is similarly composed as to its vegetational environment. The Alvar lake gets water from Möckelmosen during high water periods but superficial drainage or drainage near the surface through the joint system of the Alvar west of the Alvar lake seem to be an important factor in its water economy. This is also true of practically all wet areas of the Great Alvar.

W of Frösslunda village in the middle of the uppermost parts of the photograph it is very well seen how colonization by *Potentilla fruticosa* and *Juniperus communis* has hit former grazing areas. Photograph by Rikets Allmänna Kartverk 1959. Published by permission of the Swedish Defence Staff.

Fig. 65. The picture shows an area in the northern part of the central fen in Frösslunda Mose, parish of Stenåsa, with *Phragmites communis*, *Equisetum fluviatile* and *Carex elata* tussocks. In the southern parts of the fen area the vegetation is denser. July 1962.

water zone with its lime gyttjas kneaded by grazing cattle is also found in Möckelmosen.

The lake stage of Möckelmosen can only show lake marl in its lowest parts, and the grey lime gyttja, which was found underlaying the lake marl in Dröstorps Mose has not been proved to exist anywhere in Möckelmosen. However, there may still be possibilities of finding older sediments preserved in broader fissures in the bedrock of the basin's bottom, but no such layers have been traced during the systematical investigations of Möckelmosen's stratigraphical conditions.

The fen part of the stratigraphy comprises the bulk of the sediments. A layer with *Substantia humosa* very similar to the corresponding soil in Dröstorps Mose (p. 64) is very widespread in this Alvar lake, whereas it occurs more scattered in the other. It has been drawn into the sections of Möckelmosen.

Upon this layer a lime gyttja rests, which is very rich in detritus. It continues from its bottom contact with the *Substantia humosa* (or with the lake marl in certain parts) to the upper surface of the stratigraphy. However, the *Carex elata* tussocks rest

upon the gyttja, which has a metachronous upper surface, where the present time is represented in its superficial layer between the tussocks and in the tussocks' uppermost peat, while an older time is represented in gyttja contact with the tussock's basal peat.

In Dröstorps Mose the boundaries between the oldest sediments showed a dip towards the east. A similar situation exists in Möckelmosen too, but is less pronounced there.

The Stratigraphy

Möckelmosen, MM 1

Below the sediments is limestone.

1. Lime gyttja. Nig. 0-1, strf. 1, elas. 1, sicc. 2, color white to yellowish-white, struc. homogeneous, composition Lc, Ld, humo. 1, lim. 1, Formula Lc 3, Ld¹ 1.
2. Gyttja with lime gyttja substance. Nig. 1, strf. 1, elas. 1-2, sicc. 2, color grey to olive-grey, struc. homogeneous, composition Lc, Ld, humo. 2, lim. 0, Formula Lc 2, Ld² 2.
3. *Substantia humosa*. Nig. 4, strf. 1, elas. 3-4, sicc. 2, color black to blackish-brown, struc. homogeneous, composition Sh, humo. 4, lim. 0, Formula Sh 4.
4. Peaty gyttja. Nig. 2-3, strf. 1, elas. 1, sicc. 1, color grey to grey-brown, struc. heterogeneous, composition Ld, Th, humo. 2, Formula Ld² 2, Th² 2.

Fig. 66. Kritmosen, parish of Stenåsa. This Alvar lake is also supplied by water from springs. It shows a diverging vegetational condition to the one of the other Alvar lakes as the central fen is occupied by a more terrestrial society, where low *Carex* species dominate. I have hypothetically considered Kritmosen to be a later stage in the vegetational succession of an Alvar lake.

Note the young birches which grow in open joints in the background. June 1962.

FRÖSSLUNDA MOSE

The morphological situation is shown on the Fig. 57. As has already been shown the scarps' system has been much transformed by two furrows in the bedrock's surface, which lead from Möckelmosen to Frösslunda Mose. In the northern one a tributary stream to Frösslunda Mose flows, but it contains

water only during the wetter periods of the year. Frösslunda Mose (Fig. 64) is dammed by the extensive gravelly deposits around Frösslunda village. Unfortunately the names on Frösslunda village and Frösslunda Mose were omitted when the main physiognomic map of the Great Alvar was drawn. They are both situated west of Norra Kvinneby. Much of these deposits are undoubtedly built up by boulder

Fig. 67. Kritmosen. Sections. Legend: Fig. 81.

clay, but shore material also plays a very important rôle, especially in the surface layers.

This Alvar lake has also a free water zone, which is, however, more unevenly distributed than in most of the other Alvar lakes, and in the south-eastern part of the basin there is a contact between the fen communities of the central Alvar lake and with the shore vegetation.

The vegetation has the same principal pattern as has Möckelmosen, and *Carex elata* is a significant member of the physiognomically most important fen plants (Fig. 65).

In Frösslunda Mose no detailed studies were made, except for occasional controls of the stratigraphy. One of the collected sample series has been pollen analysed.

The Stratigraphy

Frösslunda Mose, FM 1

As in Dröstorps Mose and Möckelmosen a lake phase and a fen phase can be demonstrated in the stratigraphy.

1. The bottom below the sediments is limestone.
2. Lake marl. *Nig.* 0–1, *strf.* 1, *elas.* 1, *sicc.* 2, *color* white to grey-white, *struc.* homogeneous, *composition* *Lc*, *Ld*, *humo.* 1, *lim.* 0, *Formula Lc* 4, *Ld*¹ (+).
3. Lake marl. *Nig.* 0–1, *strf.* 1, *elas.* 1, *sicc.* 2, *color* white, *struc.* base substance homogeneous, *composition* *Lc*, *Th*, *humo.* 1, *lim.* 1, *Formula Lc* 4, *Th*¹ (+).
4. Gyttja with lime gyttja substance. *Nig.* 2, *strf.* 1, *elas.* 1, *sicc.* 2, *color* olive-brown to grey-brown, *struc.* base substance homogeneous, *composition* *Lc*, *Ld*, *Th*, *humo.* 2, *lim.* 1, *Formula Lc* 2, *Ld*² 2, *Th*² (+).
5. Peaty gyttja. *Nig.* 2, *strf.* 1, *elas.* 1, *sicc.* 2, *color* grey-brown, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *humo.* 3, *lim.* 1, *Formula Lc* (+), *Ld*³ 2, *Th*³ 2.
6. Peaty gyttja. *Nig.* 3, *strf.* 1, *elas.* 1, *sicc.* 1, *color* blackish grey-brown, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *humo.* 4, *lim.* 1, *Formula Lc* (+), *Ld*⁴ 3, *Th*⁴ 1.
7. Peaty gyttja. *Nig.* 2–3, *strf.* 1, *elas.* 1, *sicc.* 1, *color* dark grey-brown, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *humo.* 3, *Formula Lc* (+), *Ld*³ 2, *Th*³ 2.
8. Water.

KRITMOSEN

Kritmosen is situated just west of Ebbelunda Alvar village. Its basin is not very extensive (Fig. 66) and rather shallow, and its ability to store water is increased by a tributary stream from a row of springs just 100 m west of the Alvar lake. As can be seen on the map (Fig. 57), the basin of Kritmosen and its configuration is very welladapted to the scarp system of its neighbourhood. Gravels and sands may also play some rôle in the Alvar lake's damming scheme as such deposits have been found to underlay the Alvar lake's stratigraphy in many parts of the basin.

Sections have been dug and are marked on the map, Fig. 68. The sections are shown in Fig. 67.

Fig. 68. Map showing the position of the sections in Kritmosen.

Below the present surface, which is hummocky and where low *Carex* species dominate the plant communities, a lime gyttja forms the bulk of the stratigraphy. It is, however, rather poor in plant detritus and shows in many parts a tendency to be very near the lake marl in the lime gyttja series. As these stratigraphical units are not very persistent throughout the sections they have not been drawn into them. The same is true for a peaty layer, which has been found within the upper parts of the lime gyttja sequence. It may, however, be seen in the soil column of the pollen diagram KM 1.

In the lowest parts of the stratigraphy a lime gyttja, which is more rich in plant detritus has been observed. It is very similar to the bottom sediment in Dröstorps Mose, and it is also very reminiscent of the very lowest part of the lake marl in Frösslunda Mose. It has been deposited in cavities in the deepest parts of the Kritmosen's basin.

The Stratigraphy

Kritmosen, KM 1

1. Gravel. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 2, *color* grey, *struc.* granular, *composition* *Ga*, *Gs*, *Gg* (min), *humo.* 0, *lim.* 1, *Formula Ga* 2, *Gs* 1, *Gg* (min) 1.
2. Gyttja with lime gyttja substance. *Nig.* 2, *strf.* 1, *elas.* 1, *sicc.* 2, *color* greyish-white to olive-grey, *struc.* homogeneous, *composition* *Lc*, *Ld*, *humo.* 2, *lim.* 1, *Formula Lc* 1, *Ld*² 3.
3. Gyttja with lime gyttja substance. *Nig.* 1–2, *strf.* 1, *elas.* 1, *sicc.* 2, *color* greyish-white, *struc.* homogeneous, *composition* *Lc*, *Ld*, *Th*, *humo.* 1, *lim.* 1, *Formula Lc* 2, *Ld*¹ 2, *Th*¹ (+).

Fig. 69. Air photograph of Torpmosen, parish of Stenåsa. In the foreground exposed bedrock with soil filled joints is seen. The nearest fen area belongs to the southernmost extension of Kritmosen. Very near the stone wall in the centre of the picture the grave mound Örnkullen lays. Torpmosen has similar morphological conditions as were described for Frösslunda Mose, and it is dammed by a large gravelly deposit, which is a southerly continuation of the same formation that constitutes the damming unit of Frösslunda Mose.

The stratigraphy at Torpmosen has recently been destroyed in many parts as gravel pits have been opened even in the Alvar lake itself.

In the background a long row of houses is seen. This row is formed by villages, which are situated upon the Ancyclus ridge. June 1965. The picture is published by permission of the Swedish Defence Staff.

4. Lime gyttja with gyttja substance. *Nig.* 0–1, *strf.* 1, *elas.* 1, *sicc.* 2, *color* yellowish-white to white, *struc.* homogeneous, *composition* Lc, Ld, humo. 1, *lim.* 0, *Formula* Lc 3, *Ld*¹ 1.

5. Gyttja with lime gyttja substance. *Nig.* 2, *strf.* 1, *elas.* 1, *sicc.* 2, *color* yellowish-grey, *struc.* homogeneous, *composition* Lc, Ld, humo. 1, *lim.* 1, *Formula* Lc 2, *Ld*¹ 2.

6. Gyttja with lime gyttja substance. *Nig.* 2, *strf.* 1, *elas.* 1, *sicc.* 2, *color* olive-brown, *struc.* heterogeneous, *composition* Lc, Ld, Th, humo. 2, *lim.* 0, *Formula* Lc 1, *Ld*² 3, *Th*² (+).

7. Peat with gyttja and lime gyttja substances. *Nig.* 2–3, *strf.* 1, *elas.* 3, *sicc.* 1–2, *color* brown, *struc.* heterogeneous, *composition* Lc, Ld, Th, humo. 3, *lim.* 1, *Formula* Lc 1, *Ld*³ 1, *Th*³ 2.

8. Peaty gyttja with lime gyttja substance. *Nig.* 2–3, *strf.* 1,

elas. 1, *sicc.* 2, *color* olive-brown, *struc.* heterogeneous, *composition* Lc, Ld, Th, humo. 3, *lim.* 1, *Formula* Lc 1, *Ld*³ 2, *Th*³ 1.

9. Gyttja with lime gyttja substance. *Nig.* 1, *strf.* 1, *elas.* 1, *sicc.* 2, *color* brownish-grey, *struc.* heterogeneous, *composition* Lc, Ld, Th, humo. 3, *lim.* 1, *Formula* Lc 2, *Ld*³ 2, *Th*³ (+).

10. Peat with lime gyttja and gyttja substances. *Nig.* 2–3, *strf.* 1, *elas.* 2–3, *sicc.* 2, *color* brown, *struc.* heterogeneous, *composition* Lc, Ld, Th, humo. 3, *Formula* Lc 1, *Ld*³ 1, *Th*³ 2.

TORPMOSEN

This Alvar lake is situated south of Ebbelunda village, and together with Kritmosen and Ebbelunda

Pool north of the village it belongs to the same superficial hydrographical system, which has its outlet to the Baltic at Södra Kvinneby just south of Torpmosen (Fig. 69).

Its morphological situation is very much reminiscent of that of Frösslunda Mose (Fig. 57), and along its eastern shore there are rather extensive gravelly deposits. Gravelly and sandy material has also been found below the lake's own sediments in several parts of the basin.

The sections are shown on Fig. 71, and their positions are marked on map, Fig. 70.

The most interesting feature in the stratigraphical picture of Torpmosen is the occurrence of peaty layers, which can best be seen on the cross section -50. From the bottom lime gyttja is overlaid by a black, heavy layer, which is very reminiscent of the totally composed peat layers, the black layers, of Dröstorps Mose and Möckelmosen. Above this is again lime gyttja, then another peat layer which, however, has a low degree of destruction and with very much substance in it. Above this again there is a lime gyttja and on top of the sequence is a peat layer.

The middle peat layer can also be found in cross section +20, and in the southern part of the longitudinal section. In the deepest parts a lower and dark grey lime gyttja can be found. This is best seen in the longitudinal section between -60 and -130. This layer is macroscopically very similar to the grey lower lime gyttja, which has been described from Dröstorps Mose, Ekelunda Mose, Frösslunda Mose and Kritmosen.

The Stratigraphy

Torpmosen, TM 1

1. Lake marl. *Nig.* 0, *strf.* 2, *elas.* 3, *sicc.* 2, *color* white, *struc.* homogeneous, *composition* Lc, *humo.* 0, *lim.* 1, *Formula* Lc 4.

2. Gyttja with lime gyttja substance. *Nig.* 2, *strf.* 1, *elas.* 1, *sicc.* 2, *color* olive-grey, *struc.* heterogeneous, *composition* Lc, Ld, Th, *humo.* 3, *lim.* 1, *Formula* Lc 2, Ld¹ 2, Th² (+).

3. *Substantia humosa*. *Nig.* 4, *strf.* 2, *elas.* 4, *sicc.* 2, *color* black, *struc.* homogeneous, *composition* Sh, *humo.* 4, *lim.* 2-3, *Formula* Sh 4.

4. Lime gyttja with gyttja substance. *Nig.* 0-1, *strf.* 1-2, *elas.* 2, *sicc.* 2, *color* white-grey to yellowish-grey, *struc.* heterogeneous, *composition* Lc, Ld, Th, *humo.* 1, *lim.* 1, *Formula* Lc 3, Ld¹ 1, Th¹ (+).

5. Gytja with lime gyttja substance. *Nig.* 1, *strf.* 1, *elas.* 2, *sicc.* 2, *color* grey, *struc.* heterogeneous, *composition* Lc, Ld, Th, *humo.* 2, *lim.* 1, *Formula* Lc 2, Ld² 2, Th² (+).

6. Gytja with lime gyttja substance. *Nig.* 0-1, *strf.* 1, *elas.* 2-3, *sicc.* 2, *color* yellowish-white, *struc.* homogeneous, *composition* Lc, Ld, *humo.* 2, *lim.* 1, *Formula* Lc 2, Ld² 2.

Fig. 70. Torpmosen. Position of the sections.

Fig. 71. Torpmosen. Sections. Legend: Fig. 81.

7. Gytjtja with lime gyttja substance. *Nig.* 1–2, *strf.* 1, *elas.* 2, *sicc.* 2, *color* olive-grey, *struc.* homogeneous, *composition* *Lc*, *Ld*, *humo.* 2, *lim.* 1, *Formula Lc* 2, *Ld*³ 2.
8. Gytjtja with lime gyttja substance. *Nig.* 0–1, *strf.* 1, *elas.* 2, *sicc.* 2 *color* greyish-white, *struc.* homogeneous, *composition* *Lc*, *Ld*, *humo.* 1, *lim.* 1, *Formula Lc* 2, *Ld*² 2.
9. Peat with lime gyttja and gyttja substances. *Nig.* 2, *strf.* 0, *elas.* 3, *color* reddish-brown, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *humo.* 2, *lim.* 1, *Formula Lc* +, *Ld*² 1, *Th*² 3.
10. Lime gyttja with gyttja substance. *Nig.* 0–1, *strf.* 1, *elas.* 2–3, *sicc.* 2, *color* yellowish-white, *struc.* homogeneous, *composition* *Lc*, *Ld*, *humo.* 2, *lim.* 1, *Formula Lc* 3, *Ld*² 1.
11. Peaty gyttja with lime gyttja substance. *Nig.* 2, *strf.* 0, *elas.* 2–3, *color* brown, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *humo.* 2, *lim.* 1, *Formula Lc* 1, *Ld*² 2, *Th*² 1.
12. Peat with gyttja substance. *Nig.* 2, *strf.* 0–1, *elas.* 3, *sicc.* 2, *color* brown, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *humo.* 1, *Formula Lc* (+), *Ld*¹ 1, *Th*¹ 3.

Torpmsen, TM 7

1. Sandy gravel. *Nig.* 1–2, *strf.* 0, *elas.* 0, *sicc.* 1–2, *color* grey, *struc.* heterogeneous, *composition* *Ga*, *Gs*, *Gg* (min), *humo.* 0, *lim.* 1, *Formula Ga* 2, *Gs* (+), *Gg* (min) 2.
2. Sandy lime gyttja with gyttja substance. *Nig.* 2, *strf.* 2, *elas.* 2, *sicc.* 2, *color* dark grey, *struc.* heterogeneous, *composition* *Ga*, *Lc*, *Ld*, *Th*, *humo.* 1, *lim.* 1, *Formula Ga* 1, *Lc* 2, *Ld*¹ 1, *Th*¹ (+).
3. Lake marl. *Nig.* 0–1, *strf.* 1–2, *elas.* 3, *sicc.* 2, *color* white to yellowish-white, *struc.* homogeneous, *composition* *Lc*, *humo.* 0, *lim.* 1, *Formula Lc* 4.
4. *Substantia humosa*. *Nig.* 4, *strf.* 2, *elas.* 4, *sicc.* 2, *color* black, *struc.* homogeneous, *composition* *Sh*, *humo.* 4, *lim.* 2, *Formula Sh* 4.
5. Lime gyttja with gyttja substance. *Nig.* 0–1, *strf.* 1–2, *elas.* 2, *sicc.* 2, *color* white-grey, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *humo.* 1, *lim.* 1, *Formula Lc* 3, *Ld*¹ 1, *Th*¹ (+).
6. Lime gyttja with gyttja substance. *Nig.* 2, *strf.* 2, *elas.* 2, *sicc.* 2, *color* olive-grey, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *humo.* 2, *lim.* 0–1, *Formula Lc* 3, *Ld*² 1, *Th*² (+).
7. Gytjtja with lime gyttja substance. *Nig.* 3, *strf.* 2, *elas.* 1–2, *sicc.* 1–2, *color* greyish-brown, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *humo.* 2, *lim.* 1, *Formula Lc* 2, *Ld*² 2, *Th*² +.

SÖDRA BÅRBY MOSE

This Alvar lake is probably the highest elevated of all the Alvar lakes and pools. It is situated east of Södra Bårby and Bengtstorp villages, and lays on the Alvar east of the top ridge, which is deposited upon the *klint* there. The investigation of this Alvar lake has not been systematically made and thus only a couple of soil profiles have been measured. In no place within the basin the sediments have been found to exceed 60 cm in thickness.

The Alvar lake seems to be supplied by spring water to a large extent, and even during the extremely dry summer in 1959 a water surface remained in the basin all thorough the summer. At that time the wells of the nearby houses were dry.

The drainage also seems to follow subterranean ways. The outlet from the Alvar lake towards SSE has no continuation to any other hydrographical formations on the surface than the marshy meadows south of the road between Södra Bårby and Alby. However, the doline system to the SSE of Södra Bårby Mose shows one possible direction of the subterranean drainage.

The Stratigraphy

Södra Bårby Mose, SBM 1

As no pollen diagram has yet been made from this locality the degree of decomposition of the organic content of the sediments has not been recorded. This means that *humo.* is not noted in the descriptions below. The first described soil is the bottom layer.

1. Limestone constitutes the bottom of the basin.
2. Gytjtja with lime gyttja substance. *Nig.* 2, *strf.* 1, *elas.* 2, *sicc.* 2, *color* grey, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Ga*, *lim.* 1, *Formula Lc* 1, *Ld* 3, *Ga* +.
3. Gytjtja with lime gyttja substance. *Nig.* 1–2, *strf.* 1, *elas.* 2, *sicc.* 2, *color* brownish-grey, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *Ga*, *lim.* 1, *Formula Lc* 2, *Ld* 2, *Th* (+), *Ga* (+).
4. Peaty gyttja with lime gyttja substance. *Nig.* 3, *strf.* 1, *elas.* 1, *sicc.* 1–2, *color* blackish-brown, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *Ga*, *lim.* 0, *Formula Lc* 1, *Ld* 2, *Th* 1, *Ga* (+).
5. Peat with gyttja substance. *Nig.* 4, *strf.* 1, *elas.* 2, *sicc.* 2, *color* black, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *Ga*, *Formula Lc* (+), *Ld* 1, *Th* 3, *Ga* (+).

AMOSÉN

Amosen is a very extensive temporary pool, and the sedimentation seems to have been rather modest in the very shallow basin as no noteworthy sediment areas have been discovered.

TRIBERGA MOSE

Triberga Mose is dammed by the Ancyclus ridge. Most of it is now cultivated, but there is still one area with free water surface in the northern parts of the basin. A *Carex elata* - *Menyanthes trifoliata* - *Equisetum fluviatile* characterized plant community dominates the vegetational aspect.

The Stratigraphy

Triberga Mose, TRM 1

As in Södra Bårby Mose no pollen analyses have yet been made and *humo.* is therefore not noted in the descriptions. The first described layer is the bottom layer. The deepest part of the investigated basin which has been found is 60 cm.

1. Gravelly sand. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 1–2, *color* grey, *struc.* heterogeneous, *composition* *Ga*, *Gs*, *Gg* (min), *lim.* 0, *Formula Ga* 2, *Gs* 1, *Gg* (min) 1.

Fig. 72. Rosenkärret, parish of Kastlösa. This Alvar lake is dammed by a shore ridge. Along its eastern shore a local, ice pressed ridge has been formed. This ridge is a parallel to the ice pressed ridge in Dröstorp Mose (Königsson 1962, p. 97) and is assumed to develop as a result of winds and ice pressing during autumns and springs. In the lower left corner of the picture *Potentilla fruticosa*. July 1966.

2. Sandy lime gyttja. Nig. 2, strf. 0, elas. 0, sicc. 2, color grey, struc. heterogeneous, composition Ag, Ga, Lc, Ld, lim. 1, Formula Ag 1, Ga 1, Lc 2, Ld (+).
3. Peaty gyttja with lime gyttja substance. Nig. 2-3, strf. 0, elas. 1, sicc. 1-2, color brownish-grey, struc. heterogeneous, composition Ag, Lc, Ld, Th, lim. 1, Formula Ag (+), Lc 1, Ld 2, Th 1.
4. Peaty gyttja. Nig. 3, strf. 0, elas. 1, sicc. 1-2, color blackish-brown, struc. heterogeneous, composition Lc, Ld, Th, lim. 1, Formula Lc 1/2, Ld 2, Th 1 1/2.
5. Peat with gyttja substance. Nig. 3, strf. 0, elas. 3, sicc. 2, color black to brownish-black, struc. heterogeneous, composition Lc, Ld, Th, Formula Lc (+), Ld (+), Th 4.

LUNDA MOSE

Lunda Mose is situated west of Lunda and Stora Dalby villages. It was investigated by Lundqvist in 1925 when he measured two profiles, the one in the northern parts of the basin, the other in the southern. The extension of the Lunda Mose is now impossible to state as the fen has been cultivated for a long time, or since 1878-1881, when the first drainage was completed (Å. Lundqvist 1966). The present measurement has been performed in the area between G. Lundqvist's two profiles.

The Stratigraphy

Lunda Mose, LM 1

1. Silt. Nig. 1-2, strf. 0, elas. 0, sicc. 2-3, color light grey, struc. homogeneous, composition Ag, Ga, Lc, humo. 0, lim. 2, Formula Ag 2, Ga 2, Lc (+).
2. Sandy lime gyttja with gyttja substance. Nig. 1, strf. 1, elas. 1, sicc. 2, color grey, struc. homogeneous, composition Lc, Ag, Ga, Ld, humo. 1, lim. 1, Formula Ag 1, Ga (+), Lc 2, Ld¹ 1.
3. Lake marl. Nig. 0, strf. 2, elas. 3, sicc. 2, color white, struc. homogeneous, composition Lc, humo. 0, lim. 1, Formula Lc 4.
4. Peaty gyttja. Nig. 4, strf. 1, elas. 1, sicc. 3, color black to blackish-brown, struc. heterogeneous, composition Lc, Ld, Th, humo. 4, Formula Lc (+), Ld¹ 2, Th¹ 2.

ROSENKÄRRET

Rosenkärret is situated southeast of Lunda village and northeast of Penåsa ruin village. It is dammed by a shore ridge, which constitutes its eastern strand line (Fig. 72, Fig. 74, Fig. 107). Its hydrographical situation is complicated and most of its drainage seems to be subterranean, while during high water periods a superficial drainage eastwards and south-eastwards has been noted. The basin is rather shal-

Fig. 73. Air photograph of Västerstads Träsk. A shore ridge occurs along the eastern shore of the Alvar lake. This ridge is, however, not continuous and its importance as a damming factor should therefore be considered to be limited. All over the photographed area the joint systems can be followed and the scarp morphology is pregnantly developed. This may be seen very clearly on the swamps' contours. Photograph by Rikets Allmänna Kartverk 1964. Published by permission of the Swedish Defence Staff.

Fig. 74. Västerstads Träsk. The scarp system of the environment of Västerstads Träsk.

low and the exposed bedrock is frequently seen along its western strand.

The Stratigraphy

Rosenkärret, RK 1

No systematic study of the sediments has been made but a couple of measurements were made. No pollen analysis on

the collected material has yet been carried out and thus *humo.* is not included in the descriptions below. The first layer in the description is the bottom layer.

1. Silt. *Nig.* 1-2, *strf.* 0, *elas.* 0, *sicc.* 2, *color* grey, *struc.* homogeneous, *composition* *Ag, Ga, lim.* 1, *Formula* *Ag* 3, *Ga* 1.

2. Sandy gyttja with lime gyttja substance. *Nig.* 4, *strf.* 0, *elas.* 1-2, *sicc.* 2, *color* black to blackish-brown, *struc.* ho-

Fig. 75. Västerstads Träsk. Position of the sections.

homogeneous, composition Ag, Lc, Ld, Th, lim. 1, Formula Ag 1, Lc 1, Ld 2, Th (+).

3. Peat with lime gyttja and gyttja substances. Nig. 3, strf. 0, elas. 0, sicc. 1-2, color dark brown, struc. heterogeneous, composition Lc, Ld, Th, Formula Lc 1, Ld 1, Th 2.

Fig. 76. Västerstads Träsk. Sections. Legend: See Fig. 81. The material of Västerstads Träsk was measured by Mr. J. Höijer, FK, as part of his exam work and was kindly put to the author's disposal.

VÄSTERSTADS TRÄSK

Västerstads Träsk is also known as Kindberg's Mose or as Rotmosen. It is situated to the southeast of Penåsa ruin village and is an Alvar lake with a central fen community, where *Carex elata*, *Menyanthes trifoliata* and *Equisetum fluviatile* dominate the vegetational aspect.

Its morphological conditions may be seen on the air photograph, Fig. 73, and on the map, Fig. 74. Västerstads Träsk is a typical representative for the Alvar lake category which has developed in an accentuated depression against a scarp in the same way as have Möckelmosen and Dröstorps Mose. The occurrence of a shore ridge, which is not continuous but a hill series along the eastern strand of Västerstads Träsk does not change this situation much and its importance as a damming factor is limited.

The basins adaptation to the scarp system in the neighbourhood is very striking as are the adaptation to the morphology of the pools to the west and north-west of the Alvar lake. This may also be seen very clearly on the air photograph.

The basin is very shallow and the sedimentation has largely been restricted to three main areas. The deepest of these has been sectionized and the site of the sections is marked on the map, Fig. 75. The sediments are shown on Fig. 76. In the bottom peat lime gyttjas are found, which are very poor in detritus and very near to the lake marl in the lime gyttja series. In certain parts, however, more detritus-rich facies occur. Upon this layer a lime gyttja abundantly mixed with peat detritus rests and again upon this layer a peaty soil is found. The stratigraphy then shows a lake phase and a fen phase.

The Stratigraphy

Västerstads träsk, VT 3.

1. Limestone.

2. Gyttja with lime gyttja substance. Nig. 1, strf. 0, elas. 1, sicc. 2, color white-grey, struc. homogeneous, composition Lc, Ld, humo. 1, lim. 1, Formula Lc 2, Ld¹ 2.

3. Peaty gyttja with lime gyttja substance. Nig. 2, strf. 0, elas. 0, sicc. 1-2, color grey, struc. heterogeneous, composition Lc, Ld, Th, humo. 2, lim. 0, Formula Lc 1, Ld² 2, Th² 1.

4. Peat with lime gyttja and gyttja substances. Nig. 2-3, strf. 0, elas. 2, sicc. 2, color dark grey, struc. heterogeneous, composition Lc, Ld, Th, humo. 3, Formula Lc 1, Ld³ 1, Th³ 2.
5. Water.

STORMAREN

Stormaren is situated east of Södra Möckleby and south of Pilekulla. It is a remarkable Alvar lake because of its stands of *Cladium mariscus*, which is a rather rare plant on southern Öland. The vegetation of Stormaren was described by Sterner (1926, p. 78), and his vegetational sketch map has been redrawn for comparison with the Dröstorps Mose and Möckelmosen maps to enable an understanding of the physiognomic conditions of the Alvar lakes (Fig. 77).

Physiognomically Stormaren is a typical Alvar lake with a central fen community surrounded by a free water zone (Fig. 42). The morphological situa-

Fig. 77. Stormaren, Sketch map of the vegetational environment. The map is a redrawing of Sterner (1926). Designations: 2. *Carex elata*, 5. *Menyanthes trifoliata*, 7. *Phragmites communis*, 8. *Carex lasiocarpa*, 11. *Molinia coerulea*, *Carex panicea*, *C. hostiana*, *C. Oederi*, 12. *Littorella uniflora*, 13. *Cladium mariscus*, 14. *Potamogeton gramineus*, 15. *Chara* sp.

2-7 11-13
5-8 12-14 15

Fig. 78. Stormaren. The morphologic conditions and the scarp systems of the surroundings of Stormaren. Legend: See Fig. 57.

Fig. 79. Stormaren. Bottom configuration below the sediments.

tion is seen on the map, Fig. 78, where the scarp system has been marked. If this map is compared with the one which shows the bottom configuration of the basin below the sediments (Fig. 79) it is evident that Stormaren has developed in a funnel-like depression in the bedrock. This impression is accentuated by the scarps' adaptation to the basin configuration of Stormaren, which is very doline-like.

The map with the depth contour has been constructed on the basis of the information gained in stratigraphical control borings, which have been performed according to the grid system on Fig. 80. The deepest point which has been found is 240 cm below the sediment surface. This means that Stormaren is by far the deepest Alvar lake, and also that it is one of the deepest fen or lake basins on Öland in general.

Fig. 80. Stormaren. Index map showing the position of the sections in the Alvar lake.

The soils and their extension within the basin are shown in Fig. 81 and Fig. 82, where diagrammatical sections are given comprising the information from 158 control stations. In the lowest parts of the basin a grey lime gyttja is found, which macroscopically is the equivalent of the lower lime gyttjas of Dröstorps Mose, Ekelunda Mose, Frösslunda Mose, Kritmosen and Torpmosen. Upon this layer a lime gyttja, which is very poor in detritus rests. Part of this layer is a real lake marl, the rest of it forms transitional layers to lime gyttjas with varying detritus content. This is best seen in the descriptions of the soil column of the pollen diagram Stormaren STM 1.

Upon the "lake marl-sector" a compact black soil follows, which shows the same macroscopical features as do the *Sh*-4 layers in Möckelmosen, Dröstorps Mose and Torpmosen. Its value as regional stratigraphical unit is largely restricted by the occurrence of more layers with the same characteristics within the Stormaren sections.

Upon this black soil a lime gyttja sequence follows. It shows frequent changes in darkness and colour and is on the whole more heterogeneous than is the corresponding sector in the stratigraphy of

Dröstorps Mose, Möckelmosen and Västerstads Träsk. Within this sector additional *Sh* - 4-characterized layers occur.

On the top of the sequence a peaty layer is found, which represents the latest phase within the Alvar lake's soil development. In Stormaren the vegetational conditions are different from Dröstorps Mose and Möckelmosen as *Phragmites communis* is growing between the *Carex elata*-tussocks which means that the central fen shows a more closed aspect than have the two Alvar lakes mentioned, where *Equisetum fluviatile* is the usual plant between the tussocks, and where even the latter grows it does not show as dense stands as does the *Phragmites communis* in Stormaren. This means that there is a sediment between the tussocks, which is extremely rich in peat detritus, but which is still a gyttja genetically. In the tussocks proper and within the denser *Phragmites communis*- or *Cladium mariscus*-reeds the soil is genetically a peat abundantly mixed with gyttja substance.

The upper surface of the older sediments show a tendency to an eastern dip, thus giving younger sediments a better representation in the easternmost parts of the basin. This observation is in accordance with the previously shown conditions in Dröstorps Mose and Möckelmosen. It is also true of most lakes in southern Sweden and is considered to be due to the prevailing wind directions (cf. p. 65).

The Stratigraphy

Stormaren, STM 1

1. Peaty gyttja with lime gyttja substance. *Nig.* 2, *strf.* 0, *elas.* 1, *sicc.* 2, *color* dark grey, *struc.* heterogeneous, *composition* *Ag*, *Lc*, *Ld*, *Th*, *humo.* 2, *lim.* 1, *Formula* *Ag* +, *Lc* 1, *Ld*² 2, *Th*² 1.
2. Lime gyttja with gyttja substance. *Nig.* 2-3, *strf.* 0, *elas.* 2, *sicc.* 2, *color* olive-brown to olive-grey, *struc.* homogeneous, *composition* *Lc*, *Ld*, *humo.* 1, *lim.* 1, *Formula* *Lc* 3, *Ld*¹ 1.
3. Lime gyttja with gyttja substance. *Nig.* 2, *strf.* 0, *elas.* 2, *sicc.* 2, *color* olive-grey, *struc.* homogeneous, *composition* *Lc*, *Ld*, *humo.* 1, *lim.* 1, *Formula* *Lc* 2, *Ld*¹ 2.
4. Lime gyttja with gyttja substance. *Nig.* 1, *strf.* 0, *elas.* 2, *sicc.* 2, *color* greyish-white, *struc.* homogeneous, *composition* *Lc*, *Ld*, *humo.* 1, *lim.* 1, *Formula* *Lc* 3, *Ld*¹ 1.
5. Lake marl. *Nig.* 0, *strf.* 0, *elas.* 3, *sicc.* 2, *color* white, *struc.* homogeneous, *composition* *Lc*, *humo.* 0, *lim.* 1, *Formula* *Lc* 4.
6. Lime gyttja with gyttja substance. *Nig.* 1-2, *strf.* 0, *elas.* 2, *sicc.* 2, *color* olive-grey, *struc.* homogeneous, *composition* *Lc*, *Ld*, *humo.* 1, *lim.* 1, *Formula* *Lc* 2, *Ld*¹ 2.
7. Lime gyttja with gyttja substance. *Nig.* 1, *strf.* 0, *elas.* 2, *sicc.* 2, *color* yellowish-white, *struc.* homogeneous, *composition* *Lc*, *Ld*, *humo.* 1, *lim.* 1, *Formula* *Lc* 3, *Ld*¹ 1.
8. Lime gyttja with gyttja substance. *Nig.* 1-2, *strf.* 0, *elas.* 2, *sicc.* 2, *color* olive-grey, *struc.* homogeneous, *composition* *Lc*, *Ld*, *humo.* 1, *lim.* 2, *Formula* *Lc* 2, *Ld*¹ 2.
9. *Substantia humosa*. *Nig.* 4, *strf.* 0, *elas.* 3, *color* black to

blackish-brown, *struc.* homogeneous, *composition* *Sh*, *humo.* 4, *lim.* 2, *Formula* *Sh* 4.

10. Peaty gyttja. *Nig.* 2-3, *strf.* 0, *elas.* 0, *sicc.* 1-2, *color* brownish-grey, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *humo.* 2, *lim.* 0, *Formula* *Lc* (+), *Ld*² 2, *Th*² 2.

11. Peaty gyttja. *Nig.* 2, *strf.* 0, *elas.* 0, *sicc.* 1-2, *color* dark grey, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *humo.* 2, *lim.* 0, *Formula* *Lc* (+) *Ld*² 3, *Th*² 1.

12. Peaty gyttja. *Nig.* 2, *strf.* 0, *elas.* 0, *sicc.* 2, *color* brown, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *humo.* 2, *Formula* *Lc* (+), *Ld*² 2, *Th*² 2.

The Fens of Middle Öland

THE GEOLOGY OF THE AREA

An outline of Öland's geological conditions has already been given above (Fig. 2, pp. 2-5). The map, however, is a simplified redrawing of the geological maps of the island, and the aim was to give the general geological situation as an introduction to this study. Thus very little local information as to those fens which are going to be treated below can be found on the map. A detail map of central Öland has therefore been produced (Fig. 83) and a summarizing description of the geology of the investigation area is given.

The dominating soils on middle Öland are moraines. However, the designations for moraine which is untouched in the surface by wave action have been too generously used on the map, and littoral deposits should instead be expected to increase their proportional representation.

A zone with glaciofluvial deposits, covered by and continued in littoral deposits occurs in a belt from Köping to Gärdslösa. A potential glaciofluvial deposit is found west of Högrum.

Along the western coast the klint runs, partly covered by gravels and sands. The Ancyclus and Litorina ridges have developed upon or below the klint, and they may be followed in positions along the coast. However, they are not continuous over longer distances.

Along the eastern coast the classical transgressive ridges from the Ancyclus Lake and the Litorina Sea have developed and they dominate the landscape totally. The Ancyclus ridge is continuous almost all the way from Bredsättra down to Hulterstad, while the Litorina ridge has not become continuous to so great an extent. In addition to these ridges other shore ridges may be found especially east of the Litorina ridge system.

Exposed bedrock occurs scattered all over the area. Its frequency is highest along the *klint*. The soil depths are thus very varying. The deepest known re-

Fig. 81. Stormaren. Longitudinal sections. Legend: 1. Lake marl. 2. Lime gyttja. 3. Peat detritus containing gyttja. 4. The free water zone's lime gyttja. 5. Peat. 6. Peat with gyttja content. 7. *Substantia humosa*. 8. Stratigraphy partly disturbed. 9. Water.

cords occur in the potential glaciofluvial area west of Högrum, where almost 20 metres of depth have been recorded.

THE FENS OF MIDDLE ÖLAND

As said above (p. 15) the fen basins of Öland are shallow and occupy depressions in the upper surface of the island, which are only two or three metres

deep. G. Lundqvist made a table to elucidate the distribution of the basin depths (1928, p. 17); 29 % are less than 0.5 m deep, 37.8 % are 0.5–1 m, 14.5 % are 1–1.5 m, 8.7 % are 1.5–2 m, 4.3 % are 2–3 m, 4.3 % are 3–4 and 1.4 % are more than 4 m deep. Lundqvist's figures are not absolute of course but they give a good picture of the conditions.

As the upper surface of the island dips towards SSE the main drainage will also be directed towards

Fig. 82. Stormaren. Cross sections. Legend: See Fig. 81.

Fig. 83. Geological map of central Öland, compiled from the geological maps of the Swedish Geological Survey, SGU, Ser. Ac 6, 8. Legend: 1. Exposed bedrock. 2. Moraine—the right part of the legend—moraine with boulders. 3. Glaciofluvial deposits. 4. Washed moraine. 5. *Litorina* ridge. 6. *Ancylus* ridge. 7. Littoral deposits. 8. Scarp. 9. Fen.

SSE, and consequently morphological features which occur more or less perpendicular to this direction are important damming factors.

The fens on middle Öland have developed as two morphological main categories, namely those which occupy depressions in the bedrock surface or in the moraine cover, and those which are situated in basins between the island's dipping surface and the morphological units which are directed transversally to the main drainage direction.

In this paper two fens will be treated, Skede Mose and Gladvattnet (Mossberga Mose). Skede Mose is dammed by the *Ancylus* ridge and Gladvattnet occupies an accentuated depression in the bedrock surface, very near one of the highest elevated areas on Öland.

In addition to these two fens, material from sites near or below the *Ancylus* and *Litorina* ridges will be discussed according to their information as to the vegetational history of the islands. This material was

Fig. 84. Air photograph of the southernmost part of Skede Mose; the geological sampling points in the fen are marked. The longitudinal section and the three transversal sections have also been drawn in. Material was collected at more than 60 sampling points.

The pine plantation in the right part of the photograph, which is limited by straight lines, is situated on the top of the *Ancylus* ridge. Photograph by Rikets Allmänna Kartverk. Published by permission of the Swedish Defence Staff.

Fig. 85. Air photograph of the Skede Mose area from the north. The *Ancylus* ridge runs from the lower left hand corner into the centre of the picture. It can be traced even further in the tree-covered string. Skede Mose proper is the treeless area in the lower right hand part of the picture and behind the trees and bushes in the picture's middle part the southern extension of the fen is situated, where the archaeological excavations were carried out. Near the left hand margin of the picture are the houses of Övra Sandby village, which is situated on the *Litorina* ridge. Photograph by Ulf Erik Hagberg 1966. Published by permission of the Swedish Defence Staff.

previously treated from other points of view (Königsson, 1968) and will thus be rediscussed together with the whole new diagram material now available from the island.

SKEDE MOSE

The field investigations in Skede Mose were carried out at the request of the Central Office of National Antiquities in Stockholm and were run parallel with the archeological examination of the fen. Skede Mose is Sweden's richest finding place for votive deposits, and it has been excavated by Dr Ulf Erik Hagberg (Hagberg, 1967 *a*, 1967 *b*). The archæological investigations were concentrated in a southern extension of the main fen. The investigations of the Quaternary geology were also limited to this part of the basin, which has instead been studied in detail. Only

one profile has been measured and worked in the main fen.

The grid system established for the excavations was also utilized for the geological examination. Lengthwise across the fen along the base line ($\times = 300$) stratigraphical checks were made by digging at every tenth metre along a stretch of almost 1000 metres. Besides this longitudinal section three cross sections were also checked with the same distance between the diggings. The information was assembled in interpolated profile diagrams. The collected material as well as the position of the sections may be seen on Fig. 84.

Skede Mose was previously mentioned in geological literature by G. Lundqvist (1928, pp. 50–53, 81, 91–92, 101–105), who discussed the vegetational history and the shore ridge stratigraphy of Öland on the basis of pollen diagrams. He also gave a diagram-

Fig. 86. Air photograph of Skede Mose from the east. In the middle of the picture the *Ancylus* ridge runs, and behind the ridge the excavated parts of Skede Mose are situated. Photograph by Ulf Erik Hagberg 1966. Published by permission of the Swedish Defence Staff.

matical section through the *Ancylus* ridge and adjacent parts of the fen.

Skede Mose is dammed by a ridge east of the present fen (Fig. 85, Fig. 86). The ridge is a complex formation and the sections have shown how the *Ancylus* ridge rests upon an earlier existing ridge-formed unit, which was already in the pre-*Ancylus* time a damming factor in this basin (Appendix 1, section A). An outline of the early natural history of Skede Mose was published by the author and is referred to (Königsson, 1968).

In the basin west of the pre-*Ancylus* ridge possibilities existed for the development of peat-forming plant communities. These communities are represented in a fen peat/drift gyttja layer, which constitutes the lowest parts of the Skede Mose stratigraphy. The layer has two facies, one autochthonous and the other allochthonous. The former has very often tree

stumps *in situ* in it, and the latter is rather a drift gyttja, formed in the basin's wettest parts. The autochthonous facies has been found in the northern and eastern parts of the basin, the allochthonous in the middle of the basin and in its southern extension. The layer may also be missing.

Below the fen peat/drift gyttja layer moraine is usually found, in certain parts, however, underlying the fine silt.

Upon these layers sandy material follows. This part of the stratigraphy varies in thickness and has been interpreted as the distal part of the *Ancylus* ridge (Königsson, 1968, p. 16).

When the *Ancylus* transgression was ended a lake period started within the Skede Mose basin. Calcareous gyttjas were formed and with increasing plant growth around the lake and with varying climatical conditions the detritus content within the lime gytt-

Fig. 87. Longitudinal section 300 cut clean. The sequence, from the bottom upwards, is as follows: moraine, fen peat, silt layer, lime gyttja, detritus gyttja, peat and plough soil (*stratum confusum*). Between the lime gyttja and the gyttja a bed of gastropod shells is usually found. A very considerable proportion of the archaeological finds was in connection with this shell bed and in the lower part of the gyttja. Photograph by Ulf Erik Hagberg 1961.

jas shows several changes. When the former Skede Lake was filled up with sediments the reeds around the shores immigrated to new areas and narrowed the free water surface of the basin. Finally peat formation persisted over the whole area. Two examples of detailed profiles, measured in open shafts, are given in Appendix 1 (Sections B and D). In section D a crack system has been cut, which occupies most of the central part of the basin. The cracks are supposed to emanate from the draining of the fen for agricultural purposes. See also Fig. 86.

Between sections B and D there are methodically caused differences. Section B was measured every metre and interpolations between the measured profiles were made. Section D has been measured every 25 cm and those details in the stratigraphy which were observed between the measuring stations were also marked on the section, which should then be very complete.

On the air photograph (Fig. 84) the basin and the Ancyclus ridge is seen, the ridge has the geometrically delimited *Pine* plantations on it and runs along the right margin of the photograph. The situation should be compared with the air photographs, Fig.

85 and Fig. 86, where the topographical conditions are well demonstrated.

The detailed morphology is also shown in the map, Fig. 99, where 50 cm contours have been photogrammetrically measured and drawn. The longitudinal section $x=300$ and the cross section $y=505$ have been marked on the contour map. It is possible to see how the ridge extends in two rather well-defined strand spurs in the basin proper. In the field they are very pregnant too, and more details may be seen on Fig. 88. A cut through one of these ridges was investigated in the field and is given as section C, Appendix 1.

The working up of the material from Skede Mose comprises among other things an establishment of the vegetational landscape history of the fen and its surroundings and the question of when the free water surface did not exist any longer in the particular area where most of the votive deposits were made. This area corresponds rather well with the contour +16 of the contour map, where the sections cross over each other. These two aims of study of the Skede Mose material will be treated in this paper.

Fig. 88. The picture shows some smaller ridges identifiable in the eastern parts of the fen basin, whose origin is closely connected with the *Ancylus* transgression. August 1961.

Altogether 59 sampling places have been worked in the Skede Mose basin, in most cases for collecting material for pollen analysis as well as for macrodiaspore analysis. The most abundant material was collected in connection with the main excavation area, where open shafts could be studied. Along the southern edge of the so-called "field of gold", 8 series were collected in cross section $y=505$. Between the series five metres distance was chosen to enable a detailed investigation of the limno-thelmatic contact in this very area. The series were S 31–S 38.

In the excavation area the limno-thelmatic contact was generally destroyed by ploughing. However, in connection with find 270, a golden arm ring, Fig. 100, the contact was still undisturbed and S 22 was collected there.

The series S 50 and S 54 (Königsson, 1968, pp. 13–21) are situated in the northern part of the basin; S 19 within the main excavation area and S 11 in the southernmost part. S 59 has finally been collected

in Skede Mose proper some 1000 metres north of the air photographed area.

The Stratigraphy

Skede Mose S 11

1. Peat. *Nig.* 4, *strf.* 1, *elas.* 0, *sicc.* 2, *color* blackish-brown to black, *struc.* heterogeneous, *composition* Ga, Th, Dl, *humo.* 3, *lim.* 1, *Formula* Ga +, Th³ 3, Dl 1.
2. Sandy lime gyttja. *Nig.* 2, *strf.* 0, *elas.* 2–3, *sicc.* 2, *color* greyish-white, *struc.* homogeneous, *composition* Ga, Lc, *test.* (moll), *humo.* 0, *lim.* 2, *Formula* Ga 1, Lc 3, *test.* (moll) (+).
3. Sand. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 2, *color* yellowish-grey, *struc.* homogeneous, *composition* Ga, *humo.* 0, *lim.* 2, *Formula* Ga 4.
4. Sandy lime gyttja. As layer 2, *lim.* 2.
5. Sand. As layer 3, *lim.* 2.
6. Lake marl. *Nig.* 0–1, *strf.* 0–1, *elas.* 3, *sicc.* 2, *color* white to yellowish-white, *struc.* homogeneous, *composition* Lc, *humo.* 0, *lim.* 2, *Formula* Lc 4.
7. Sand. As layer 3, *lim.* 2.
8. Lime gyttja. *Nig.* 2, *strf.* 3, *elas.* 2, *sicc.* 2, *color* olive-grey, *struc.* homogeneous, *composition* Lc, Ld, *test.* (moll), *humo.* 1, *lim.* 1, *Formula* Lc 3, Ld¹ 1, *test.* (moll) +.

9. Lime gyttja. *Nig.* 2–3, *strf.* 1, *elas.* 2, *sicc.* 2, *color* olive-brown, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *humo.* 2, *lim.* 1, *Formula* *Lc* 1, *Ld*² 2, *Th*¹ 1.
10. Peaty gyttja. *Nig.* 3, *strf.* 1, *elas.* 2, *sicc.* 2, *color* brown, *struc.* heterogeneous, *composition* *Ld*, *Th*, *humo.* 2, *lim.* 1, *Formula* *Ld*² 2, *Th*² 2.
11. Peat with gyttja substance. *Nig.* 3, *strf.* 0, *elas.* 0, *sicc.* 2, *color* brown to dark brown, *struc.* heterogeneous, *composition*, *Ld*, *Th*, *humo.* 3, *lim.* 0, *Formula* *Ld*³ 1, *Th*³ 3.
12. *Stratum confusum* (Troels-Smith 1955, p. 71).

Skede Mose S 19

1. Moraine. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 3, *color* grey, *struc.* granular, heterogeneous, *composition* *Gg* (*maj*), *Gs*, *Ga*, *Ag*, *humo.* 0, *lim.* 1, *Formula* *Gg* (*maj*) 1, *Gs* +, *Ga* 2, *Ag* 1.
2. Peat. *Nig.* 4, *strf.* 0, *elas.* 0, *sicc.* 1–2, *color* dark brown to blackish-brown, *struc.* heterogeneous, *composition* *Ga*, *Ld*, *Th*, *DI*, *humo.* 3, *lim.* 1, *Formula* *Ga* 1, *Ld*³ (+), *Th*³ 3, *DI* (+).
3. Sand with gyttja substance. *Nig.* 1, *strf.* 1, *elas.* 0, *sicc.* 2, *color* grey, *struc.* homogeneous, *composition* *Ga*, *Ld*, *humo.* 1, *lim.* 1, *Formula* *Ga* 3, *Ld*¹ 1.
4. Sand. *Nig.* 0–1, *strf.* 0, *elas.* 0, *sicc.* 2, *color* greyish-white, *struc.* homogeneous, *composition* *Ga*, *humo.* 0, *lim.* 1, *Formula* *Ga* 4.
5. Sand with lime gyttja substance. *Nig.* 0–1, *strf.* 1, *elas.* 0, *sicc.* 2, *color* white, *struc.* homogeneous, *composition* *Ga*, *Lc*, *humo.* 0, *lim.* 1, *Formula* *Ga* 3, *Lc* 1.
6. Sandy lime gyttja. *Nig.* 0–1, *strf.* 1, *elas.* 2–3, *sicc.* 2, *color* grey-white, *struc.* heterogeneous, *composition* *Ga*, *Lc*, *Ld*, *test.* (*moll*), *humo.* 1, *lim.* 0, *Formula* *Ga* 1, *Lc* 2, *Ld*¹ 1, *test.* (*moll*) (+).
7. Lime gyttja. *Nig.* 1, *strf.* 1, *elas.* 3, *sicc.* 2, *color* olive-grey, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *test.* (*moll*), *humo.* 1, *lim.* 1, *Formula* *Lc* 3, *Ld*¹ 1, *test.* (*moll*) +.
8. Detritus gyttja with lime gyttja substance. *Nig.* 2–3, *strf.* 1–2, *elas.* 3, *sicc.* 2, *color* olive-brown, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *test.* (*moll*), *humo.* 1, *lim.* 2, *Formula* *Lc* 1, *Ld*³ 3, *Th*¹ (+), *test.* (*moll*) (+).
9. Shell containing detritus gyttja with lime gyttja substance. *Nig.* 1–2, *strf.* 0, *elas.* 0, *sicc.* 2–3, *color* basic substance brown, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *test.* (*moll*), *part.test.* (*moll*), *humo.* 1, *lim.* 2, *Formula* *Lc* 1, *Ld*¹ 2, *Th*¹ (+), *test.* (*moll*) ++, *part.test.* (*moll*) ++.
10. Detritus gyttja with lime gyttja substance. *Nig.* 2, *strf.* 1, *elas.* 2, *sicc.* 2, *color* dark olive-brown, *struc.* homogeneous, *composition* *Lc*, *Ld*, *test.* (*moll*), *humo.* 2, *lim.* 1, *Formula* *Lc* 2, *Ld*² 2, *test.* (*moll*) +.
11. Sandy detritus gyttja. *Nig.* 3, *strf.* 1, *elas.* 1, *sicc.* 2–3, *color* dark brown, *struc.* heterogeneous, *composition* *Ld*, *Th*, *Ga*, *humo.* 3, *lim.* 1, *Formula* *Ga* 1, *Ld*³ 3, *Th*³ (+).
12. Peat with gyttja substance. *Nig.* 3–4, *strf.* 0, *elas.* 1, *sicc.* 2–3, *color* blackish-brown, *struc.* heterogeneous, *composition* *Ld*, *Th*, *humo.* 3, *lim.* 0, *Formula* *Ld*³ 1, *Th*³ 3.
13. Peat. *Nig.* 4, *strf.* 0, *elas.* 0, *sicc.* 3, *color* black, *struc.* homogeneous, *composition* *Th*, *humo.* 4, *lim.* 0, *Formula* *Th*⁴ 4.
14. *Stratum confusum*.

Skede Mose S 22

1. Peaty gyttja. *Nig.* 2–3, *strf.* 2, *elas.* 3, *sicc.* 2, *color* olive-brown, *struc.* heterogeneous, *composition* *Ld*, *Th*, *part.test.* (*moll*), *humo.* 1, *lim.* 0, *Formula* *Ld*¹ 3, *Th*¹ 1, *part.test.* (*moll*) (+).
2. Peat. *Nig.* 2–3, *strf.* 0, *elas.* 3, *sicc.* 4 (when the sample collection and soil description were made, the spot had be-

come completely dried out through the excavation nearby), *color* brown, *struc.* homogeneous, *composition* *Th*, *Ld*, *humo.* 1, *lim.* 0, *Formula* *Th*¹ 4, *Ld*¹ +.

3. *Substantia humosa*.

Skede Mose S 31

1. Lime gyttja with gyttja substance. *Nig.* 1, *strf.* 2, *elas.* 2, *sicc.* 2, *color* olive-grey, *struc.* homogeneous, *composition* *Lc*, *Ld*, *test.* (*moll*), *humo.* 1, *lim.* 1, *Formula* *Lc* 2, *Ld*¹ 2, *test.* (*moll*) (+).
2. Gyttja with lime gyttja substance. *Nig.* 2, *strf.* 2, *elas.* 2–3, *sicc.* 2, *color* olive-brown, *struc.* homogeneous, *composition* *Lc*, *Ld*, *test.* (*moll*), *humo.* 1, *lim.* 1, *Formula* *Lc* 1, *Ld*¹ 3, *test.* (*moll*) +.
3. Gyttja. *Nig.* 2, *strf.* 2, *elas.* 2, *sicc.* 2, *color* brown, *struc.* homogeneous, *composition* *Lc*, *Ld*, *part.test.* (*moll*), *humo.* 1, *lim.* 0, *Formula* *Lc* (+), *Ld*¹ 3, *Th*¹ 1.
4. Peaty gyttja. *Nig.* 3, *strf.* 0, *elas.* 2, *sicc.* 2, *color* dark brown, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *humo.* 1, *lim.* 0, *Formula* *Lc* (+), *Ld*¹ 3, *Th*¹ 1.
5. Peat. *Nig.* 3, *strf.* 0, *elas.* 0, *sicc.* 3, *color* dark brown, *struc.* homogeneous, *composition* *Ld*, *Th*, *humo.* 2, *lim.* 0, *Formula* *Ld*² (+), *Th*² 4.
6. *Stratum confusum*.

Skede Mose S 32

1. Sandy lime gyttja. *Nig.* 1, *strf.* 0, *elas.* 1, *sicc.* 2, *color* greyish-white, *struc.* heterogeneous, *composition* *Ga*, *Lc*, *humo.* 0, *lim.* 0, *Formula* *Ga* 1, *Lc* 3.
2. Lime gyttja with gyttja substance. *Nig.* 1, *strf.* 1, *elas.* 2, *sicc.* 2, *color* olive greenish-grey, *struc.* homogeneous, *composition* *Lc*, *Ld*, *test.* (*moll*), *humo.* 1, *lim.* 0, *Formula* *Lc* 3, *Ld*¹ 1, *test.* (*moll*) +.
3. Lime gyttja with gyttja substance. *Nig.* 1, *strf.* 3, *elas.* 2, *sicc.* 2, *color* olive-green, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *Th*, *test.* (*moll*), *humo.* 1, *lim.* 1, *Formula* *Lc* 2, *Ld*¹ 2, *test.* (*moll*) (+).
4. Lime gyttja with gyttja substance. *Nig.* 0–1, *strf.* 0, *elas.* 2, *sicc.* 2, *color* yellowish-white grey, *struc.* homogeneous, *composition* *Lc*, *Ld*, *humo.* 1, *lim.* 2, *Formula* *Lc* 3, *Ld*¹ 1.
5. Shell layer with gyttja substance. *Nig.* 0–1, *strf.* 0, *elas.* 0, *sicc.* 3, *color* white, gyttja component grey, *struc.* heterogeneous, *composition* *Ld*, *test.* (*moll*), *part.test.* (*moll*), *humo.* 1, *lim.* 2, *Formula* *Ld*¹ 1, *test.* (*moll*) 1, *part.test.* (*moll*) 2.
6. Gyttja with lime gyttja substance. *Nig.* 2, *strf.* 0, *elas.* 2, *sicc.* 2, *color* olive-brown, *struc.* homogeneous, *composition* *Lc*, *Ld*, *part.test.* (*moll*), *humo.* 1, *lim.* 1, *Formula* *Lc* 2, *Ld*¹ 2, *part.test.* (*moll*) +.
7. Gyttja with lime gyttja substance. *Nig.* 3, *strf.* 0, *elas.* 2, *sicc.* 2, *color* olive-brown, *struc.* homogeneous, *composition* *Lc*, *Ld*, *Th*, *humo.* 1, *lim.* 1, *Formula* *Lc* 1, *Ld*¹ 3, *Th*¹ (+).
8. Gyttja. *Nig.* 3, *strf.* 0, *elas.* 3, *sicc.* 2, *color* brown, *struc.* homogeneous, *composition* *Ld*, *Th*, *humo.* 1, *lim.* 1, *Formula* *Ld*¹ 4, *Th*¹ (+).
9. Peaty gyttja. *Nig.* 3, *strf.* 0, *elas.* 2, *sicc.* 2, *color* brown, *struc.* heterogeneous, *composition* *Ld*, *Th*, *humo.* 1, *lim.* 1, *Formula* *Ld*¹ 2, *Th*¹ 2.
10. Peat. *Nig.* 3, *strf.* 0, *elas.* 0, *sicc.* 3, *color* dark brown, *struc.* heterogeneous, *composition* *Ld*, *Th*, *humo.* 2, *lim.* 0, *Formula* *Ld*² (+), *Th*² 4.
11. *Stratum confusum*.

Skede Mose S 33

1. Gyttja with lime gyttja substance. *Nig.* 1–2, *strf.* 1, *elas.* 2, *sicc.* 2, *color* olive-grey, *struc.* homogeneous, *composition*

- Lc, Ld, test. (moll), humo. 1, lim. 1, Formula Lc 2, Ld¹ 2, test. (moll) (+).
2. Gyttja with lime gyttja substance. Nig. 2, strf. 1, elas. 2, sicc. 2, color olive-brown, struc. homogeneous, composition Lc, Ld, test. (moll), humo. 1, lim. 1, Formula Lc 1, Ld¹ 3, test. (moll) (+).
43. Gytja. Nig. 3, strf. 0, elas. 3, sicc. 2, color brown, struc. homogeneous, composition Lc, Ld, Th, humo. 1, lim. 0, Formula Lc (+), Ld¹ 4, Th¹ (+).
4. Peaty gyttja. Nig. 3, strf. 0, elas. 2, sicc. 2, color brown, struc. heterogeneous, composition Lc, Ld, Th, humo. 1, lim. 0, Formula Lc (+), Ld¹ 3, Th¹ 1.
5. Peat. Nig. 3, strf. 0, elas. 2, sicc. 3, color brown, struc. heterogeneous, composition Ld, Lt, humo. 2, lim. 0, Formula Ld² (+), Th² 4.
6. *Stratum confusum*.

Skede mose S 34

1. Lime gyttja with gyttja substance. Nig. 1, strf. 2, elas. 2, sicc. 2, color grey, struc. homogeneous, composition Lc, Ld, test. (moll), humo. 1, lim. 2, Formula Lc 3, Ld¹ 1, test. (moll) (+).
2. Shell layer with gyttja substance. Nig. 0-1, strf. 0, elas. 0, sicc. 3, color white, gyttja component brownish-grey, struc. heterogeneous, composition Ld, test. (moll), part.test. (moll), humo. 1, lim. 2, Formula Ld¹ 1, test. (moll) 2, part.test. (moll) 1.
3. Gytja with lime gyttja content. Nig. 3, strf. 2, elas. 3, sicc. 2, color olive-brown, struc. homogeneous, composition Lc, Ld, part.test. (moll), humo. 1, lim. 0, Formula Lc 1, Ld¹ 3, part.test. (moll) (+).
4. Peaty gyttja with lime gyttja content. Nig. 3, strf. 0, elas. 2, sicc. 2, color brown, struc. heterogeneous, composition Lc, Ld, Th, humo. 1, lim. 0, Formula Lc 1, Ld¹ 2, Th¹ 1.
5. Peat. Nig. 4, strf. 0, elas. 0, sicc. 3, color blackish-brown, struc. heterogeneous, composition Ld, Th, humo. 4, lim. 0, Formula Ld¹ (+), Th¹ 4.
6. *Stratum confusum*.

Skede Mose S 35

1. Lime gyttja with gyttja substance. Nig. 1, strf. 0, elas. 2, sicc. 2, color greyish-white, struc. homogeneous, composition Lc, Ld, test. (moll), humo. 1, lim. 2, Formula Lc 3, Ld¹ 1, test. (moll) (+).
2. Shell layer with gyttja substance. Nig. 0-1, strf. 0, elas. 0, sicc. 3, color white, gyttja component olive-brown, struc. heterogeneous, composition Ld, part.test. (moll), test. (moll), humo. 1, lim. 2, Formula Ld¹ 1, test. (moll) 2, part.test. (moll) 1.
3. Lime gyttja with gyttja substance. Nig. 2, strf. 2, elas. 2, sicc. 2, color olive-grey, struc. homogeneous, composition Lc, Ld, part.test. (moll), humo. 1, lim. 1, Formula Lc 2, Ld¹ 2, part.test. (moll) (+).
4. Gytja with lime gyttja substance. Nig. 2, strf. 2, elas. 2, sicc. 2, color olive-brown, struc. homogeneous, composition Lc, Ld, Th, test. (moll), part.test. (moll), humo. 1, lim. 1, Formula Lc 1, Ld¹ 3, Th¹ (+), test. (moll) (+) part.test. (moll) (+).
5. Peaty gyttja. Nig. 3, strf. 0, elas. 2, sicc. 2-3, color brown, struc. heterogeneous, composition Ld, Th, humo. 2, lim. 0, Formula Ld² 3, Th² 1.
6. Peat. Nig. 4, strf. 0, elas. 0, sicc. 3, color blackish-brown, struc. homogeneous, composition Ld, Th, humo. 4, lim. 0, Formula Ld¹ (+), Th¹ 4.
7. *Stratum confusum*.

Skede Mose S 36

1. Lime gyttja with gyttja substance. Nig. 2, strf. 2, elas. 2, sicc. 2, color greenish-grey, struc. homogeneous, composition Lc, Ld, test. (moll), part.test. (moll), humo. 1, lim. 1, Formula Lc 3, Ld¹ 1, test. (moll) (+), part.test. (moll) (+).
2. Lime gyttja with gyttja substance. Nig. 2, strf. 2, elas. 2, sicc. 2, color olive-grey, struc. homogeneous, composition Lc, Ld, test. (moll), part.test. (moll), humo. 1, lim. 1, Formula Lc 2, Ld¹ 2, test. (moll) (+), part.test. (moll) (+).
3. Gytja. Nig. 3, strf. 2, elas. 3, sicc. 2, color olive-brown, struc. homogeneous, composition Lc, Ld, humo. 1, lim. 1, Formula Lc (+), Ld¹ 4.
4. Peaty gyttja. Nig. 3, strf. 0, elas. 1, sicc. 2, color brown, struc. heterogeneous, composition Lc, Ld, Th, humo. 1, lim. 1, Formula Lc (+), Ld¹ 2, Th¹ 2.
5. Peat. Nig. 3, strf. 0, elas. 1, sicc. 3, color brown, struc. heterogeneous, composition Ld, Th, humo. 2, lim. 0, Formula Lc² (+), Th² 4.
6. *Stratum confusum*.

Skede Mose S 37

1. Lime gyttja with gyttja substance. Nig. 2, strf. 2, elas. 2, sicc. 2, color olive-green, struc. homogeneous, composition Lc, Ld, test. (moll), humo. 1, lim. 1, Formula Lc 2, Ld¹ 2, test. (moll) (+).
2. Gytja with lime gyttja substance. Nig. 2, strf. 2, elas. 3, sicc. 2, color olive-brown, struc. homogeneous, composition Lc, Ld, test. (moll), humo. 1, lim. 1, Formula Lc 1, Ld¹ 3, test. (moll) (+).
3. Gytja. Nig. 3, strf. 1, elas. 3, sicc. 2, color brown, struc. homogeneous, composition Lc, Ld, Th, part.test. (moll), humo. 1, lim. 0, Formula Lc (+), Ld¹ 4, Th¹ (+), part.test. (moll) (+).
4. Peat. Nig. 3, strf. 0, elas. 1, sicc. 3, color dark brown, struc. heterogeneous, composition Ld, Th, humo. 2, lim. 0, Formula Ld² (+), Th² 4.
5. *Stratum confusum*.

Skede Mose S 38

1. Gytja. Nig. 3, strf. 1, elas. 3, sicc. 2, color brown, struc. homogeneous, composition Lc, Ld, Th, part.test. (moll), humo. 1, lim. 0, Formula Lc (+), Ld¹ 4, Th¹ (+), part.test. (moll) (+).
2. Peaty gyttja. Nig. 3, strf. 0, elas. 1, sicc. 2, color brown, struc. heterogeneous, composition Lc, Ld, Th, humo. 2, lim. 1, Formula Lc (+), Ld² 3, Th² 1.
3. Peat. Nig. 3, strf. 0, elas. 1, sicc. 3, color brown, struc. heterogeneous, composition Ld, Th, humo. 2, lim. 0, Formula Ld² (+), Th² 4.
4. *Stratum confusum*.

Skede Mose S 50

The diagram from Skede Mose S 50 was published in Königsson 1958 a (p. 15). As it is republished here to be discussed from other points of view, I have considered it necessary to describe the soils again. This is also true of the diagrams Skede Mose S 54, Melösa MÖ 1, Övra Sandby ÖS 1, Norra Kvinneby NK 1, Hulterstad (Triberga Bro) TB 1 and TB 3.

1. Moraine. Nig. 1, strf. 0, elas. 0, sicc. 3, color grey, struc. granular, heterogeneous, composition Gg (maj), Gs, Ga, Ag, humo. 0, lim. 1, Formula Gg (maj) 1, Ga 2, Gs +, Ag 1.
2. Sand. Nig. 1, strf. 0, elas. 0, sicc. 3, color grey, sometimes white, composition Ga, humo. 0, lim. 1, Formula Ga 4.
3. Peat. Nig. 4, strf. 0, elas. 0, sicc. 2, color black to blackish-

- brown, *struc.* heterogeneous, *composition* *Th*, *Tl*, *humo.* 2, *lim.* 1, *Formula* *Th*² 3, *Tl*² 1.
4. Sandy lime gyttja with gyttja substance. *Nig.* 2, *strf.* 0, *elas.* 1, *color* grey, *struc.* heterogeneous, *composition* *Ga*, *Lc*, *Ld*, *Th*, *humo.* 1, *lim.* 2, *Formula* *Ga* 1, *Lc* 2, *Ld*¹ 1, *Th*¹ +.
5. Sand As layer 2, *lim.* 2.
6. Sandy gyttja with gyttja substance. As layer 4, *lim.* 2.
7. Sand. As layer 2, *lim.* 2.
8. Sandy lime gyttja with gyttja substance. As layer 4, *lim.* 2.
9. Sand. As layer 2, *lim.* 2.
10. Sandy lime gyttja with gyttja substance. As layer 4, *lim.* 2.
11. Sand. As layer 2, *lim.* 2.
12. Sandy lime gyttja with gyttja substance. As layer 4, *lim.* 2.
13. Sand. As layer 2, *lim.* 2.
14. Gyttja with lime gyttja substance. *Nig.* 3, *strf.* 2, *elas.* 3, *sicc.* 2, *color* olive-brown, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *test.* (moll), *humo.* 1, *lim.* 1, *Formula* *Lc* 1, *Ld*¹ 3, *Th*¹ +, *test.* (moll) (+).
15. Peaty gyttja. *Nig.* 3, *strf.* 2, *elas.* 3, *sicc.* 2, *color* brown, *struc.* heterogeneous, *composition* *Ld*, *Th*, *test.* (moll), *humo.* 3, *lim.* 1, *Formula* *Ld*³ 3, *Th*³ 1, *test.* (moll) +.
16. Gyttja. *Nig.* 3, *strf.* 2, *elas.* 3, *sicc.* 2, *color* dark olive-brown, *struc.* heterogeneous, *composition* *Lc*, *Ld*, *part.* *test.* (moll), *humo.* 3, *lim.* 1, *Formula* *Lc* (+), *Ld*³ 4, *part.* *test.* (moll) (+).
17. Peaty gyttja. *Nig.* 3–4, *strf.* 2, *elas.* 3, *sicc.* 2, *color* dark olive-brown, *struc.* heterogeneous, *composition* *Ld*, *Th*, *humo.* 3, *lim.* 1, *Formula* *Ld*³ 3, *Th*³ 1.
18. Peaty gyttja. *Nig.* 3–4, *strf.* 1, *elas.* 1, *sicc.* 2, *color* dark brown to black, *struc.* heterogeneous, *composition* *Ld*, *Th*, *humo.* 3, *lim.* 1, *Formula* *Ld*³ 2, *Th*³ 2.
19. Peat. *Nig.* 4, *strf.* 0, *elas.* 0, *sicc.* 2, *color* black, *struc.* heterogeneous, *composition* *Th*, *humo.* 4, *lim.* 0, *Formula* *Th*⁴ 4.
20. *Stratum confusum*.

Skede Mose S 54

1. Moraine. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 3, *color* grey, *struc.* granular, heterogeneous, *composition* *Gg* (maj), *Gs*, *Ga*, *Ag*, *humo.* 0, *lim.* 0–1, *Formula* *Gg* (maj) 1, *Gs* +, *Ga* 1, *Ag* 2.
2. Peat. *Nig.* 4, *strf.* 0, *elas.* 0, *sicc.* 2, *color* black to blackish-brown, *struc.* heterogeneous, *composition* *Th*², *Tl*, *humo.* 2, *lim.* 1, *Formula* *Th*² 3, *Tl* 1.
3. Sandy gyttja with lime gyttja substance. *Nig.* 1–2, *strf.* 0, *elas.* 1, *sicc.* 2, *color* grey to olive-grey, *struc.* heterogeneous, *composition* *Ga*, *Lc*, *Ld*, *Th*, *humo.* 2, *lim.* 1, *Formula* *Ga* 1, *Lc* 1, *Ld*² 2, *Th*² +.
4. Sand. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 2, *color* white grey, *struc.* granular, heterogeneous, *composition* *Gs*, *Ga*, *humo.* 0, *Formula* *Ga* 2, *Ga* 2.

Skede Mose S 59

1. Gyttja. *Nig.* 3, *strf.* 1, *elas.* 3, *sicc.* 2, *color* olive-brown, *struc.* homogeneous, *composition* *Lc*, *Ld*, *humo.* 1, *lim.* 1, *Formula* *Lc* (+), *Ld*¹ 4.
2. Peaty gyttja. *Nig.* 3, *strf.* 0, *elas.* 2, *sicc.* 2, *color* olive-brown, *struc.* heterogeneous, *composition* *Ld*, *Th*, *humo.* 2, *lim.* 1, *Formula* *Ld*² 2, *Th*² 2.
3. Peat with gyttja substance. *Nig.* 3, *strf.* 0, *elas.* 1, *sicc.* 2, *color* brown, *struc.* heterogeneous, *composition* *Ld*, *Th*, *humo.* 3, *lim.* 1, *Formula* *Ld*³ 1, *Th*³ 3.
4. Peat. *Nig.* 4, *strf.* 0, *elas.* 0, *color* blackish-brown, *struc.* heterogeneous, *composition* *Ld*, *Th*, *humo.* 4, *lim.* 0, *Formula* *Ld*⁴ +, *Th*⁴ 4.
5. *Stratum confusum*.

MELÖSA

The pollen diagram from Melösa was first published in Königsson 1968 (p. 28). It has been analysed on material from a beach-covered gyttja/peat sequence below the present Litorina ridge. The sequence was formed in a basin, which was dammed by some morphological unit east of the finding place. This unit has now disappeared or has been covered by the proximal parts of the Litorina ridge.

The Stratigraphy

Melösa MÖ 1

1. Sand. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 1–2, *color* bluish-white, *struc.* granular, homogeneous, *composition* *Ga*, *humo.* 0, *lim.* 1, *Formula* *Ga* 4.
2. Sandy gyttja. *Nig.* 3, *strf.* 0, *elas.* 1, *sicc.* 1–2, *color* dark brown, *struc.* heterogeneous, *composition* *Ga*, *Ld*, *humo.* 3, *Formula* *Ga* 1, *Ld*³ 3.
3. Peat. *Nig.* 3, *strf.* 0, *elas.* 2–3, *sicc.* 3, *color* brown, *struc.* heterogeneous, *composition* *Th*, *humo.* 2, *lim.* 1, *Formula* *Th*² 4.
4. Gravelly sand. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 3–4, *color* white to yellowish-grey, *struc.* heterogeneous, granular, *composition* *Gg* (maj), *Gg* (min), *Gs*, *Ga*, *test.* (moll), *humo.* 0, *Formula* *Gg* (maj) 1/2, *Gg* (min) 1/2, *Gs* 2, *Ga* 1, *test.* (moll) +.

ÖVRA SANDBY

The morphological conditions are very similar to the ones described from Melösa. It was published in Königsson 1968 (p. 28).

The Stratigraphy

Övra Sandby ÖS 1

1. Sand. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 2–3, *color* yellowish-grey, *struc.* granular, heterogeneous, *composition* *Gs*, *Ga*, *humo.* 0, *lim.* 0–1, *Formula* *Gs* 2, *Ga* 2.
2. Sandy gyttja. *Nig.* 3–4, *strf.* 0, *elas.* 0, *sicc.* 2, *color* brown, *struc.* heterogeneous, *composition* *Gs*, *Ga*, *Ld*, *humo.* 4, *lim.* 1, *Formula* *Ld*⁴ 3, *Gs* 1/2, *Ga* 1/2.
3. Peat with gyttja substance. *Nig.* 4, *strf.* 0, *elas.* 0, *sicc.* 3, *color* very dark brown, *struc.* heterogeneous, *composition* *Ga*, *Ld*, *Th*, *humo.* 3, *lim.* 1, *Formula* *Ga* +, *Ld*³ 1, *Th*³ 3.
4. Peat. *Nig.* 3, *strf.* 0, *elas.* 0, *sicc.* 3, *color* very dark brown, *struc.* heterogeneous, *composition* *Th*, *humo.* 2, *lim.* 1, *Formula* *Th*² 4.
5. Peat with gyttja substance. *Nig.* 3, *strf.* 0, *elas.* 0, *sicc.* 3, *color* very dark brown, *struc.* heterogeneous, *composition* *Ga*, *Ld*, *Th*, *humo.* 3, *lim.* 1, *Formula* *Ga* +, *Ld*³ 1, *Th*³ 3.
6. Gravelly sand. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 3–4, *color* white to white-grey, *struc.* heterogeneous, *composition* *Gg* (maj), *Gg* (min), *Gs*, *Ga*, *test.* (moll), *humo.* 0, *Formula* *Gg* (maj) 1/2, *Gg* (min) 1/2, *Gs* 2, *Ga* 1, *test.* (moll) +.

SILVERBÄCKEN

Silverbäcken belongs to a material collected from the beach ridge systems on eastern Öland, which has not yet been fully completed in the field and which

deals with the time-table for various transgressive periods of the Baltic. The sampling spot is situated in a cut through the distal parts of a beach ridge east of Gärdslösa church (Fig. 83). The cut was made by a little stream which according to tradition is said to be identical with *Silverbäcken* (the Silver Stream) in a famous poem "the Neckan" by Sweden's greatest poet from the romantic period, Erik Johan Stagnelius, a native of the island.

The Stratigraphy

Silverbäcken SB 1

1. Gravelly silt. *Nig.* 2, *strf.* 0, *elas.* 0, *sicc.* 2, *color* brownish-grey, *struc.* heterogeneous, *composition* Gg (maj), Ga, Ag, *humo.* 0, *lim.* 1, *Formula* Gg (maj) 1, Ga 2, Ag 1.
2. Silt. *Nig.* 1, *strf.* 0, *elas.* 1, *sicc.* 2, *color* grey, *struc.* homogeneous, *composition* Ag, *humo.* 0, *lim.* 1, *Formula* Ag 4.
3. Peat. *Nig.* 4, *strf.* 0, *elas.* 2, *sicc.* 2, *color* blackish-brown, *struc.* homogeneous, *composition* Th, *humo.* 4, *lim.* 2, *Formula* Th⁴ 4.
4. Sand. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 2, *color* yellowish-grey, *struc.* homogeneous, *composition* Gs, *humo.* 0, *lim.* 2, *Formula* Gs 4.
5. Gytja. *Nig.* 3, *strf.* 0, *elas.* 2, *sicc.* 2, *color* olive-brown, *struc.* homogeneous, *composition* Ga, Ld, Th, *humo.* 2, *lim.* 2, *Formula* Ga (+), Ld² 4, Th² (+).
6. Sand. As layer 4, *lim.* 2.
7. Gytja. As layer 5, *lim.* 1.
8. Silt. *Nig.* 1, *strf.* 0, *elas.* 2, *sicc.* 2, *color* olive-grey, *struc.* heterogeneous, *composition* Ag, Ld, Th, *humo.* 3, *lim.* 1, *Formula* Ag 4, Ld³ (+), Th³ (+).
9. Sand. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 2, *color* whitish-grey, *struc.* homogeneous, *composition* Ga, *humo.* 0, *lim.* 0, *Formula* Ga 4.
10. Sand. As layer 4, *lim.* 1.
11. Peaty gyttja. *Nig.* 3–4, *strf.* 0, *elas.* 2, *sicc.* 2, *color* brown, *struc.* heterogeneous, *composition* Gs, Ga, Ld, Th, *humo.* 2, *Formula* Gs (+), Ga (+), Ld³ 3, Th³ 1.

GLADVATTNET

Gladvattnet or Mossberga Mose (*sensu* G. Lundqvist) was described by Hemmendorff 1897 (pp. 45–47) and by G. Lundqvist 1928 (pp. 46–48). Lundqvist's pollen diagram is his most complete section through the Late Pleistocene and Holocene vegetational development on Öland, and as the lake Gladvattnet could be expected to provide a still better material than that of Lundqvist, which was collected in the surrounding fen area of the Gladvattnet basin, this locality was chosen for a comparative investigation.

The investigations were carried out in the field with Livingstone sampler from ice in March 1963, when profiles were cored and three complete soil pillars were collected. When the analysis work started the age of the bottom samples was discovered to be of late Atlantic time in all three cores, and the desired older sediments were entirely missing.

The analysis work was then discontinued and future investigations are needed to elucidate the causes of the unexpected and very extensive *hiatus* in Gladvattnet.

However, there was still a need for a comparative investigation at this locality, and I have therefore reanalysed Lundqvist's original material from Gladvattnet. The material was archived in the peat archives of the Geological Survey of Sweden (SGU), and it was kindly put at the author's disposal.

Besides the establishing of a modern pollen diagram on this important site, a reanalysing of the original material has an additional value, namely that it provides a possibility of direct comparison between the results of a pollen analytical investigation during the twenties with the results of a corresponding investigation to-day. This may offer methodical advantages as to the interpretation of samples exclusively prepared with KOH-treatment when compared with acaetolysed and, if minerogene, HF-treated material.

The soil descriptions of G. Lundqvist are repeated. They should be compared with the renewed descriptions, which, however, have been carried out on dried samples, which is very disadvantageous as no other soil-descriptive criterions than *composition* and *humo.* are possible to state. The micropaleontological facts obtained at the analysis work are included.

G. Lundqvist's descriptions (From the top downwards)

- A. 32 cm. *Sphagnum*-humus with hyfes. Pollen content very badly preserved.
- B. 10 cm. Forest humus. Pollen content badly preserved, but still possible to analyse.
- C. 28 cm. Peat from fen with leaf trees, downwards with increasing dy-content. *Carex*-radicells, *Bryophyta*.
- D. 110 cm. Fen peat, H. 7 (von Post's "squeezing methods" 1924, p. 291, H. 7 corresponds to Troels-Smith's *humo.* 3, 1955, p. 57). Coarse detritus as radicells from *Carex* and *Phragmites*, rhizom from *Cladium*. Downwards the gyttja content increases and there one may find mollusc shells, *Pediastrum*, *Desmidiaceae* among other things.
- E. 80 cm. Lime gyttja with layers of gyttja within it. Fine detritus constitutes the bulk of the material. *Myxophyceae* is present in the upper part of the layer only.
- F. 10 cm. Gytja of fine detritus gyttja type. Contains minerogene material. Transits downwards into layer G.

G. 10 cm. Clay gyttja with among other things the diatoms *Epithemia argus* and *Melosira arenaria*.

H. 40 cm. Clay, grey.

The Stratigraphy

Gladvattnet GV 1

1. Gravelly sand (known from my own investigations), *Composition* Gg (maj), Gg (min), Gs, Ga, humo. 0, *Formula* Gg (maj), 1, Gg (min) 1, Gs 1, Ga 1. (The Formula is estimated.)
2. Clay. *Composition* As, Ag, humo. 0, *Formula* As 2, Ag 2.
3. Clay gyttja. *Composition* Ld, Ag, humo. 2, *Formula* Ag 3, Ld² 1.
4. Sandy gyttja with lime gyttja substance. *Composition* Ga, Lc, Ld, humo. 2, *Formula* Ga 1, Lc 1, Ld² 2.
5. Lime gyttja with gyttja substance. *Composition* Lc, Ld, humo. 1, *Formula* Lc 3, Ld¹ 1.
6. Gyttja with lime gyttja substance. *Composition* Lc, Ld, humo. 1, *Formula* Lc 1, Ld¹ 3.
7. Gyttja with lime gyttja substance. *Composition* Lc, Ld, humo. 1, *Formula* Lc 2, Ld¹ 2.
8. Peaty gyttja. *Composition* Lc, Ld, Th, humo. 2, *Formula* Lc (+), Ld² 2, Th² 2.
9. Peat. *Composition* Th, humo. 2, *Formula* Th² 4.
10. Peat with wood pieces. *Composition* Th, Dl, humo. 3, *Formula* Th³ 2, Dl 2.
11. Peat. *Composition* Th, humo. 4, *Formula* Th⁴ 4.
12. Peat with wood fragments. *Composition* Th, Dl, humo. 3, *Formula* Th³ 3, Dl 1.

NORRA KVINNEBY

This locality has the same morphological conditions as Melösa and Övra Sandby. However, the peat and gyttja sequence is preserved below the Ancyclus ridge in this case.

The Stratigraphy

Norra Kvinneby NK 1

1. Gravelly silt. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 1, *color* blue-grey, *struc.* granular, heterogeneous, *composition* Gg (min), Ga, Ag, humo. 0, *lim.* 0–1, *Formula* Gg (min) 1, Ga 1, Ag 2.
2. Gravelly, sandy gyttja. *Nig.* 3, *strf.* 0, *elas.* 0, *sicc.* 2, *color* brownish-grey, *struc.* granular, heterogeneous, *composition* Gg (min), Ga, Ag, Ld, humo. 4, *lim.* 1, *Formula* Gg (min) 1, Ga +, Ag 1, Ld⁴ 2.
3. Peat. *Nig.* 4, *strf.* 0, *elas.* 0, *sicc.* 2, *color* black, *struc.* homogeneous, *composition* Ga, Th, humo. 4, *lim.* 1, *Formula* Ga 1/2, Th⁴ 3 1/2.
4. Sandy peat with gyttja substance. *Nig.* 3, *strf.* 0, *elas.* 0, *sicc.* 2, *color* dark brown, *struc.* heterogeneous, *composition* Ga, Ld, Th, humo. 2, *lim.* 1, *Formula* Ga 1, Ld² 1, Th² 2.
5. Sandy gyttja. *Nig.* 2, *strf.* 0, *elas.* 0, *sicc.* 2, *color* grey, *struc.* heterogeneous, granular, *composition* Ga, Ld, humo. 2, *Formula* Ga 2, Ld² 2.
6. Sandy lime gyttja with gyttja substance. *Nig.* 2, *strf.* 0, *elas.* 1, *sicc.* 2, *color* grey, *struc.* heterogeneous, partly granular, *composition* Ga, Lc, Ld, humo. 2, *lim.* 1, *Formula* Ga 1, Lc 2, Ld² 1.
7. Sand with lime gyttja substance. *Nig.* 1, *strf.* 0, *elas.* 0,

sicc. 3, *color* white to grey, *struc.* granular, heterogeneous, *composition* Ag, Lc, humo. 0, *lim.* 0–1, *Formula* Ag 3, Lc 1.

8. Gravelly sand. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 3–4, *color* white to yellowish-grey, *struc.* heterogeneous, granular, *composition* Gg (maj), Gg (min), Gs, Ga, humo. 0, *Formula* Gg (maj) 1/2, Gg (min) 1/2, Gs 2, Ga 1.

HULTERSTAD (TRIBERGA BRO)

The morphological conditions of the deposits at Triberga Bro are similar to those at Norra Kvinneby.

The Stratigraphy

Hulterstad (Triberga Bro) TB 1

1. Washed moraine. *Nig.* 2, *strf.* 0, *elas.* 0, *sicc.* 2, *color* yellowish to reddish-grey, *struc.* granular, heterogeneous, *composition* Gg (maj), Gs, Ga, humo. 0 *lim.* 1, *Formula* Gg (maj) 1, Gs 1, Ga 2.
2. Peat with gyttja substance. *Nig.* 4, *strf.* 0, *elas.* 1, *sicc.* 2, *color* black, *struc.* homogeneous, *composition* Ld, Th, humo. 3, *lim.* 1, *Formula* Ld³ 1, Th³ 3.
3. Peat with gyttja substance. *Nig.* 3, *strf.* 0, *elas.* 1, *sicc.* 2, *color* brownish-grey, *struc.* heterogeneous, *composition* Ld, Th, humo. 1, *lim.* 1–2, *Formula* Ld¹ 2, Th¹ 2.
4. Lime gyttja with gyttja substance. *Nig.* 2, *strf.* 1, *elas.* 1, *sicc.* 2, *color* grey, *struc.* heterogeneous, *composition* Lc, Ld, Th, humo. 1, *lim.* 0, *Formula* Lc 3, Ld¹ 1, Th¹ +.
5. Sand. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 2–3, *color* yellowish-grey, *struc.* heterogeneous, granular, *composition* Ga, Gs, humo. 0, *lim.* 0, *Formula* Ga 4, Gs +.
6. Gravelly sand. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 3–4, *color* white to yellowish-grey, *struc.* granular, heterogeneous, *composition* Gg (maj), Gg (min), Gs, Ga, *test.* (moll), humo. 0, *Formula* Gg (maj) 1/2, Gg (min), 1/2, Gs 2, Ga 1, *test.* (moll) +.

Hulterstad (Triberga Bro) TB 3

1. Washed moraine. *Nig.* 2, *strf.* 0, *elas.* 0, *sicc.* 2, *color* yellowish to reddish-grey, *struc.* granular, heterogeneous, *composition* Gg (maj), Gs, Ga, humo. 0, *lim.* 1–2, *Formula* Gg (maj) 1, Gs 1, Ga 2.
2. Peat. *Nig.* 4, *strf.* 0, *elas.* 0, *sicc.* 2, *color* black, *struc.* homogeneous, *composition* Th, humo. 4, *lim.* 1, *Formula* Th⁴ 4.
3. Peat with gyttja substance. *Nig.* 4, *strf.* 0, *elas.* 1, *sicc.* 2, *color* black, *struc.* heterogeneous, *composition* Ld, Th, *part.test.* (moll), humo. 3, *lim.* 2, *Formula* Th³ 3, Ld³ 1, *part.test.* (moll) +.
4. Lime gyttja with gyttja substance. *Nig.* 2, *strf.* 1, *elas.* 1, *sicc.* 2, *color* white-grey, *struc.* heterogeneous, *composition* Lc, Ld, Th, the latter diminishing upwards, Ga, humo. 1, *lim.* 1, *Formula* Lc 3, Ld¹ 1, Th¹ +.
5. Sandy lime gyttja with gyttja substance. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 2, *color* white-grey, *struc.* heterogeneous, granular, *composition* Lc, Ld, Ga, humo. 3, *lim.* 0–1, *Formula* Ga 1, Lc 2, Ld³ 1.
6. Sand. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 2–3, *color* yellowish-grey, *struc.* homogeneous, granular, *composition* Ga, humo. 0, *lim.* 0, *Formula* Ga 4.
7. Gravelly sand. *Nig.* 1, *strf.* 0, *elas.* 0, *sicc.* 3–4, *color* white to yellowish-grey, *struc.* heterogeneous, granular, *composition* Gg (maj), Gg (min), Gs, Ga, *test.* (moll), humo. 0, *Formula* Gg (maj) 1/2, Gg (min) 1/2, Gs 2, Ga 1, *test.* (moll) +.

THE DIAGRAM MATERIAL

The Material

Three of the Skede Mose diagrams include macrodiaspore analysis together with microscopic material.

The Macrodiaspore Analysis Samples

The samples were collected in open shafts, and every sample contained 200 cm³ of soil, which has been treated with HNO₃, sieved and the macrodiaspores were then taken out.

The Microfossil Samples

In the entire Skede Mose material, the samples were collected in open shafts. This was also the case with the material from Melösa, Övra Sandby, Silverbäcken, Norra Kvinneby, Hulterstad (Triberga Bro), Tranekärr, Ekelunda, Linträsk, Kritmosen, and Torpmosen TM 1. At all the other localities Hiller sampler was used.

The samples were prepared for pollen analysis according to Troels-Smith's (1955, p. 15) modification of Erdtman's method (1936). However, when HF-treatment has been necessary, boiling with this acid has not been carried out. The sample was instead left standing with HF for one or a couple of days (cf. Jørgensen 1963 *b*, p. 9).

The analysis work was performed on material which was stained with basic fuchsin and 250 times magnification was used for the routine work.

Determinations by the author were continuously controlled with the aid of phase contrast for certain pollen types (1000 times magnification), while all other phase contrast demanding determinations were controlled afterwards. The determinations by Dr. Ingrid Sørensen, Copenhagen, were thus controlled by Dr. Sørensen herself; the determinations by Messrs. Th. Candolin, J. Höijer and I. Pålsson, Uppsala, were controlled by the author.

In those diagrams, where general vegetational development of the landscape was the aim of the study, at least 1000 *AP* should be counted in every analysis. However, this was not possible in some samples, where the *AP* numbers mentioned represent all the material available.

In Skede Mose S 22 and S 31–S 38, the aim of

the study was to follow the development of the limno-thelmatic contact, (LTC), within a restricted area of Skede Mose. 500 *AP* in every analysis were considered to be enough to give the desired results, and this is also the case with the material from the great Baltic Shore ridges (Königsson 1968), where dating of some Baltic stages was the main interest.

The Diagrams

THE MACRODIASPORE DIAGRAMS

The macrodiaspores found have been drawn together with the corresponding pollen diagrams. However, the absolute numbers of macrodiaspores identified are shown in the histograms and no percentual calculation has been carried out.

THE MICROFOSSIL DIAGRAMS

The Identified Pollen and Spores

Nowadays it is possible to identify so many pollen types that it is quite impossible to show the whole analysis material in one diagram, if this shall remain readable. I have therefore chosen to divide the material in certain groups.

In the *AP* section I have used a presence respectively non presence of an *AP* producer on the Alvar today as divisional base. This means that also the material from middle Öland has been divided in this way to enable an easy comparison between the vegetational development of the two areas.

The *NAP* and Spores section has been constructed according to the different pollen and spore producers' moisture demand and to their culture dependence. In both cases the information given in Sterner's "Flora der Insel Öland" (1938) has been used for the division.

As this paper mainly deals with the vegetational landscape history of the Great Alvar, the exclusive palaeofloristic material is of minor direct interest. However, a review of identified pollen and spore types is given on p. 165, and a more complete presentation of the paleofloristic material will follow in a future common paper from the research team, mentioned in the introduction.

The AP Section (A–E). This section comprises the groups A–E, and the percentage calculation has used the *AP* registered as basic sum. No reduction calculation has been performed.

Group A: Trees and bushes which grow on the Great Alvar now. Curves have been calculated for *Salix*, *Betula*, *Populus*, *Juniperus*, *Corylus*, and *Rhamnus cathartica*.

Group B: *Hippophaë*. This species does not grow spontaneously on Öland today. Its pollen is common in the earlier parts of the Alvar diagrams and occurs with isolated finds in the diagrams as late as in Subatlantic time. *Hippophaë* is ecologically a typical apocrate (Erdtman 1963), and it would not be impossible to expect *Hippophaë* to be favoured by the edaphic conditions in many Alvar areas. *Hippophaë* is then a little problematic to group, and I have chosen to give it its own heading, B, and to place it close to the Alvar trees' and bushes' group.

Group C: *Pinus*. This tree grows spontaneously on the Alvar today. As the landscape is open, *Pinus* pollen can be expected to be overrepresented in the diagrams (cf. L. Aario 1940), and it thus seems more accurate to me to give *Pinus* its own heading.

Group D: Trees and bushes which normally do not grow on the Alvar today, but which are represented in adjacent areas of the island. Curves have been calculated for *QM*, *Ulmus*, *Quercus*, *Fraxinus*, *Tilia*, *Carpinus*, *Alnus* and *Taxus*.

Group E: Late immigrants or non-immigrants. Curves have been calculated for *Picea* and *Fagus*.

The Ratio AP/Certain NAP and Spores. (Group F.) This curve may be looked upon as an indicator of the landscape development. The two dotted curves in the right part of the column represent the *NAP* (and a few spores') part of the material. Thus the inner curve comprises the entire material registered from terrestrial plants (H:a, see below) together with the remaining pollen, which belong to pollen types, where it for several reasons is impossible to say anything about the pollen producers' moisture demand (J:g), and where the curves J:a–f have been left out. The outer curve gives the two mentioned categories together with *Gramineae* (J:d) as *Gramineae* could be expected to play an important rôle within the Alvar's pollen production. *Polypodiaceae* (exclusive *Lastrea dryopteris*, *Polypodium* sp., and *Pteridium* sp.), *Equisetum* sp., *Sphagnum*, *Cyperaceae* and *Com-*

positae liguliflorae have been left out. The reason for this is that the bulk of the pollen from these types is interpreted as very locally produced or as long distance transported, and they should thus not be representative components in the construction of a curve dealing with the landscape development.

The NAP and Spores Section (G–M). The calculation of all curves uses *AP* together with the pollen from respectively entitled type as base. Thus e.g. *Gramineae* is given in percentage of *AP* together with all *Gramineae* (except *Cerealina*) registered.

The reason for this calculation is to put each pollen type treated in relationship to a sum, which as far as possible is constant, and it is then natural to choose the *AP* sum. Additionally the percentual values never exceed 100 when calculated in this way, which is very handy. Finally according to Troels-Smith (personal communication) and to Faegri & Iversen (1964, pp. 84, 134, 135) it is not recommendable to calculate percentual curves of pollen types "outside" the pollen sum for strictly statistical reasons.

The method of calculating the curves, which has been used in this paper was already used by Troels-Smith (1955), Jørgensen (1963 a) and Berglund (1966).

Group G: *Hedera* and *Viscum*.

Group H: Terrestrial plants.—When dividing the material according to the different pollen producers' moisture demand, the information given by Sterner (1938) about the various plants' growth places has been used. At the same time the whole analysis material was criticized according to the detail determinations. A short review of these judgments is given together with the paleofloristic review (pp. 163–167) *Artemisia* sp. is encountered in H:a, but I have considered it desirable to give the separate curve for *Artemisia* sp. in spite of this fact. This curve is H:b. In Stormaren, however, *Artemisia* was not encountered in H:a.

Group J: Ecologically non differentiated plants in regard to their moisture demand.—Within this group those pollen types are found, where many potential pollen contributors to the type exist, and where the moisture demand varies greatly within the type. Example: *Potentilla/Fragaria* type. Additionally those pollen types have also been collected in the group if the determined pollen emanates from a plant with rather wide ecological amplitude in the same sense.

Example: *Solanum dulcamara*. In J:a *Polypodiaceae* (exclusive *Lastrea dryopteris*, *Polypodium* and *Pteridium*) have been collected, J:b *Equisetum* sp., J:c *Sphagnum*, J:d *Gramineae* (exclusive *Cerealia*), J:e *Cyperaceae*, J:f *Compositae liguliflorae* and J:g the rest.

Concerning *Compositae liguliflorae* this section has shown amazingly high records in some of the Alvar diagrams (p. 106). Albertsson (1950, p. 315) has distinguished an association with *Taraxacum limnanthes* in it, and it is very probable that most of the *Compositae liguliflorae*—pollen emanates from this or closely related associations.

Group K: Plants which are connected to cultural activity in some way.—Sterner (1938, p. 34, 35) discusses Öland's flora and its different species and their relation to the cultural influence. Those species which he considered to be indigenous on Öland, but which were found to be favoured by cultural influence, were said to be *Hemerophilous* plants. Those which he considered to be dependent on cultural activity for their existence were named *Synanthropic* plants.

In his flora Sterner published notes in these two respects on all species which he thought to be connected to cultural development.

In some cases it is possible to correct Sterner's opinion on the basis of the now existing paleofloristic material, e.g. *Helianthemum oelandicum*, which obviously is a *Hemerophilous* plant or *Typha latifolia*, which is not a Neophyte on Öland. But I have tried to follow Sterner's opinion about the flora's cultural connection for the division of the material without exceptions, to have a definable base for the division, which might give more detailed information in this respect.

When dividing the identified material I have had to make the following restriction: Many of my distinguished pollen types can not be so differentially determined, that they safely can be put in one or another of the two groups. For instance there are potential pollen producers from both groups within the family *Caryophyllaceae*.

Pollen determination mainly or exclusively supported by pollen keys and without the aid of very good reference material together with the key, should be avoided. As our reference material has not yet reached a stage which I can consider sufficient for safe determinations within the family, I prefer to give a *Caryophyllaceae* type only (apart from the *Sclearanthus* type, which has been distinguished). See also Fredskild (1967 a, pp. 16–20, Plates III, IV och V, 1967 b, pp. 115, 117–119).

Fig. 89. The diagram curves have been constructed with a true value in the bottom curve and a five times magnification of the true value in the outer curve. When only the outer curve is present, as in analysis 8 in this figure, the representation of the diagram component is less than 0.5 %.

Black cover of the true curve indicates that the component is a single pollen type unit, horizontal dense lines that the component is a group of several pollen types. The diagonal dense lines stand for *Pediastrum* and the diamond pattern for the Destruction degree. The dotted curves, finally, comprise the NAP constituents in the ratio diagram AP/NAP .

When grouping the analysis material for the *Hemerophilous* and *Synanthropic* plants' curves, *Caryophyllaceae* then has been added to both curves.

In K:a Cultivated plants, K:b *Synanthropic* plants and K:c *Hemerophilous* plants have been grouped.

Group L: Fen plants.

Group M: Aquatic plants.

The Algae Section. Group O: *Pediastrum*.

The Destruction Degree Section Group P: Destruction was recorded and calculated according to Jørgensen's (1963 b) modification of Troels-Smith's method (1941). The following pollen have been investigated as to the destruction degree: *Betula*, *Corylus*, *Carpinus*, *Alnus*, *Tilia*, *Ulmus* and *Gramineae*.

The Charcoal Section. Group Q: Charcoal fragments $> 10\mu$ have been recorded. The percentage is given with AP as calculation base.

THE DIAGRAM CONSTRUCTION

All curves but the one for the destruction degree (P) have been constructed in an identical way. This means that the horizontal scale with the mentioned exception, where the scale unit equals 20 %, always

has the unit to equal 10 %. In certain cases the curves for minor constituents are difficult to follow. A multiple of 5 has then been used to enlarge the curve and make it easier to read, and the new limitation is shown on Fig. 89.

All curves which comprise pollen and spores from systematical units have been drawn with a black designation. Collective curves are marked with dense horizontal lines. The *NAP* constituents of the landscape development indicating curve, group F, are shown with dotted designation. *Pediastrum* has dense diagonally directed lines, the Destruction degree a diamond pattern and Charcoal again has been marked black (see also Fig. 89).

The Zone Systems

In most pollen analytical works the description and discussion of the vegetational development is accompanied by a zone system, which may be a regional or a strictly local one. Both types of systems serve the aim to enable an easier reading of the diagrams treated, but the local system seems to be the most important one for the detailed discussion of the vegetational events of an investigation area, while the regional system helps to make comparison of the discussed material and diagrams from other regions.

Normally the existing zone systems have been adapted to the classic Blytt–Sernander Late and Post-glacial palaeobotanical classification, and the original phase or period names of the classification are still used in the discussion of pollen diagrams.

The chief demand one must make upon a zone system is that it must provide a solid base for the comparison and the discussion. The criterions of the zones and their limitations then have to be without objections. Such criterion is often connected to the first appearance of a certain tree pollen or to a very marked change in a specie's representation. Such vegetational events have long been looked upon as practically synchronous over greater regions and an established zone system thus has been treated as equal to an absolute chronology.

When putting together results concerning the appearance of zone limit indicators, it becomes evident that the lower limits of certain tree pollen curves very often are metachronous, and that thus the absolute chronologic value of the existing zone systems is limited if not very restricted areas only are discussed. See for instance R. Aario (1965, pp. 215–232), where he shows the time difference of *Picea*'s immigration to southwestern Finland, which amounts to some 2000 years if compared with the

immigration of the same tree to the northwestern parts of the country. Similar results have been obtained for Sweden (Olsson, I. U. & Königsson, L.-K., *in preparation*). The same aspects may also be attached to the occurrence of the Late Glacial pollen diagram type, which for instance appears in sediments formed in Denmark during the Late Glacial tundra period, but which also can be expected to be found in sediments formed very recently in northern Norway, Sweden, Finland and Russia in the present tundra areas.

It then seems natural to propose another division of the Late Pleistocene and Holocene periods, which according to my opinion must be built upon the coming international convention of the Pleistocene-Holocene boundary, and it must be worked out according to the common stratigraphic practice (cf. Fairbridge & Newman 1961, pp. 400–402, Neustadt & Gudelis 1961, pp. 468, 476), and dated by use of the radiocarbon method. It seems natural to me to keep the classic period names of the Blytt–Sernander system also in this new classification but to adapt them to more stable criterions than has been done before (cf. T. Nilsson 1965, p. 487).

In spite of this fact there has been a need for a regional zone system in this paper, and I have chosen the Danish zone system (Jessen 1935, 1938) without any changes or additions to its original form. The reason for the choice is that Jessen's system seems to be the most widely used one today, and it will probably remain so till a system like the one suggested above has come to construction and convention. The reason for the usage of the original form of this zone system is that it gives the desired possibility of regional comparison already in this version.

In addition to Jessen's zones a local division has been marked on the diagrams. These zones will be described below, and they are also shown in the summary of other zone systems of interest for this paper, Fig. 97 a.

Jessen's Zones. No older sediments than those formed during the Preboreal period have been investigated and this summary of the zones and their criterions therefore starts with this period. No lower limit of the Preboreal period has been isolated.

Zone limit IV–V: The *Corylus* pollen curve permanently exceeds 1 %.

Zone limit V–VI: The *Alnus* pollen curve permanently exceeds 1 %.

Zone limit VI–VII: The *Tilia* pollen curve permanently exceeds 1 %.

Zone limit VII–VIII: The *Ulmus* permanently and very markedly diminishes.

Zone limit VIII–IX: It has not been possible to distinguish a safe zone limit between two zones as *Fagus* is too weakly represented in the diagrams and the *Picea* pollen curve is very problematic in the older parts of the zones VIII/IX.

Local Zones Well-defined diagram sectors have been taken as local zones. Two of them, F and G, are identical with Jessen's respective zones VI and VII.

Zone A is characterized by high *Pinus* percentages which decrease upwards, accompanied by a rising *Betula* pollen curve. *Juniperus* exceeds 1% in the whole zone, *Hippophaë* occurs and *NAP* is high.

Zone B. Lower zone limit: The rising *Betula* pollen curve crosses over the diminishing *Pinus* pollen curve just above the zone limit. *Juniperus* increases remarkably. The zone itself is characterized by *maxima* for *Betula*, *Juniperus* and *Hippophaë*. *Ulmus* appears in the lower part of the zone and continues throughout the zone but never reaches as high as 1%. *NAP* is still high, but is lower than in zone A.

Zone C. Lower zone limit: The *Betula* and *Pinus* pollen curves cross over each other again, *Juniperus* diminishes as does *Hippophaë*. The *NAP* content diminishes markedly.—The whole zone is characterized by high percentages for *Pinus*, and rather modest values for *Betula*. The *Juniperus* values are still rather high, while the *NAP* curve has decreased still more.

Zone D. Lower zone limit: The *Corylus* pollen curve permanently exceeds 1%.—The zone is characterized by the rising *Corylus* curve, stable *Pinus* and *Betula* curves and, in the upper half of the zone, a slightly higher *NAP* curve. This may, however, be less pregnantly seen in some cases. The *Ulmus* and *Quercus* curves rise throughout the zone. **Zone E.** Lower zone limit: A rise in the *QM*-curve is accompanied by a transition to very low values for *Juniperus*, and a change for the *Betula* curve, which has been stable and which gets a diminishing trend instead.—The zone is characterized by low *Betula* values if these are compared with the ones in zone D, and by a *minimum* for *Juniperus*.

Zone F: Lower zone limit: The *Alnus* pollen curve permanently exceeds 1% and *Corylus* has a *minimum* just in the zone limit itself.—The zone is characterized by a slightly diminishing but still rather stable *Betula* pollen curve, by slightly raised values for *Juniperus*, a new culmination for *Corylus* and by rising *Ulmus*, *Quercus* and *Alnus* curves. The *NAP* values are low.

Zone G. Lower zone limit: The *Tilia* pollen curve exceeds 1%.—Within the upper part of the zone the diminishing *Betula* curve gets its lowest values all through the Holocene vegetational development. *Juniperus* gets a new *minimum* in the zone and the *Pinus* curve decreases throughout the zone, accompanied by a marked rise in the *QM* curves and caused by the increased percentages of all the *QM* components. *Picea* occurs scattered in the lowest parts of the zone and becomes more frequent in the upper parts. *NAP* values are extremely low.

Zone H. Lower zone limit: The first start of the decrease in the *Ulmus* pollen curve.—The zone is characterized by the decreasing *Ulmus* and *Tilia* curves, which is accompanied by a slight rise of the *Quercus* curve and by the increase of the *Betula* percentages. The amount of *NAP* pollen rises, less pregnantly, however, in the diagrams from middle Öland than in those from the Great Alvar.

Zone J. Lower zone limit: The *minimum* for the *Ulmus* and *Tilia* pollen curves.—Within the zone there are increased values for *Ulmus* and *Tilia*, which together with *Fraxinus* show peaks in the middle of the zone. The amount of *NAP* increases still more. In the upper part of the zone *Picea* increases and *Carpinus* appears together with *Fagus*. **Zone K.** Lower zone limit: New *minima* for *Ulmus* and *Tilia*.—The zone shows high values for *NAP* and it is characterized also by *minima* for *Ulmus*, *Tilia* and *Fraxinus*. *Carpinus* shows a *maximum* in the zone and so does *Picea*. *Fagus*, which was first represented in the upper part of zone J, diminishes again towards the upper zone limit,

Zone L. Lower zone limit: A very marked decrease in the *NAP* and *Juniperus* curves.—The zone is above all characterized by *minima* for *NAP* and *Juniperus*.

Zone M. Lower zone limit: *Juniperus* increases again.—The zone is characterized by the amount of *NAP*, which shows a very slow rise all through the zone, by decreasing *QM* (which above all means *Quercus* itself), and by a *Carpinus* culmination. *Alnus* also diminishes.

Zone N. Lower zone limit: Together with a marked increase in *Picea*, the *NAP* curve also rises. At the same time *Alnus* and *Corylus* decreases.—The zone is characterized by the increasing *Picea* and *Juniperus* curves and by decreasing *Corylus* and *Alnus*. The *Quercus* pollen curve shows a slight rise in the lower part of the zone, but it then decreases again.

Zone O. Lower zone limit: The *Picea* curve rises very pregnantly. At the same time the *NAP* curve has a *maximum*.—The zone is characterized by high *Picea* values and by a slightly decreasing *NAP* curve in the diagrams from the Great Alvar.

Diagram Descriptions and Interpretations

THE DIAGRAMS FROM THE GREAT ALVAR

Dröstorps Mose DM 1

For the diagram from Dröstorps Mose, the description and interpretation given in Königsson (1962) are referred to. The sedimentological historical aspect is, however, summarized on Fig. 102 and discussed together with the soils of the treated Alvar lakes and fens.

Tranekärr TK 1

The diagram from Tranekärr has been made to give an idea of the age of the bottom soil of its stratigraphy. Thus only two analyses were carried out. The diagram shows a very high Destruction degree, which may have influenced the curves. Thus within the Destruction degree curve such pollen grains exist, which have not been identified as they were too destructed. The bulk of these belongs to *Betula* and *Corylus*, whose curves then must be interpreted with greatest caution.

Description. The diagram is characterized by a dominating *Pinus* curve. The *Alnus* curve amounts 12% and the *QM* components together show around 8%, the bulk of which is *Quercus*, but *Tilia* is also important. The *NAP* curve in group F is very high, more than 10%, and the culture indicating Synanthropic and Hemerophilous plants have high representations too. The curve for the Destruction degree is remarkably high, more than 90%, and there is much charcoal in the sediment.

Correlation. The correlation of the diagram with the other Alvar diagrams gives the result that the bottom part of the Tranekärr stratigraphy was formed during the local zones J or K. It is not possible to put it in an older zone because of the high *Picea* values, and if it should be put in a later zone, this must be zone N for the same reason. But the curves for *Alnus* and *QM* both speak against such a correlation.

Sedimentation. The sedimentation then started in zone J or K.

Landscape development. At the time when the analysed sediment in Tranekärr was formed an open landscape existed. This is shown in the ratio *NAP/AP* (group F), where the high percentage of *NAP* indicates an almost tree and bushless land, if compared with the corresponding ratio in the more complete Alvar diagrams.

Linträsk LT 1

Description. The diagram is characterized by very high *Pinus*, *NAP* and *Cyperaceae* curves, and by an amazingly high curve for *Compositae liguliflorae*. The general trend of the *Picea* curve is rising all through the diagram, while the opposite is valid for *Alnus*. In the middle of the diagram *Juniperus* shows a very pregnant increase and at the same time the curve for cultivated plants (*Cerealia*) rises.

Correlation. Zone L has been marked in the bottom part in spite of high percentages for *NAP* and it is possible that the lower limit of the zone is represented in the bottom analysis, but this interpretation does not seem to be so sufficiently safe to be drawn into the diagram.

The lower limit for zone M has been put at the sudden rise of the *Juniperus* curve.

The lower limit of zone N has been placed where the *NAP* curve rises. The rise is accompanied by an increase in the *Picea* values, which is not very pregnant.

Finally zone O has been placed where the *Picea* curve rises very markedly.

Sedimentation. The stratigraphy is young and it only goes back to the lower part of zone L. The internal vegetational fen history shows a normal change from minerogenic sediments to gyttjas, and to peats with gyttja content.

Landscape development. From the zone limit M/N and upwards the open landscape increases its pollen depositional influence in the soils (*NAP* increases). This is most evidently shown in the uppermost two analyses. The cultural influence can be traced in the whole diagram. However, an increased cultural activity is registered in the curve for the Cultivated plants, which starts at the same time as the *Juniperus* increase in the zone change L/M. Its *maximum* value is very late, in the zone limit N/O.

Möckelmosen MM 1

Description. The diagram is characterized by a high *Pinus* curve, an undulating *Betula* curve and an upwards diminishing *Corylus* representation. In the bottom part of the diagram *Ulmus* shows values around 3%, but it soon decreases and is replaced by a low continuous *Picea* pollen curve. In the upper half of the diagram *Juniperus* is an important species.

Correlation. The uppermost zone, O, does not seem to be represented in the diagram. This may be due to the fact that the Hiller sampler had difficulties in cutting the uppermost layer, and that it then is possible that there was some loss of material at the sampling.

Zone F. The lower limit of the zone has not been found.

Zone G. The lower limit has been marked according to the

development of the *Tilia* curve. No other criteria have been used.

Zone H. The first decrease of the *Ulmus* curve marks the zone limit. At the same point the *Alnus* curve rises, as does the *Tilia* curve (which, however, may be due to low sedimentation rate in the actual diagram sector, which presses the vegetational events very close together). From the zone limit a rise in the *NAP* curve starts.

Zone J. The lower zone limit has been placed where the decline in the *Ulmus* curve reaches its lowest value, and where the first peak in the *Alnus* culmination, which follows upon the *Ulmus* decline, appears. A culmination of *Betula* starts in the zone limit. The *NAP* values increase still more.

Zone K. The lower limit of the zone has been placed where the *Alnus* culmination ends and where a rise in the *Picea* curve appears. At the same time the *Betula* culmination, which started in the zone limit H/J ends. *Juniperus* increases and *Carpinus* shows an indistinct *maximum*. *Fagus* appears and the curve for the Cultivated plants starts.

Zone L. The lower limit has been put where the *NAP* curve drops.

Near the zone limit *Tilia* shows a small *maximum*. *Fagus* and *Carpinus* end culminations just above the limit and there is a slight decrease in the *Picea* curve.

Zone M. Lower limit. A new rise in the *Juniperus* curve ends the zone L and together with this the *NAP* amount increases and so does the curve for the Cultivated plants.

Zone N. A new *Picea* rise starts the zone. This zone limit is, however not quite safe.

Sedimentation. In the bottom part of the sequence, during the zones F and G, lime gyttjas were formed. The layer with *Substantia humosa* (p. 75) was first formed when the zone limit G/H was developed, and its formation continued during the whole of zone H and most of zone J. At least in the lower delimitation of the layer there is a *hiatus* and it is possible that there is another one on the top of the layer too. During the rest of the diagram, zones upper J–N, a peaty gyttja with lime gyttja content was formed. There are no signs of more peaty soil in connection with zone L in Möckelmosen.

The landscape development. In the bottom part of the diagram the *NAP* part of the registered pollen is small, which may be seen in the curves in group F. At the zone limit G/H the *NAP* part has a *minimum* and then increases its portion of the pollen total. With minor and unimportant exceptions (there is, however, a *minimum* in the middle of zone J, which may have some importance) this trend is followed till the zone limit K/L, where a sudden and lasting decline appears. Again the *NAP* amount increases and reaches even higher values than earlier, before zone L.

Evidently a more forest pollen productive period was replaced by a more weed pollen productive at the zone limit G/H. During zone K the open landscape with its greater production of *NAP* reaches its first *maximum* development, replaced by a "reafforestation" period during zone L. A new open landscape period thus starts with zone M. In the Möckelmosen diagram the open landscape period has its greatest extensiveness in the middle of zone M. There then follows a slight increase in the *AP* deposition in the uppermost parts of the diagram, indicating another period of more tree and bush growth within the area.

Frösslunda Mose FM 1

Description. The diagram shows two different parts, both of them with very high *Pinus* percentages. The lower part, which

comprises the analyses 1–7 shows very high *Pinus* values together with a rather high *Betula* curve. *Alnus* occurs scattered and has its rational limit in the uppermost analysis. *QM* and *NAP* are very low. In the upper part of the diagram the *Pinus* representation is considerably lower and instead *Alnus*, *Juniperus*, *Picea* and the *QM* components occur. The amount of *NAP* is higher and the locally produced *Gramineae* and *Cyperaceae* pollen shows violently increasing curves.

Correlation. Zone D. The lower limit has not been reached. Zone E. The lower limit has been placed where the *Betula* curve drops. At the same time *Corylus* increases.

Zone F. This zone seems to be fragmentarily represented and its lower limit is represented by the start of the *Alnus* pollen curve.

Zone G is lacking.

Zone H. The lower limit is placed at what has been interpreted as the first *Ulmus* decline. At the time *Quercus* and *Betula* rise their curves as is the case with the curves of *NAP* and *Juniperus* too.

Zone J has no safely recognized lower limit in this diagram. It is, however, possible that analysis 9 represents the zone limit.

Zone K. The second *Ulmus minimum* after the *Ulmus* decline. The *minimum* is accompanied by an increased *Picea* curve and by a *minimum* for *Tilia*.

Zone L. The lower limit has been placed where *Juniperus* declines. At the same time the curve for *NAP* drops.

Zone M. The lower limit has been placed at the renewed rise of the *Juniperus* curve. This is accompanied by a decrease in the *Ulmus* and *Tilia* curves and by an increase in the *NAP* records.

Zone N. The lower limit has been put where *Picea* and *NAP* increase their values, which is accompanied by a decline in the *Alnus* curve.

Zone O does not seem to be represented in the diagram, which may be for the same reason as has been given for the corresponding lack of the layer in Möckelmosen, namely that the Hiller sampler had great difficulties in cutting the uppermost layer.

Sedimentation. During the zones D, E, and F lake marl and lime gyttja were deposited. In zone F there is a very important sediment change, namely the one from lake marl to lime gyttja. The delimitation between the two layers is very abrupt. Judging from the pollen analytical evidences, there is a *hiatus* which includes most parts of zone F and the whole zone G. The new sedimentation seems to have started very soon after the zone limit G/H. In the upper zones H–N, there is a peaty gyttja with some lime gyttja substance in it. The sedimentation is summarized on Fig. 102.

Landscape development. During the zones D, E, and F, the *NAP* production is very low and some kind of tree or bush cover must have existed in the neighbourhood of Frösslunda Mose. Together with the *Ulmus* decline, which marks the entrance of zone H, the amount of *NAP* increases, and this trend continues accentuated through the zones J and K. In zone L, however, the amount of *NAP* decreases again and some "reafforestation" occurs, which by the beginning of zone M again is changed to a more *NAP* producing, open landscape. This situation is also characteristic for zone N.

Kritmosen KM 1

Description. As was the case with the Frösslunda Mose diagram this one can also be divided into two main parts. The oldest part is characterized by high *Pinus* and *Betula* values

together with low *NAP* values, and the younger part shows high values for *Juniperus*, *Alnus*, *NAP*, *Gramineae* and *Cyperaceae*.

Correlation. Zone D. It is possible that the lower limit of this zone is present in the bottom analysis, where the *Corylus* values are very low (below 0.5%). The configuration of the *NAP* curve also speaks for this.

Zone E. Lower limit. The drop of the *Betula* and *Juniperus* curves together with the rising curves for *Corylus* and *Pinus* and the increasing *QM* curve (which above all means *Ulmus*) indicate the limit.

Zone F is lacking.

Zone G is lacking.

Zone H is lacking.

Zone J is lacking.

Zone K is lacking.

Zone L is lacking.

Zone M. The lower limit may be missing. The represented part of the zone, however, starts with a violent increase of the *Juniperus* and *NAP* curves.

Zone N. The lower limit has been placed where a not very pregnant rise in the *Picea* curve appears. Together with this there is a *minimum* in the *Quercus* curve.

Zone O. The lower limit of the zone has been put where the *Picea* curve rises again.

Sedimentation. Lime gyttjas were deposited during the zones D and E. Then the lime gyttja continues in zone M, and in the first part of zone N there is a peaty layer, which again is overlaid by lime gyttja. On the top of the sequence a peaty gyttja with some lime gyttja content is deposited.

Landscape development. In the zones D and E extremely poor *NAP* depositing conditions prevailed and during these zones a tree and bush cover existed in some areas on the Great Alvar in the surroundings of Kritmosen. When zone M started and the sedimentation continued after the end of the conditions which created the mentioned *hiatus*, the open landscape already existed. There is a slight increase of the *NAP* amount during the zone M, which also continues upwards through the zones N and O, and there does not seem to have existed any long lasting interruptions of the Alvar development in this part of the area after the entrance of zone M.

Torpmsen

Torpmsen TM 1

Description. The diagram is characterized by a rather even and high *Pinus* curve and by the rapidly increasing curves for *Gramineae* and *Cyperaceae* in the upper half of the diagram. In the bottom part there is a *maximum* for *Corylus* and in the upper part for *Juniperus*.

Correlation. Zone F. The lower limit of the zone has not been reached and it is very doubtful if anything of the zone's later part is represented.

Zone G lacks.

Zone H. The very lowest part of the zone does not seem to be represented in the diagram, and there is a *hiatus* in the sediment change 2/3. The *Ulmus* decline is accompanied by an increase in the *Quercus* curve and the *Tilia* curve diminishes above the zone limit. The *NAP* curve rises at the same time.

Zone J. The lower zone limit has been placed where the *Picea* curve exceeds 0.5%, which takes place at what has been interpreted as the first *minimum* of the *Ulmus* curve after the decline. Just above the zone limit the *Betula* curve rises which has a continuation within the zone. The same is valid

also for *Carpinus*. The *NAP* curve remains on the same level as it reached in the upper zone H or diminishes slightly. Zone K. The lower limit has been put at the start of the *Picea* culmination within the zone. This appears together with a second *Ulmus* minimum and the rises in the *Juniperus* and *NAP* curves.

Zone L. The lower limit is placed where the *Juniperus* curve drops, which is accompanied by a simultaneous drop of the *NAP* curve.

Zone M. The lower limit has been put where the *Juniperus* curve increases again.

Zone N. The lower limit has been placed where the *Picea* curve increases together with a corresponding evident decrease in the *Alnus* and *Quercus* curves. At the same time *NAP* increases.

Zone O. The lower limit has been marked where the *Picea* curve rises again.

Sedimentation. During Zone F there was deposition of lake marl and lime gyttja in Torpmosen. Much of the zone's upper part seems to be hidden in the *hiatus*, which also covers the total zone G and probably also a minor portion of the lower-most part of zone H. During the rest of the first half of zone H the *Substantia humosa* layer was formed, and above this and during the rest of the zone there was a lime gyttja deposition. Although the limit between the two sediments ($\frac{2}{3}$) is sharp, no pollen analytical signs of a *hiatus* are visible.

During the rest of zone H and through the zones J, K and the lowermost parts of zone L lime gyttjas with varying detritus gyttja content occur.

In the uppermost part of zone L and in the beginning of zone M a peat with gyttja substance was formed and above this in the rest of zone M there is lime gyttja deposition with increasing peat detritus content. During the uppermost two zones a peat with some gyttja substance was formed. The sedimentation is summarized on Fig. 102.

Landscape development. During zone F there was very little *NAP* deposition and a tree and bush period lasted in the surroundings of Torpmosen. Then there was a period with increased *NAP* deposition, which has been interpreted as a period with more open landscape than before. During zone L as the *Juniperus* curve diminishes there is a drop in the *NAP* curve too, and this means that some kind of "reafforestation" took place. Above zone L the amount of *NAP* increases again, and the open landscape returns. From zone N on and upwards, finally, there is an accentuated *NAP* deposition, which shows that a still more open landscape developed very late.

Torpmosen TM 7

Description. The diagram, which only comprises the lowest part of the sequence, can be divided in two parts, the lower one with very high *Pinus*, and *NAP* values, and the upper one with high curves for *Betula*, *QM* (*Quercus*), *Carpinus*, *Alnus* and *NAP* instead.

Correlation. The lower limit of zone F is not represented in the diagram.

Zone G lacks.

Zone H. The lower limit of the zone has been put where the *Ulmus* decline starts. At the same time the *Quercus* and *Tilia* curves rise, and a diminishing trend in the *Pinus* curve starts. The amount of *NAP* increases.

Zone J. The lower limit of the zone has been put where the *Picea* curve, which started already in the preceding zone, increases. This takes place at the same time as the *Ulmus*

curve reaches its minimum after the decline. A culmination of *Carpinus* in the zone starts near the zone limit, *Betula* culminates in the zone, the *NAP* curve remains fairly stable and the *Pinus* curve has a marked minimum in the zone. Zone K. The lower zone limit has been placed where the *Picea* curve rises, which occurs together with an increase in the *Juniperus* curve. At the same time *Pinus* increases. The *NAP* curve remains stable.

Sedimentation. During the first part of zone F there is a sedimentation of lime gyttja, which is succeeded by a lake marl deposition. During the whole of zone G, a *hiatus* exists. During most part of zone H the *Substantia humosa* layer was formed, and upon this layer one will find lime gyttjas with a varying content of detritus gyttja substance. The sedimentation is summarized in Fig. 102.

Landscape development. Zone F, with its low amount of *NAP* was a period with some kind of tree and bush growth within the neighbourhood of Torpmosen. Together with the *Ulmus* decline the *NAP* percentages increase and a more open landscape remains through the zones H, J, and those parts of zone K, which have been analysed in this diagram.

Västerstads Träsk VT 3

Description. The diagram shows two different parts, both with a high *Pinus* curve. In the lower part high percentage for *Betula* occurs which is replaced by the increasing curves for *Juniperus* and *Alnus* in the diagram's upper parts. The amount of *NAP* is amazingly low in the whole diagram. Correlation. In the lowermost parts of the diagram the upper part of zone E is represented.

Zone F. The lower limit was put where the *Alnus* curve starts.

Zone G lacks.

Zone H lacks.

Zone J. It has not been possible to distinguish anything of zone H, but it is still possible that it may be represented together with zone J. The lower limit of the zone J has not been defined pollenanalytically. It has been placed after the sediment change $\frac{2}{3}$. This is, however, a limit which is interpreted and not a defined one. The *Betula* culmination within zone J, which has been described from Möckelmosen and Torpmosen seems to be present with its uppermost parts in this diagram sector, and it is thus possible that only the latest part of this zone has been registered in Västerstads Träsk. Consequently the *hiatus* in the sediment limit $\frac{2}{3}$ is supposed to involve part of zone F, the whole zones G and H and the lowest parts of zone J.

Zone K. The lower limit has been placed where the *Betula* curve diminishes against a minimum in the zone, and where the curves for *Juniperus*, *Quercus* and *Picea* simultaneously increase.

Zone L. The lower limit has been put where the *Juniperus* and *Corylus* curves diminish, which is accompanied by a slight increase in the curves for *Quercus*, *Alnus* and *Picea*. The zone does not seem to be very clearly developed in Västerstads Träsk.

Zone M. The lower limit has been marked where the *Juniperus* curve rises.

Zone N. The lower limit has been connected with an increase in the *Picea* curve, which is accompanied by simultaneous decreases in the curves for *Betula* and *Alnus*.

Zone O lacks.

Sedimentation. During what is represented of the zones E and F lime gyttja was deposited. During the rest of the

diagram (upper zone J—zone N) gyttja with peat detritus and some lime gyttja substance was formed.

Landscape development. Throughout the diagram the amount of *NAP* is very low. There is, however, a change above the sediment change $2/3$, where the curve for *NAP* increases. This indicates the appearance of a less *AP* productive vegetation within the surroundings of Västerstads Träsk.

Stormaren STM 1

Description. Except for a *minimum* in the lower parts of the diagram *Pinus* has a very high representation throughout the diagram, mostly exceeding 50 %. Apart from the *Pinus* curve the diagram can be divided in a lower section with much *NAP*, a middle section with a very low amount of *NAP*, and an upper section with again high *NAP* values.

If only the *AP* part of the diagram is referred to there are the following main parts: a lower *Pinus maximum* followed by *Betula*, *Juniperus* and *Hippophaë maxima*. The *Pinus* has a new culmination, which is followed by the increasing and culminating *Corylus* curve, which is succeeded by the *Alnus* immigration and, later, by the culminating curves of *Juniperus* and *Quercus*. In the uppermost parts of the diagram *Picea* rises its curve.

Correlation. Zone A. No lower zone limit has been distinguished in this material.

Zone B. The lower zone limit is characterized by the decreasing *Pinus* representation and by the rising curves of *Betula*, *Juniperus* and *Hippophaë*, all of which culminate within the zone. The *NAP* curve also diminishes.

Zone C. The lower zone limit has been placed where *Betula*, *Juniperus* and *Hippophaë* again decrease while *Pinus* increases. At the same time there is a drop in the *NAP* curve.

Zone D. The lower zone limit has been put where the *Corylus* curve starts. *Juniperus* has a *minimum* at the same time but increases again within the zone. In the upper part of the zone there is a small *NAP maximum* as the *Corylus* curve rises.

Zone E. The lower limit of the zone has been marked where there is a rise in the *QM* curve, accompanied by a transition to very low *Juniperus* values. The trend in the *Betula* curve changes to a diminishing one. Within the zone *Corylus* has its culmination and the *NAP* values are very low.

Zone F. The lower limit represents the immigration of *Alnus*. Zone G is very fragmentarily developed. It may even be discussible if it is present at all. I have come to the conclusion that there is a very small portion of the zone represented in the analyses 66 and 67, where the lower zone limit equals the immigration of *Tilia*. The rest of the zone is lacking.

Zone H. The lower limit has been marked where the *Ulmus* declines. This occurrence is accompanied by a rise in the *Quercus* and *Tilia* curves and by an increase of the amount of *NAP* as well.

Zone J. The lower zone limit has been placed where the *Ulmus* decline reaches a *minimum* value. At the same time *Tilia* declines and *Juniperus* rises.

Zone K. The lower zone limit should be placed where the second *Ulmus minimum* appears together with a *Tilia minimum* and *maximum* values for *Juniperus*, *Carpinus*, *Picea* and *Fagus*. The *Ulmus minimum* was probably developed in a quite normal way, but there seems to be a *hiatus* in the sediment change $10/11$, which may have included the preceding *Ulmus maximum* in its sediments, and the *minimum* thus is very difficult to distinguish. As the other zone

limit criteria are present, the discussed *hiatus* is regarded as proved.

Zone L. The lower zone limit corresponds to the decline in the *Juniperus* and *NAP* curves.

Zone M. The lower zone limit is placed where the *Juniperus* curve again rises.

Zone N. The lower zone limit is marked at the *Picea* rise, which is accompanied by a diminishing trend in the curves for *Corylus* and *Alnus* and a rise in the *NAP* curve.

Zone O. The lower limit is put where the big *Picea* increase starts.

Sedimentation. During the zones A, B, C, D and most parts of E, lime gyttjas were deposited in Stormaren. No signs in the pollen diagram indicate the occurrence of *hiatus*. During the later part of zone E, the whole zone F and what is present of zone G, *Substantia humosa* was formed, Zone H starts with gyttja formation, and the sediment is rich in peat detritus and has some lime gyttja substance too. In the sediment change $9/10$ there is a *hiatus*, which comprises most of zone G. The formation of a peat detritus containing gyttja continues through the remaining zones. There is, however, a *hiatus* in the sediment change $10/11$, which comprises the upper part of zone J.

Landscape development. During the zones A and B, there is a high *NAP* percentage and during that time the landscape must have had a rather open aspect. During the following zones (C, D, E, F and G) the amount of *NAP* is very low, and an *AP* producing vegetation must have predominated in the vicinity of Stormaren. During the later part of zone D, however, in the same diagram sector where the *Corylus* curve rises for the first time, there is a lasting increase in the *NAP* part of the deposited pollen amount. There then seems to have existed a shorter period with diminishing growth of bushes and trees in the area. The *Juniperus* curve has a small simultaneous culmination. From the start of zone H, there is an upward trend of increasing *NAP*. In zone L, however as the *Juniperus* curve drops very strikingly, the amount of *NAP* decreases remarkably much too. The open landscape, which had developed during the zones H, J and K then passes through a "reafforestation stage" which has not been totally reversed again on this part of the Great Alvar until the start of zone N. In the upper two zones there is an accentuated increase in the *NAP* deposition. This means that a still more open landscape was developed very late in the Holocene.

THE DIAGRAMS FROM MIDDLE ÖLAND

Gladvattnet GLV 1

Description. The survey diagram with the ratio *AP/NAP* in group F shows four distinct diagram sectors: A lower one with high *NAP* values, a lower with very low *NAP* values, an upper with slightly higher *NAP* values and an upper sector with very high *NAP* values. If only the *AP* diagram is concerned the following main division can be made: A lower part with dominating *Betula* and *Pinus* curves, together with culmination of *Juniperus* and *Hippophaë* is succeeded by a *Pinus maximum*. Above this the *Corylus* curve rises succeeded by the *Alnus* immigration. With the appearance of the *Tilia* curve the *QM* increases and together with *Pinus* it dominates the diagram. After a sudden increase of *Myrica* and *Betula* these elements are diminishing again and are replaced by a violent increase of the *Juniperus* curve. In the uppermost two analyses *Picea* rises. Correlation. In the bottom part I have considered the dia-

gram to correspond to my zone A on the Great Alvar. Although the *NAP* values in analysis 2 are very high, I do not think that the diagram reaches an older stratigraphical unit than the mentioned one. Thus no lower limit of the zone has been defined.

Zone B. The peak in the sediment change $\frac{3}{4}$ is evidently due to a *hiatus*. This seems to include zone C and perhaps also a little of zone D and the bulk of zone B, which then is only present in one analysis (6). This is not a statistically satisfying diagram sector, and thus the interpretation of analysis 6 as zone B must be handled with care and considered to be very unsafe.

Zone D. Lower limit of the zone: The immigration of *Corylus*.

Zone E. Lower limit of the zone: The decrease in the *Betula* curve accompanied by an increase in the *QM*.

Zone F. The lower limit of the zone has been placed where the immigration of *Alnus* appears.

Zone G. The lower limit of the zone has been put where the immigration of *Tilia* appears.

Zone H. The *Ulmus* decline starts. The *NAP* curve rises slightly.

Zone J. The lower limit of the zone has been placed where the *Ulmus minimum* after its decline is reached.

Zone K seems to be lacking.

Zone L. The decrease in the *Juniperus* curve in analysis 33 is interpreted as the entrance to the zone.

Zone M. The lower limit has been put where the *Juniperus* curve rises again together with an increase in the *Picea* curve and a simultaneous rise in the *NAP* curve.

Zone N. The increase of the *Picea* curve appears at the lower zone limit together with a decrease in the curves for *Alnus* and *Quercus*.

Zone O. The lower zone limit has been placed at the rise of the *Picea* curve.

Stratigraphy. In the lowermost parts clay and clay-gyttja have been deposited, which happened in the zones A and B. In the upper part of zone B, there is a *hiatus* at the sediment change $\frac{3}{4}$, which contains most of zone B and the entire zone C, probably also parts of zone D.

From the mentioned sediment change and up to and including layer 7, lime gyttjas have been formed during the zones upper B, D, E, F, and G. During the zone H a peaty gyttja is deposited and later, above the zone change J/L, peat is formed. In the sediment change G/H there is a *hiatus*, which seems to include part of zone H only.

As the samples, according to the common methods during the early twenties, were not taken very densely, it is not possible to make more detailed observations about the sedimentology. It had been desirable to have had a more complete material especially in the lowest parts of the sequence. Landscape development. After the zone change $\frac{9}{10}$ the local vegetation in the fen seems to influence the diagram to such an extent that it is impossible to say anything about the landscape development apart from the appearance of pollen from cultivated plants, which, however, will be mentioned later.

In the first two zones there are very high values for *NAP*, which indicate the presence of an open landscape. After these two zones very low quantities of *NAP* were deposited and the forest landscape existed untouched till the *Ulmus* decline, when a slight increase in the amount of *NAP* indicates the entrance of a more open landscape fairly near the lake. Above the zone limit L/M this trend becomes accentuated in the pollen diagram, and the open landscape in the vicinity of Gladvattnet increased its area at that time.

THE SKEDE MOSE DIAGRAMS

Skede Mose S 11

Description. The diagram is characterized by a high *Pinus* curve in its lowest part and by high percentages for *Corylus*, *QM* and *Alnus* in its upper parts. The *NAP* curve is high in the bottom part, above this is a sector with very low *NAP* values and above this again the amount of *NAP* increases.

Correlation. The lowest part of the diagram represents a very local vegetation, a fen community, whose pollen production is very difficult to correlate even with pollen diagrams from very nearby situated localities, which have been analysed on gyttja material (Königsson 1968, p. 33). However, it is possible to place the diagram sector in the zones D–E because of the presence of *Corylus* and the non presence of *Alnus* in the sector. An attempt to distinguish these two zones' common limit seems to be meaningless.

Zone F. The lower limit has been put where the *Alnus* curve first appears. At the same time the stratigraphy changes from fen peat to lake marl and the pollen diagram can then be expected to reflect more regional conditions above this stratigraphical boundary.

Zone G. The lower zone limit has been put at the *Tilia* curve's appearance. At the same time there is a rapid increase in the other *QM* members' curves too and the *Corylus* curve also rises.

Zone H. The lower limit of the zone has been marked at the *Ulmus* decline.

Zone J. The lower zone limit has been put where the first *Ulmus minimum* appears after its decline.

Zone K. The lower limit of the zone has been marked at the second *Ulmus minimum* after the decline.

Zone L. The lower zone limit has been put where a new rise is registered for the *Ulmus*, *Quercus*, and *Tilia* curves, accompanied by a decrease in the *Corylus* curve. No upper zone limit has been distinguished as the plough soil, *Stratum confusum*, follows upon layer 11.

Stratigraphy. In the zones D–E the forming of a fen peat took place. After the stratigraphical change $\frac{1}{2}$, lake marl interrupted by two silt layers (3 and 5) appears in zone F and the lake marl deposition continues in the entire zone G. In the lower part of zone H there is still deposition of lake marl, which via a silt layer (7), which represents the zone limit H/J, transits into a lime gyttja. The deposition of this type of sediment continues till the upper part of zone K, where a peaty gyttja is deposited instead. Upon this a peat with some gyttja content rests, which in its upper part has the zone limit K/L.

Landscape development. Apart from the local diagram sector (D–E), which represents the vegetation of a local swampy pine wood, the zones reflect the vegetation around the basin. During the zones F and G the amount of *NAP* is very low, and forests predominated in the area around the former Skede Lake.

Slightly after the *Ulmus* decline a not very striking but still evident increase in the deposition of *NAP* occurs. Later on, in the zone limit H/J this trend becomes more significant and during zone K, there is a very marked increase. The configuration of the *NAP* curve indicates a gradually more open land, which has its *maximum* extension within the diagram in the middle of zone K, and thereafter it has a stagnant development. In the uppermost analysis it even diminishes.

Skede Mose S 19

Description. The diagram shows the same basic trend as the diagram Skede Mose S 11, but the very local diagram sector in the lower fen peat is not so extensive. The sediments, which for the narrow Skede Mose region and its vegetational history are more valuable than the bottom soil, thus are more extensive than in S 11. The development of the curves also seems to be more complete than in the former diagram.

The general aspect of the diagram is that it is divided by the *NAP* curve in one lower *NAP* rich, a middle *NAP* poor and an upper *NAP* rich sector. If only the *AP* section is concerned the *Pinus* curve dominates the diagram showing two distinct parts, one lower with a diminishing trend and one upper with a low, even and stable *Pinus* representation. Together with the decreasing *Pinus* values *Ulmus* and *Corylus*, later also *Alnus*, *Quercus* and *Tilia* increase. The low and stable upper *Pinus* curve is balanced by rather even and stable curves for *Corylus*, *QM*, and *Alnus*.

Correlation. Zone D. The lowermost part belongs to zone D as *Corylus* is present, *Alnus* is non present and the upper zone limit seems to have developed.

Zone E. The lower zone limit has been put where the *Corylus* curve gets a rise together with a decrease in the *Betula* curve and an increase in the *Ulmus* curve. The *Quercus* curve at the same time becomes continuous.

Zone F. The lower zone limit has been marked where the *Alnus* curve starts.

Zone G. The lower zone limit has been put where the *Tilia* curve starts.

Zone H. The lower zone limit has been marked where the *Ulmus* curve declines.

Zone J. The lower limit has been put at the first *Ulmus* minimum after the decline.

Zone K. The lower zone limit has been placed where the second *Ulmus* minimum appears.

Zone L. The lower zone limit has been marked where the *Juniperus* curve decreases, which is accompanied by a decline in the *Betula* and *Corylus* curves and by a simultaneous increase in *Pinus* and *QM*.

Stratigraphy. During the first part of the zone D the fen peat was formed. It is covered by a silt layer with some gyttja content and upon this a new silt layer is found. This layer belongs to zone E. In this zone the uppermost part contains a silt layer with lime gyttja content and upon this a silty lime gyttja. The latter layer continues through the entire zone F till the middle of zone G. In the upper part of the zone G a lime gyttja with increasing amount of detritus gyttja exists. The zone limit G/H has developed in a gastropod shell layer (9) and during the rest of the zone J a lime gyttja appears followed by a detritus gyttja and above this a peat with some gyttja substance and finally a destructed peat is found. The zone limit J/K lays in the gyttja containing peat and K/L in the peat.

Landscape development. Except for the bottom part where the high *NAP* means a very local vegetational formation connected to the *Ancylus* transgression within the Skede Mose area (cf. Königsson 1968), the amount of *NAP* is very low. During the *Ancylus* transgressive period a lake was formed west of the present *Ancylus* ridge (Figs. 90, 91) and the open landscape around this lake and its shore vegetation is reflected in the *NAP* curve.

After the end of the *Ancylus* transgression a closed forest covered the landscape and dominated the pollen production entirely. Not until the *Ulmus* decline there are any signs of increasing *NAP* values and even at that time the increase is very modest. By the entrance of zone J, however, the pic-

ture changes and a rapid increase in the *NAP* deposition follows with a maximum just above the zone limit J/K. The amount of *NAP* then decreases again and has its minimum in the zone L, together with the minima for *Betula*, *Juniperus* and *Corylus*. There is then a more open landscape during the zones J, K and L and a reafforestation period seems to occur in zone L. Unfortunately no younger soils have been pollen analysed from Skede Mose as the uppermost stratigraphical units were destroyed by ploughing.

Skede Mose S 22

Description. The diagram is characterized by very even and stable curves and by a dominance of *Betula*, *Corylus*, *Pinus*, *Quercus* and *Alnus*. The *Tilia* curve decreases through the diagram and the amount of *NAP* is high.

Correlation. Zone K is present but the lower limit has not been reached.

Zone L. The lower limit of the zone has been placed in analysis 7, where *Juniperus*, *Corylus* and *NAP* decrease. Stratigraphy. The peaty gyttja of zone K transits just in the zone limit K/L into a peat.

Landscape development. An open landscape is indicated by the high *NAP* values.

Skede Mose S 31

Description. The pollen diagram is dominated by *Betula*, *Corylus*, *Pinus*, *Quercus* and *Alnus*. The *NAP* values increase in the upper half of the diagram.

The macrodiaspore diagram is characterized by a lower part with oospores from *Characeae* and with *Najas marina* seeds and by an upper part with dominance of *Cladium mariscus* fruits. The same picture is seen also in S 37 and S 38.

Correlation. Zone H. The lower zone limit has not been reached in the analyses.

Zone J. The lower zone limit has been placed at the minimum values of *Ulmus* and where the *Betula* and *Alnus* curves get diminishing trends. At the same time *Quercus* rises. *Ulmus* culminates within the zone.

Zone K. The lower limit has been placed just before the *Pinus* peak and at the second *Ulmus* minimum. *QM* culminates in the zone limit and *Betula* has a minimum value. Just above the zone limit a minimum appears also in the *Corylus* curve.

Stratigraphy. In zone H a lime gyttja is deposited, which continues in the lowermost parts of zone J. The rest of this zone shows a more detritus gyttja containing lime gyttja and upon this is a gyttja followed by a peaty gyttja. The limit between this unit and the peat was put in analysis 11 and the zone limit J/K has been placed in the same analysis. The rest of the stratigraphy is occupied by the peat and by *Stratum confusum*.

Landscape development. In the middle of zone J an increase in *NAP* appears, which accentuated continues in zone K. It is then evident that a somewhat more open landscape was created with a beginning in the middle of zone J but which had its maximum extension within the period covered by this diagram in zone K.

Skede Mose S 32

Description. According to the *NAP* values the diagram may be divided into two main parts, the older one with low values, the upper one with higher. If only the *AP* section is considered there is a lower part with higher *Pinus* and *Betula* curves but with low *QM*, a middle part with culminating

Corylus and *QM* combined with lower values for *Pinus* and *Betula*, and an upper part with again increasing curves for *Pinus* and *Quercus*.

Correlation. Zone F. The lower zone limit has been placed where the *Tilia* curve starts.

Zone H. The lower zone limit has been marked at the *Ulmus* decline.

Zone J. The lower zone limit has been put at the first *Ulmus minimum* after its decline.

Zone K. The lower zone limit has been marked at the second *Ulmus minimum* after its decline. The upper zone limit does not seem to be present in the diagram.

Stratigraphy. In the lowest parts of the sequence lake marl with silt layers has been deposited. It entirely belongs to zone F and the lime gyttja formation, which continues through zone G starts just below the zone limit F/G. In the zone limit G/H a gastropod shell layer (5) is found and above this there is a continued lime gyttja sedimentation to the middle of zone J, whereafter a gyttja, later with increasing amount of peat detritus, is formed. The zone limit J/K is in the middle of the peaty gyttja and upon this is a peat. In the uppermost part of the sequence *Stratum confusum* follows to the top.

Landscape development. A low productive period as to the amount of *NAP* exists from what is represented in this diagram of zone F to the upper part of zone J, where an increasing trend in the *NAP* succeeds. This trend becomes accentuated above the zone limit J/K. A forest landscape during the periods F—middle J seems to be more open upwards.

Skede Mose S 33

Description. The diagram is characterized by an increasing *NAP* curve in the uppermost parts and by a *QM* curve which increases throughout the whole diagram.

Correlation. Zone H. The lower limit of the zone has not been reached.

Zone J. The lower limit of the zone has been placed at the first *minimum* in the *Ulmus* curve after the *Ulmus* decline. The limit is very well developed in this diagram.

Zone K. The lower limit of the zone was placed at the second *Ulmus minimum* after the decline. The upper limit of the zone is not present in the diagram.

Stratigraphy. In what is present in the diagram of zone H a lime gyttja exists. This layer continues also in the lowest parts of zone J and in the upper parts of this zone a gyttja with a gradually increasing amount of peat detritus occurs. The change gyttja/peat (4/5) coincides with the zone limit J/K. Above the layer 5, *Stratum confusum* follows.

Landscape development. The increase in the amount of *NAP* comes in this diagram nearer to the zone limit J/K than has been observed in the other diagrams. It, however, still occurs within the zone J, and the more open landscape type increases its extensiveness from this time and upwards.

Skede Mose S 34

Description. In this diagram the amount of *NAP* increases in the middle of the diagram from very low values in the lower parts. The *AP* section shows high *Corylus* and *QM* values in the bottom part, and *Corylus* then diminishes. *QM* has a *minimum* in the middle of the diagram accompanied by a culmination in *Betula* and *Alnus*. In the uppermost part *Pinus* and *QM* increase.

Correlation. Zone G. The lower limit of the zone has not been reached.

Zone H. The lower limit of the zone has been put where the *Ulmus* decline appears.

Zone J. The lower zone limit has been marked at the first *Ulmus minimum* after the decline.

Zone K. The lower limit of the zone has been placed at the second *Ulmus minimum* after the decline. The upper limit of the zone has not been reached.

Stratigraphy. During the present part of zone G a lime gyttja is deposited and above this is a gastropod shell layer. The zone limit G/H is between analyses 2 and 3, and the shell layer is also between these two analyses. According to the evidences in S 19 and S 32 I then consider the zone limit to coincide with the shell layer. During zone H and zone J there is a lime gyttja deposition. The uppermost part of the layer has an increasing amount of peat detritus in it. Just before the zone limit J/K the lowest part of the peat was formed. The peat formation continues above the zone limit. Upwards from the peat layer *Stratum confusum* completes the stratigraphy.

Landscape development. Up to the middle of zone J there is a very low deposition of *NAP*. Above this limit the amount of *NAP* increases. The forest landscape becomes gradually more open from the middle of the zone J and upwards.

Skede Mose S 35

Description. The diagram has an increasing amount of *NAP* from its middle parts and upwards. The curves for *Betula* and *Corylus* diminish throughout the diagram, whereas the opposite is true for *Pinus* and *QM*.

Correlation. Zone H. The lower limit of the zone has not been reached.

Zone J. The lower limit has been put at the first *Ulmus minimum* after the *Ulmus* decline.

Zone K. The lower zone limit has been marked at the second *Ulmus minimum* after the *Ulmus* decline. The upper limit of the zone has not been reached.

Stratigraphy. According to the evidences from S 19 and S 32 I consider the layer 2, the gastropod shell layer, to have been formed in the zone limit G/H. Above this layer and during zone H and also most parts of zone J a lime gyttja is formed. In the uppermost parts of zone J the stratigraphy changes from lime gyttja to peaty gyttja and then to peat. In the present parts of zone K only peat is found. *Stratum confusum* continues to the top of the sequence.

Landscape development. The *NAP* increase starts in the upper part of zone J. From this time the forest landscape of the Skede Mose's surroundings gradually become more open.

Skede Mose S 36

Description. The *NAP* curve shows a lower part with low values and an upper part with increasing values. In the *AP* section *Betula* and *Alnus* show diminishing values throughout the diagram, *Pinus* and *QM* increasing.

Correlation. Zone J. It is possible that the lower zone limit is present in the diagram, but the first *Ulmus minimum* after the *Ulmus* decline is then not very well developed. If it is present it should be placed in analysis 2 as the curve configuration of *Pinus* and *Alnus* then supports this interpretation to a certain degree. However, I do not think that the lower limit has been reached.

Zone K. The lower zone limit has been placed where the second *Ulmus minimum* after the *Ulmus* decline appears. The upper limit of the zone does not seem to be reached.

Stratigraphy. In the first part of the zone J there is still lime gyttja formation. The gyttja and peaty gyttja follow

and before the zone limit J/K the peaty gyttja transits into peat. From the peat and to the top of the sequence *Stratum confusum* follows.

Landscape development. In the upper part of the zone J

the amount of *NAP* increases, and this trend continues through zone K. The forest landscape around Skede Mose then became more open from the later part of zone J and this openness increased during zone K.

Skede Mose S 37

Description. In the upper part of the diagram the *NAP* curve rises. In the *AP* section there is an increasing trend throughout the diagram for the *QM* curve and decreasing for the *Betula*, *Corylus* and *Alnus* curves. The macrodiaspore diagram shows the same basic picture as S 31 and S 38.

Correlation. Zone H. The lower limit of the zone has not been reached.

Zone J. The lower limit of the zone was put where the first *Ulmus minimum* after the *Ulmus* decline appears.

Zone K. The lower limit of the zone was placed where the second *Ulmus minimum* after the *Ulmus* decline occurs. The upper zone limit has not been reached.

Stratigraphy. In the present part of zone H a lime gyttja has been deposited. This sedimentation continues during the first part of zone H and is then succeeded by a gyttja, which transits into a peat. The zone limit J/H is then in the peat layer. From this layer's upper limit and to the top of the sequence is *Stratum confusum*.

Landscape development. The *NAP* curve rises in the later part of zone J. The forest landscape of the Skede Mose area then becomes a more open impression from this time.

Skede Mose S 38

Description. The diagram is characterized by the rapidly increasing *Pinus* curve and the diminishing *Betula*, *Corylus* and *Alnus* curves. The *NAP* curve increases from the middle of the diagram.

The macrodiaspore diagram shows the same basic picture as S 31 and S 37.

Correlation. The whole diagram belongs to zone J. Neither the lower nor the upper zone limit has been reached.

Stratigraphy. In the middle of the diagram and in the middle of the zone as well a peaty gyttja transits into peat. From the peat layer's upper limit to the top of the sequence is *Stratum confusum*.

Landscape development. In the middle of the diagram the change from low to increasing *NAP* values appears. This takes place in the middle of zone J, and from this time on a gradually more open landscape develops in the Skede Mose area.

Skede Mose S 50

Description. The diagram is characterized by a very dominating *Pinus* curve in the lower parts, and by increasing values for *Alnus*, *Corylus* and *QM* into the upper part (Fig. 90).

Correlation. Zone D. The zones D/E are very difficult to distinguish as the lowest parts of this diagram have been worked out in a fen peat where utmost local vegetational results can be yielded from the pollen analyses. However, if the diagram is compared with S 19, there seem to be enough details which coincide in the two diagrams to justify a proposition of the defining of the zone limit D/E to analysis 8/9. The lower zone limit has not been reached.

Zone E. The lower zone limit has been placed after a decline in the *Betula* curve, which takes place together with a simultaneous increase in the curves for *Corylus* and *Ulmus*.

Zone F. The lower zone limit has been placed where the *Alnus* curve first appears.

Zone G. The lower zone limit has been placed where the *Tilia* curve starts.

Zone H. The lower zone limit has been placed where the *Ulmus* declines.

Zone J. The lower zone limit has been marked where the first *Ulmus minimum* after the *Ulmus* decline appears.

Zone K. The lower limit has been put at the second *Ulmus minimum* after the *Ulmus* decline.

Zone L. The zone limit has been marked in analysis 33. I am not 100% sure of this limit, but I consider that enough details coincide in this diagram to defend my interpretation of this zone limit being put there. If the diagram is compared with S 19, I want to stress the curves for *Corylus*, *Betula* and *QM* (with components) in the two diagrams. The *NAP* curve speaks against the interpretation.

Stratigraphy. During zone D the fen peat and the lower lime gyttja was formed. In zone E a silty layer with lime gyttja layers interrupting it was formed. This layer corresponds to the distal part of the *Ancylus* ridge (cf. Königsson 1968). Also in zones F and the lowest G, silt was deposited. The interpretation of these late silt depositions is unsafe, but I have as a theory assumed them to be outwash from the ridge. Up till now no diatom analyses have been performed to support or contradict the theory.

From the middle of zone G and upwards, lake sediments and fen soils are to be found. In the rest of zone G there is a lime gyttja succeeded in the zones H and J by peaty gyttjas and finally by peat, which happens from zone K and upwards. From the top of this layer and during the remaining part of the sequence there is *Stratum confusum*.

Landscape development. Apart from the lowest diagram sector, where the vegetational events were discussed in detail in Königsson (1968), the diagram from zone G and upwards shows remarkably few pronounced features in the *NAP* curve. There is, however, in the zone limit G/H an increase in the amount of *NAP*, which can also be seen in S 19, but less marked. There then seems to have existed a period, just at this zone change, when a more open landscape was created, but the duration of the formation seems to have been rather short. Then, near the zone limit J/K a new increase remains throughout the diagram. This means that a new opening period started, which at least lasted as long as the time represented by the remaining diagram part.

Skede Mose S 54

Description. The diagram is characterized by a dominant *Pinus* curve and by an increasing *Betula* curve in the upper part (Fig. 91).

Correlation. The diagram belongs to zones D–E and by comparing it with S 50, which was collected only some five metres north of S 54, it is possible to place it in zone D. (This interpretation is, however, to a very high degree made upon stratigraphical facts. The diagram is also a special diagram, which has been worked out to elucidate the vegetational event connected with the stratigraphical change $\frac{3}{4}$ in S 50, see also Königsson 1968, pp. 18, 19, 21.) It has not been possible to find either the lower or the higher limits of the zone.

Stratigraphy. A fen peat, which is succeeded by a lime gyttja, was formed during zone D.

Landscape development. The very local diagram in the fen peat reflects the vegetational environment within its source community. After the soil change, the diagram more reflects a vegetation around the Skede Mose basin and the relatively high *NAP* values indicate a fairly open landscape around the lake during the later part of zone D, if it is compared with the *NAP* amounts in the diagram S 19.

Skede Mose S 59

Description. If the *NAP* curve is considered there is an upwards increasing trend throughout the diagram, however,

Melösa, Bredsättra sn. Öland MÖ 1

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Fig. 94. The pollen diagram Norra_Kvineby NK 1.

Fig. 93. The pollen diagram Övra Sandby ÖS 1.

Fig. 95. The pollen diagram Triberga Bro TB 1.

Fig. 96. The pollen diagram Triberga Bro TB 3.

with fairly low values in the lowermost analyses. If only the *AP* section is treated there is a slightly diminishing trend in the *Corylus* and *Alnus* curves, while the *Pinus* curve increases. The *QM* curve first declines but has then a very marked culmination in the upper part of the diagram.

Correlation. Zone H. The lower limit of the zone has not been reached.

Zone J. The lower limit has been put where the first *Ulmus minimum* after the *Ulmus* decline appears.

Zone K. The lower limit has been marked where the second *Ulmus minimum* after the *Ulmus* decline appears. The upper zone limit has not been reached.

Stratigraphy. In zone H and in the lowermost parts of zone J a gyttja was deposited. Upwards the gyttja gradually transits into a peaty gyttja and then into a gyttja containing peat. Finally a pure peat was formed. In the upper part of the peaty layer the zone limit J/K is found.

Landscape development. Just below the middle of zone J, the amount of *NAP* increases and this trend continues through the rest of the zone. The forest landscape, which predominated in the Skede Mose area gets a more open aspect from the middle of the zone J and remains so during the period, which is covered by this diagram.

THE DIAGRAMS FROM THE SHORE RIDGES OF EASTERN ÖLAND

These diagrams, which have been published before, are again discussed for special comparisons. The zone systems used in the earlier publication (Königsson 1968) have been removed and the zones used in this paper have instead been marked. The construction of these diagrams differs from the others (Together with the following diagrams also the diagrams S 50 and S 54 were included in the mentioned paper), which has been considered to be of minor importance for the coming discussion. The diagram from Silverbäcken has not been published before.

Melösa MÖ 1

Description. The diagram is characterized by low *NAP* values, by increasing curves for *Corylus*, *QM* and *Alnus* and by a decreasing *Pinus* curve (Fig. 92).

Correlation. Zone F. The *Tilia* curve has its lower limit in the middle of the diagram. Thus zone F persists in the lower half of the diagram. The lower limit of the zone has not been reached.

Zone G. The lower limit of the zone has been marked where the *Tilia* curve rises. The upper zone limit has not been reached.

Stratigraphy and landscape development. The discussion in Königsson 1968 (pp. 31, 32) is referred to.

Övra Sandby ÖS 1

Description. The diagram is characterized by an enormous *Salix* curve in the lower parts. The *Corylus* and *QM* curves increase throughout the diagram. The amount of *NAP* is low (Fig. 93).

Correlation. Zone F. *Tilia* has its lower limit in the diagram and below this zone F persists. No lower limit for this zone has been reached.

Zone G. The lower zone limit has been placed at the *Tilia* curve's rise. The upper zone limit has not been reached. **Stratigraphy and landscape development.** The discussion in Königsson 1968 (pp. 31, 32) is referred to.

Silverbäcken SB 1

Description. The diagram is characterized by a rather high *Pinus* curve, by a very high *NAP* curve in the upper part of the diagram and by increasing *Salix*, *Juniperus* and *Picea* values together with the *NAP* increase.

Correlation. The correlation of this diagram with the others treated in this paper, offers difficulties as the diagram belongs to a type reflecting an extremely local vegetation. The zonation in the stratigraphical unit 3 is very uncertain. In spite of the C_{14} dating, which places the layer at 4300 radiocarbon years BP, I have with much doubt put the layer in zone L, which has been made with a question mark after the zone designation. The reason for this treatment of the mentioned C_{14} dating will be further discussed below.

Zone L (?) The lower zone limit has not been reached.

Zone M. The lower zone limit has been placed where the pregnant rise appears in the *Juniperus* curve simultaneously together with the *Picea* increase.

Zone N. The lower limit has been placed at the decrease in the curves for *Juniperus* and *QM* together with a less pregnant increase in the *Picea* curve.

Zone O. The lower limit of the zone has been placed at the increase in the *Picea* curve, which takes place together with a decrease in the curves for *Betula*, *Juniperus* and *NAP*. **Stratigraphy.** During zone L (?) a *stratum* which has been interpreted as a totally decomposed peat layer was formed. During the zones N and M, a silt deposition interrupted by gyttja and clay sedimentations of short duration occurred. In what has been analysed of zone O a peaty gyttja was deposited.

Landscape development. In zone L (?) the low *NAP* amount indicates a forest cover around the site. The *NAP* values during the zones M and N reflect the open landscape on the shores near the site and the fairly high *NAP* values of zone O indicate an open landscape type.

Norra Kvinneby NK 1

Description. The diagram is characterized by a very high *Pinus* curve accompanied by a high amount of *NAP* in the lower part of the diagram. In the upper parts *Betula*, *Corylus* and *QM* increase and the amount of *NAP* diminishes (Fig. 94).

Correlation. As *Corylus* but not *Alnus* is present in the diagram it belongs to zones D or E. According to the configuration of the *Betula* and *Corylus* curves in the gyttja part of the stratigraphy it seems clear that the entire diagram belongs to zone D. Neither the lower nor the upper zone limit has been reached.

Stratigraphy and landscape development. The discussion in Königsson 1968 (pp. 26, 27) is referred to.

Triberga Bro

Triberga Bro TB 1

Description. The diagram is characterized by a high *Pinus* curve, which in the middle of the diagram has a very marked *minimum* corresponding to a *maximum* in the *Betula* curve. The *Corylus* curve increases throughout the diagram (Fig. 95).

Correlation. As *Corylus* is present in the diagram but not *Alnus* the diagram belongs to the zones D or E. There is, however, no definite signs that it belongs to zone E, which is supported by the diagram TB 3, sampled some twenty metres more westerly, and I have thus considered the entire diagram TB 1 to belong to zone D.

Table 1. C_{14} -Datings.
The following C_{14} datings have been performed:

Sample Nr	Dating Nr	Pollen Diagram or Samples Series	$T_{1/2} = 5570$	$T_{1/2} = 5730$
Skede Mose				
13 G	St. 1297	S 31	3775 ± 95	3888 ± 95
14 G	St. 1298	S 31	4075 ± 85	4197 ± 85
15 G	St. 1299	S 32	8470 ± 210	8683 ± 210
20 G	St. 1300	S 36	3880 ± 75	3996 ± 75
21 G	St. 1301	S 36	4310 ± 75	4439 ± 75
513 G	St. 1349	S 50	8735 ± 110	8997 ± 110
2 G	St. 1821	S 19	1780 ± 75	1833 ± 75
3 G	St. 1823	S 19	9080 ± 145	9363 ± 145
11 G	St. 1825	S 31	2935 ± 100	3023 ± 100
12 G	St. 1826	S 31	3520 ± 70	3626 ± 70
16 G	St. 1827	S 36	3700 ± 100	3811 ± 100
17 G	St. 1828	S 36	4025 ± 100	4146 ± 100
18 G	St. 1829	S 36	3890 ± 80	4007 ± 80
19 G	St. 1830	S 36	3855 ± 95	3970 ± 95
Silverbäcken				
548.5	St. 2381	SB 1	565 ± 100	581 ± 100
547.5	St. 2380	SB 1	625 ± 100	685 ± 100
551	St. 1379	SB 1	4360 ± 100	4491 ± 100
545	St. 2378	SB 1	2070 ± 100	2132 ± 100
Torpmsen				
1095				
1097	U 444	TM 1	4080 ± 90	4202 ± 90
400	U 1003	TM 1	1110 ± 50	1184 ± 50
397	U 484	TM 1	540 ± 70	556 ± 70
397	U 1017	TM 1	620 ± 40	639 ± 40
Stormaren				
60/70	U 635	STM 3	2310 ± 80	2370 ± 80
70/75	U 633	STM 3	4620 ± 90	4751 ± 90
70/80	U 2090	STM 3	4120 ± 100	4240 ± 100
80/85	U 637	STM 3	4570 ± 80	4700 ± 80
85/90	U 634	STM 3	5550 ± 100	5710 ± 100
90/97	U 636	STM 3	6360 ± 100	6540 ± 100
75/80	U 638	STM 3 (humus)	5870 ± 120	6030 ± 120
Excavation — charcoal				
F 114.1	U 654	KB	1430 ± 70	1480 ± 70
F 124.1	U 653	KB	1710 ± 70	1760 ± 70
F 124.3	U 662	KB	1640 ± 70	1690 ± 70
F 114.2	U 2063	KB	1630 ± 100	1680 ± 100
F 124.2	U 649	KB	1800 ± 80	1850 ± 80
Melösa				
494	U 488	Mel 1	7650 ± 120	7879 ± 120
493	U 489	Mel 1	7570 ± 120	7797 ± 120
493	U 1016	Mel 1	7750 ± 70	7983 ± 70
483	U 485	Mel 1	6570 ± 180	6767 ± 180
483	U 571	Mel 1	6410 ± 110	6602 ± 110
Övra Sandby				
544	U 486	ÖS 1	7480 ± 90	7704 ± 90
497	U 495	ÖS 1	6510 ± 110	6705 ± 110
497	U 514	ÖS 1	6910 ± 110	7117 ± 110
Recent Vegetation Samples				
			$\delta C 13$	Δ
Dröstorpe, submerged plants	U 2072		- 30.9	579.1 ± 11.6
Dröstorpe, <i>Carex elata</i>	U 651		- 28.1	699.5 ± 12.6
Little pond, <i>Characeae</i>	U 2068		- 28.7	406.3 ± 11.4
Dröstorpe, floating plants	U 2083		- 32.4	556.0 ± 11.4
Dröstorpe, <i>Characeae</i>	U 652		- 21.4	457.1 ± 9.0

Stratigraphy and landscape development. The discussion in Königsson 1968 (pp. 26, 27) is referred to.

Triberga Bro TB 3.

Description. In the lowermost part of the diagram the *Pinus* curve is very high, but as it decreases the *Betula*, *Corylus* and *Q*M curves increase and all the mentioned curves remain rather stable in the rest of the diagram (Fig. 96). Correlation. As in TB 1 *Corylus* but not *Alnus* is present in the diagram and it thus belongs to zones D or E. The configuration of the *Corylus* and *Betula* curves indicates that the entire diagram belongs to zone D and this interpretation is supported by the *Quercus* and *Ulmus* curves as they have developed in TB 3.

Stratigraphy and landscape development. The discussion in Königsson 1968 (pp. 26, 27) is referred to.

C₁₄-Datings and the Zone Systems

Those St.-numbered datings, which have already been published in Radiocarbon will be found in Volumes 4, 5, 7 and 9 while the U-numbered datings may be found in Volumes 7 and 9 (Stockholm IV: Östlund & Engstrand 1962, Stockholm V: Östlund & Engstrand 1963, Stockholm VI: Engstrand 1965, Stockholm VII: Engstrand 1967, Uppsala V: Olsson & Piyanuj 1965, Uppsala VII: Olsson, Stenberg and Göksu 1967).

Many of the datings have been worked out on soil samples as it is difficult to get wood samples in all desired stratigraphical positions.

It has long been known that calcareous sediments often yield too old radiocarbon ages when analysed. This is on Öland dependent on the submerged plants' ability to use the C₁₄ inactive carbon dissolved into the water from the CaCO₃ of the Ordovician limestone bedrock. However, it seems as though other gyttjas than the lime gyttjas show too old radiocarbon age on Öland, and that to a certain degree this is true also for the thelmatic peats.

In the pollen diagrams S 31 and S 36 two series of C₁₄ datings have been marked. All these datings were performed on peat or gyttja, and these soils showed very little traces of lime when they were treated with HCl, or showed no reaction at all. The zone limit J/K, which has been marked at the second *Ulmus minimum* after the *Ulmus* decline, has in these two diagrams the following datings: 3775 ± 95 radiocarbon years BP (analysis 12, S 31) and 3885 ± 95 radiocarbon years BP (analyses 12/13, S 36).

In the diagram S 19, however, where a wooden stick has been dated at the same zone limit, the age is 1780 ± 75 radiocarbon years BP. Together with this zone limit the *Secale* curve starts, and this plant has been cultivated in Scandinavia since the first centuries after Christ (cf. Helbaek 1938, pp. 220,

226, Mikkelsen 1952, p. 122, Fries 1958, p. 54. See also Hjelmqvist 1955, pp. 142, 143). It seems most probable that the dating in S 19 gives a more correct age, and it is then evident that the datings of the soils in S 31 and S 36 have got too old radiocarbon ages.

Greatest care must be taken when dating sediments and thelmatic peats in areas with limestone bedrock, and if possible only wooden samples should be used (cf. Fries 1958, pp. 40–42).

In order to elucidate the circumstances of the contamination of the soils with C₁₄ inactive carbon, datings of several recent plant types and communities have been started. This investigation is carried out in cooperation with Dr. Ingrid U. Olsson, head of the C₁₄ laboratory at Uppsala, and certain experiments have also been initiated. The first results are now available and they are shown in the datings U 2072, U 651, U 2068, U 2083 and U 652. It seems as if the floating plants and the submerged plants have a similar radiocarbon activity. This activity is considerably lower than that of a *Carex* sample and also considerably higher than those of the *Characeae* samples.

This means that both floating and submerged plants use some of the C₁₄ inactive carbon in the water. Whether this is true to a certain degree for the *Carex* too, is not possible to judge from these figures.

As most thelmatic peats have a gyttja component in them these soils should also, if possible, be avoided for radiocarbon dating.

I have then decided not to trust those of my datings, which have been worked out on soils, till the results of the experiments and the extended series of the dating of recent vegetation samples have been worked out. Only those of my datings, which have been performed on wooden material will be used. However, the soil datings will be further mentioned below together with a survey of existing zone datings from southern Sweden.

With this restriction in the use of my C₁₄-datings only three results remain to be used for the discussion of the zones and their time limits. However this restriction was necessary to make. Instead I have had to correlate my diagrams with the available material from southern Sweden, and I have made a general survey of this material which has been summarized on Fig. 97 a. Together with this summary the recurrence surfaces of Granlund (1932) and the Swedish archaeologic division as proposed by Stenberger (1964) are given. When correlating the diagram material from a special area with diagrams from greater regions errors may occur as the correlated zone lim-

Fig. 97 a. A diagram showing zone systems and other diagram features of interest for this paper. The diagram is treated on the pages 121–123. Designations: P/B — *Pinus/Betula* crossing, BM — *Betula maximum*, + means increasing, — decreasing. Co° means the limit of *Corylus*, R- and E-indexes means rational and empiric limits. Pin — *Pinus*, Pc — *Picea*, T — *Tilia*, A — *Alnus*, U — *Ulmus*, Fag — *Fagus*, Q — *Quercus*, Bet — *Betula*, QM — *Quercetum Mixtum*, Sec — *Secale*.

its do not necessarily have to be synchronous all over the region. This has already been noted above (p. 104).

In the first column the time scale is given and in the second column, which has been subdivided into three columns, my local zones and the Danish (Jessen's) have been marked in the first two. The Danish zones have then been adapted to their most probable time limits by transference to the dated zone systems of Skåne and Blekinge (T. Nilsson 1964, and Berglund 1966). Blekinge is a province, which is situated very near the southern parts of Öland, and because of this Berglund's time scale for his zones is considered to be very valuable for the discussion of age circumstances in the diagrams from Öland. In my third column, finally, I have marked my three remaining C_{14} -datings.

In column 2, the zone system of von Post (1925) for the island of Gotland is given, which was used by G. Lundqvist in his work on the fens of Öland (1928). However, von Post's description of his system and also of the zone limits was brief, partly even fragmentary, and because of this it has not been possible to give all zone limit characteristics. The

Fig. 97 b. Map showing the position of the provinces treated in the diagram 97 a.

time limits of von Post's zones are the ones given by Fries (1951, p. 121).

Column 3 shows Jessen's original zones (1935, 1938) and the time limits are identical with those given for this system by Fries (1951, p. 121).

Column 4 gives Fries' system, which is Jessen's zones adapted to the local conditions in northwestern Götaland (the material emanates from the provinces of Västergötland, Dalsland and Bohuslän).

Column 5 shows Jørgensen's (1954) proposition for new zone characteristics for the Danish zones VI and VII.

Column 6 shows T. Nilsson's original Skåne zones (1935), while his new-named zones are given in column 7, where the time of the zone limits is based upon a great number of C_{14} -datings.

Column 8 gives the zones and their radiocarbon ages given by Magnusson (1964). His work was carried out in the northwestern part of the province of Östergötland.

In column 9 Berglund's zones from Blekinge and their radiocarbon datings are given (Berglund 1966). Also his zones have been based upon a great number of C_{14} datings. Together with T. Nilsson's work also Berglund's paper offers the most excellent example of an exemplarily realized study in this respect.

In the following three columns single datings of interesting vegetational events are given, namely in column 10: a dating of the zone limit VII/VIII (Jessen) from Södermanland (M.-B. Florin, 1957), in column 11: a dating of the beginning of the *Secale* curve and of a violent *Juniperus* increase in northwestern Östergötland (Helmfrid, 1958) and in column 12: dating of the *Juniperus* increase and the beginning of the *Picea* curve on the Åland islands, Finland (Fries, 1961).

Finally the mentioned recurrence surfaces are shown in column 13 and the archaeologic division in column 14. An index map of the named Swedish provinces is also included in the figure (Fig. 97 b).

As stated above I have correlated my local zones with Berglund's and with T. Nilsson's. However, for some of my zones no corresponding datings are available. This is especially true of my preboreal zones A, B, and C, which can be distinguished in some of Berglund's diagrams, i.e. Bäckes mosse and Storemosse. My zone limit D/E may also be found in some diagrams as in analysis 17 in Färskesjön and in analysis 8 in Bäckes mosse, but no direct datings have been placed at these points in the diagrams.

My own datings of the empiric limit of *Alnus* shows two very different values, the upper one well corresponding with T. Nilsson's zone limit BO 1/BO 2, the other one considerably older.

The Atlantic time has been divided into two zones in Blekinge and in Skåne. On Öland the sediments from the Atlantic time are almost lacking on the Great Alvar. In Skede Mose and in Gladvattnet the period is well developed but the zone limit AT 1/AT 2 does not seem to be very clear. Instead Jørgensen's defined zone limit VI/VII is very easily seen and should be placed in analysis 23 in Gladvattnet, 33 in S 19 and 21 in S 11. This limit has, however, not been marked on the diagrams or in the figure.

The value for the transition VII/VIII (G/H) has been placed at T. Nilsson's and Berglund's zone limit AT 2/SB 1.

The upper limit of zone H is problematic. There is no directly corresponding niveau in the diagrams. I have tried to follow the *Ulmus* curve in the Blekinge diagrams, but no quite clear examples have appeared. The best example is offered by Bäckes mosse, where the *Ulmus* curve after its first decline shows four distinct *Ulmus minima*, two of which have been dated, the oldest to 2920 ± 75 BC, the slightly younger one to 2580 ± 80 BC. The third marks the transition SB 1/SB 2 (where also the empiric *Carpinus* limit is to be found), and the fourth is up in the Sub-atlantic zone. Because of the *Carpinus* curve it is most probable that one of the older two *minima* corresponds to my H/J limit, but it is impossible to rule out which one it really is. I therefore mark the zone limit as a broad limit covering the time between the two datings.

Zone J/K has a C_{14} -dating from S 19, which gives 1833 ± 75 radiocarbon years BP (117 ± 75 AD). This zone limit also covers an increase in the *NAP* curve. In Storemosse (Berglund 1966) a diagram sector around the dating U-447 (320 ± 80 AD) seems to correspond rather well with the zone change J/K, and I therefore have placed my zone limit in accordance with the mentioned dating from S 19.

The transition K/L is marked in the diagrams from the Great Alvar by a very pregnant *Juniperus* curve, which starts an increase during the zone J together with a simultaneous increase in the *NAP* curve. The two curves then diminish in and above the zone change K/L. In the diagrams from middle Öland, the *Juniperus* decrease is less pregnant, but the accompanying *NAP* decrease is normally evident. A soil dating from Torpmosen on the Great Alvar (gyttja containing peat in TM 1) gave 776 ± 90 AD for a level just above the decrease. A similar picture of the *Juniperus* and *NAP* curves may also be found in some of Berglund's diagrams and in a few others a very pregnant *NAP* decrease occurs but no *Juniperus* curve exists before, during or after this decrease. In Storemosse this is the case

and a dating 720 ± 50 AD marks the beginning of the *NAP* decrease. This time for the zone limit also corresponds with T. Nilsson's and Berglund's zone change SA 1/SA 2.

The zone change M/N has got a soil dating just above the limit, in Torpmosen (the same gyttja containing peat), which gave 1330 ± 40 and 1410 ± 70 AD. In the Blekinge diagrams a corresponding value in Storemosse gave 1180 ± 50 AD and Bredasund 940 ± 165 AD. It then seems probable to place this zone limit somewhere around 1,000–1,100 AD. The C_{14} -datings from Torpmosen are however, not proving anything, as they represent thelmatic environment (p.m.).

The zone limit M/N is difficult to establish in the Skåne and Blekinge diagrams and I have placed it around 1,300 AD. This has been made with much doubt and partly because of the datings of the *Picea* curve in Silverbäcken, where gyttja datings gave $1,379 \pm 100$ and $1,275 \pm 100$ AD. These are the only indications I have and in spite of their uncertainty (p.m.) I use them but more as an experiment. On the other hand the limit has got to be placed after the zone limit L/M (1,000–1,100 AD) and before the limit N/O discussed below, and it does not seem unreasonable to expect this limit in the mentioned time.

The zone limit N/O, finally, is considered to correspond to T. Nilsson's and Berglund's uppermost Pc-limits, which have been placed around 1500 AD both in the Skåne diagrams and in those from Blekinge.

The Vegetational History of Middle Öland Reflected in the Pollen Diagrams

The woods of the island of today have been described summarily on pp. 19–21. It should be added that the woods of middle Öland form the greatest area in all Sweden with continuous deciduous woods.

On the basis of pollen diagrams G. Lundqvist gave an outline of the island's forest history (1928). His work mainly covered the pre-historic and early historic times and the latest changes were very seldom found in his diagrams. Danielsson (1918) reviewed what could be seen in the archives and on old maps of late changes in the forest cover of Öland, and additional information in this respect was quite recently given by Sjögren (1964).

Lundqvist gives a summary of his results and together with a review of these results one of his diagrams is republished in this paper. The diagram from

Mossberga Mose (= Gladvattnet) has been redrawn and *Corylus*, which by G. Lundqvist was kept outside the *AP* sum, has here been calculated within the sum. The limits of the Danish zones have been based upon the reanalysed original material of this diagram. It should be noted that G. Lundqvist only analysed the lower 44 samples in his series. He considered the pollen content to be so destructed that there was no possibility of continuing the analysis work higher up in the sequence.

According to G. Lundqvist *Picea* was found in the oldest zones but he considered that it did not grow on the island until in zone V (VII, Jessen) and later during zone IV (lower VIII, Jessen) it was growing all over the island. Its expected increase during the early Iron Age was not so marked as in other areas of Sweden, and it seemed to diminish from the middle of Subatlantic time and upwards except in the Alvar areas on southern Öland.

Pinus was a common tree during the older zones but during the warmer periods the amount of *Pinus* pollen decreased to such an extent that G. Lundqvist even thought that it could be entirely missing in some parts. From period 5 of the Bronze Age the *Pinus* pollen again increased, which was interpreted as partly depending on the gradually diminishing general forest cover.

Betula shows a *maximum* during zone IX (IV, Jessen), and partly remained so during zone VIII (V, Jessen). In zone III (upper VIII, Jessen) the *Betula* curve rose again and decreased in the youngest two zones (IX, Jessen).

Alnus occurs scattered in zones X and IX (III and IV, Jessen), and sometimes also in zone VIII (V, Jessen). Its lower limit is in zone VII (lower VI, Jessen), and it shows two distinct *minima*, the first in zone VI and the second in zone V (upper VI and lower VII, Jessen), the second in zone IV (lower VIII, Jessen). Also during the younger Bronze Age there are such high percentages that G. Lundqvist thought that *Alnus* was a dominating species in the woods.

Ulmus shows a continuous curve during zone VIII (V, Jessen). At this time scattered *Quercus* pollen also occurs. From zone V (VII, Jessen) the *Quercus* curve dominates over *Ulmus* and *Tilia*. *Quercus* shows its *maximum* during zone IV (lower VIII, Jessen), while *Ulmus* culminates during zone V (VIII, Jessen). *Tilia* occurs scattered during zone VI (upper VI, Jessen) but starts a continuous curve not until zone V (VII, Jessen). *Tilia* shows two *maxima*, the first in zone V, the second in zone III (VII and upper VIII, Jessen).

Fagus and *Carpinus* seem to occur regularly not

until zone III (upper VIII, Jessen) with a *maximum* in the upper zone part.

Corylus immigrates in zone VIII (V, Jessen) and has many *maxima* there. From zone VI (upper VI, Jessen) *Corylus* diminishes in zone V (VII, Jessen) but shows a short *maximum* there as well. During Subatlantic time *Corylus* is relatively unimportant.

Hippophaë has been found until zone V (VII, Jessen).

The following review of the vegetational history of middle Öland is based upon the diagrams from Gladvattnet, Skede Mose S 11, S 19, S 50, S 54, S 59, Melösa, Övra Sandby and Silverbäcken. Only the diagram from Gladvattnet covers most of the time from early preboreal to present time and in the entire material from middle Öland only my local zone C seems to be totally lacking.

For the descriptions Jessen's zones are used and when my local zones are mentioned, they will be given in the following way: IV: A, VIII: H.

Preboreal—Zone IV

The lowest part of the zone IV: A has a very high amount of *NAP*. It is possible that the lowest two analyses belong to zone III, but there are no definite proofs for this and I therefore treat the lowest part of the diagram as belonging to zone IV.

In the zone there are two subdivisions IV: A and IV: B. The first of them has higher *Pinus* and the other has higher *Betula*. These zones should be compared with the subdivision of zone IV in the Stormaren diagram, p. 109, where a high *Pinus* period is succeeded by a high *Betula* period, again succeeded by a high *Pinus* period. (IV: A, B, and C.)

The *Betula* peak in the Gladvattnet diagram is taken as a rudimentary zone IV: B and thus a *hiatus* exists in the soil change $3/4$, which involves most parts of zone IV: B and the whole IV: C. Unfortunately the IV: B representation is only a one-analysis-*maximum*, which means that no statistical significance can be attached to it.

A similar subdivision of the Preboreal can be carried out on some of Berglund's (1966) diagrams, for instance the diagram from Hallarums mosse. The lowest zone is however very fragmentary, and Berglund distinguishes only two zones, namely subzone *a* with dominating *Betula*, and subzone *b* with dominating *Pinus*. These zones are very well defined, and the distinguishing of an additional lower zone may be questionable.

A subdivision as the one from Stormaren has been made very recently in Denmark (Dr. S. Jørgensen, Copenhagen, personal communication). Another similar subdivision has been performed in Ostfries-

land by Behre (1966), who has distinguished a period with higher *Pinus* corresponding to lower *NAP* (IV a), a period with lower *Pinus*, higher *Betula* and increased *NAP* (IV b) and a period with rising *Pinus* curve and diminishing *Betula* and *NAP* curves (IV c). Behre has interpreted this succession as a climatical oscillation, where subzone IV b corresponds to the cold, alpine Piottino oscillation (Zoller 1960), and he gives the subzone IV a the name "the Friesland oscillation", which is then considered to be temperate. Subzone IV c corresponds to the final climatic improvement during the Preboreal.

The zones on Öland do not give any support to a climatical interpretation of the vegetational succession on the island during the Preboreal corresponding to Behre's oscillations from Ostfriesland. It rather seems to be the question of the establishment of an *AP* productive succession on Öland, which gradually presses down the *NAP* curve as the establishment continues. Thus the bulk of the *Pinus* pollen in zone IV: A is interpreted as long distance transport, while first *Juniperus*, *Betula* and *Hippophaë* later also *Pinus* immigrate and become pollen productive. A similar interpretation of the mentioned Danish diagram has also been made (Dr. S. Jørgensen, Copenhagen, personal communication).

Early Boreal—Zone V

In the Skede Mose diagrams most of this period is covered by extremely locally influenced diagram sections. Thus V: A seems to be normally developed only in Gladvattnet, and even there it is not very well established because of the long intervals between the samples which were made when the sampling was performed. In the zone there is, however, still some *Juniperus* and *Hippophaë* left and the amount of *NAP* decreases upwards. The immigration of *Corylus* takes place in the lowest zone parts.

The open landscape, which dominated around Gladvattnet in the earliest parts of the Boreal and which during the course of the zone gradually became less and less open, does not seem to have become quite closed until the upper part of the early Boreal period. This is evident if the development of the *NAP* curve in this diagram sector is compared with the one in the zones VI or VII.

The *Corylus* immigration, which in the older pollen analytical work from Öland often shows very high percentages (when calculated outside the *AP* sum), never had those fantastic peaks of more than 100 % which appear in some of G. Lundqvist's diagrams. On his recalculated Gladvattnet diagram the highest *Corylus* percentages show values around 25 % near the curve's lower limit, and in the re-

analysed diagram these values are still more reduced.

The immigration instead has a smooth curve, which does not show any signs of dominating *Corylus* vegetation, which has sometimes been assumed for this period. In analyses of the recent "pollen rain" in Hazel stands on Öland (cf. Hässlen, p. 20). Erdtman (1963, p. 113) found that the amount of *Corylus* pollen was considerably lower than the early Boreal high values. This is, however, not amazing as the closed hazel woods on Öland show their most intense flowering in the top layer of the canopies or where glades appear and fields and roads adjoin.

The early Boreal *Corylus* curve on middle Öland (which emanates from a locality in the middle of one of the most hazel rich areas of the island today) shows no higher values than it does during the following late Boreal and Atlantic periods. *Corylus* does not seem to have played a dominant rôle in the early Boreal vegetation of Öland, but was a member of a birch-pine-hazel dominated forest which in the zone's lower parts still had a somewhat open character.

During the later part of the zone the *QM* curve rises which is due to both *Ulmus* and *Quercus*, the latter to a lesser degree. At the same time *Juniperus* diminishes and reaches one of its *minima* during the Holocene vegetational development.

Late Boreal—Zone VI

The lower zone limit is marked by the rational *Alnus* limit. This one is present in all diagrams mentioned above, except S 54, S 59, Melösa and Övra Sandby. The *NAP* curve has decreased and has reached its *minimum*, which means that the woods covered the landscape almost totally. The *Pinus* curves decrease in the zone and the amount of pollen from *Corylus*, *QM* (which above all means *Ulmus*) and *Alnus* increases. The locally produced *AP* presses back the long distance transported pollen, which means much of the *Pinus* pollen. Against the upper zone limit the amount of *Pinus* pollen again increases, and there is a culmination at or near the zone limit.

During the zone *Alnus*, *Corylus*, and *QM* increase their proportion of the local forest composition.

Atlantic—Zone VII

The lower limit was marked at the immigration of *Tilia*. During the first part of the zone a culmination in the *Pinus* curve occurs, which corresponds to a simultaneous decrease in the *Corylus* curve. This means that there has been an increased local representation of *Pinus* growth or that a more open landscape developed, which enabled the long distance transported *Pinus* pollen to increase its pro-

portional representation in the pollen sedimentation. The latter does not seem to be the case, as the amount of *NAP* does not show any signs of a simultaneous increase as *Pinus* culminates.

As the *Pinus maximum* again diminishes it is accompanied by the rising *QM* curve. In the middle of the zone, this rise reaches a *maximum* and afterwards fairly stable forest conditions persist and very few changes in the pollen curves occur within the rest of this part of the diagrams.

The Atlantic deciduous woods increase their portion of the forest areas and a *climax stadium* begins, when the rise in the *QM* curve has stopped.

Both the *Betula* and *Pinus* curves reach *minimi* values and much of the *Pinus* pollen, perhaps even most of it must be long distance transported at this time.

All through the period very low *Picea* values appear, never reaching 0.5 %, The *Picea* culmination within this zone, which was reviewed from G. Lundqvist's summary above, is identical with the so-called "Baltic *Picea*", well known from the pollen diagrams of Gotland and middle Sweden. No signs of such a culmination within Atlantic time have been observed on Öland.

Subboreal—Zone VIII

The zone limit is marked by the *Ulmus* decline, which is very pregnantly developed in all diagrams. At the same time the *NAP* curve slightly rises in Gladvattnet and, less pregnant, in Skede Mose. The rise in the *NAP* curve corresponds to increases in both the curves for the Synanthropic and Hemerophilous plants in Gladvattnet. The corresponding increases in Skede Mose come a little later and seem to be connected to the local zone limit VIII: H/VIII: J. In this zone limit in Gladvattnet a modest increase in the curve for the Hemerophilous plants occurs. Just above the *Ulmus* decline in Gladvattnet one isolated *Hordeum* pollen was found.

The decline in the *Ulmus* curve is accompanied by a decline in the *Tilia* curve in Skede Mose but not in Gladvattnet, by a decrease also in the *Corylus* curve in all mentioned diagrams and by an *Alnus* culmination in Skede Mose. Where the charcoal fragments have been registered there is a slight increase in its curve in S 19, but no increase at all in Gladvattnet.

After the local zone limit, *Ulmus*, *Fraxinus* and *Tilia* again culminate but with a lower amplitude of the oscillation now in all diagrams. As a new *Ulmus minimum* appears this is accompanied by a changed trend in the *Pinus* and *QM* curves to increasing respectively decreasing.

Before this zone limit (VIII: J/IX: K) the *NAP* curve increases markedly in Skede Mose but not in Gladvattnet. The increase is accompanied by a peak in the charcoal curve in S 19 and at the same time the curve for the Cultivated plants passes its empiric limit. The *Secale* curve starts at the zone limit VIII: J/IX: K, and the Hemerophilous plants' curve increases very pregnantly together with the rise in the charcoal curve.

The forest elements seem to have changed very conformably in the two areas during the Subboreal. When the *Ulmus* decline comes, it takes place identically in all diagrams and also the continued development shows very few exceptions of a general trend.

If the *NAP* curves are considered the picture changes. Immediately at the decline there is an evident increase in the amount of *NAP* in group F in Gladvattnet which has nothing corresponding to it in Skede Mose. This *NAP* increase can also be followed very well in the curves for the Synanthropic and the Hemerophilous plants, where, however, for the latter a small increase may be registered in S 19. Instead the increase of the *NAP* in the Skede Mose starts in the middle of zone VII: J, where on the other hand no corresponding increase is to be found in Gladvattnet. The curve for Cultivated plants has its oldest marks in the lower part of zone VIII: J in S 19, while in S 59 (which is situated in the northernmost parts of the main Skede Mose) the first pollen from Cultivated plants occurs in the first part of zone IX: K, and in Gladvattnet the corresponding increase does not appear until the middle of zone M (apart from the isolated *Hordeum* in zone VIII: H).

Subatlantic—Zone IX

According to the survey of the zones, Fig. 97, where T. Nilsson (1964) and Berglund (1966) place the transition SB 2/SA 1 in 300 BC, I have taken this time limit for the zone change VIII/IX. If compared with my local zone system, the change appears in zone VIII: J. It seems problematic to express the transition Subboreal-Subatlantic more precisely in the diagrams from Öland.

The Subatlantic of middle Öland is only fragmentarily known through the treated diagrams as the uppermost part of the Gladvattnet diagram is the only one which covers the youngest part of the period. Additionally this diagram sector (above analysis 40) reflects the local fen vegetation to such an extent that the more regional information about the landscape's vegetation becomes distorted. This is especially true about the local zones IX: N and IX: O,

but even in these there is still valuable information about the cultural influence upon the landscape.

During the upper zone VIII: J and in the lower part of zone IX: K the amount of *NAP* continues to increase in the Skede Mose diagrams. In Gladvattnet, where zone IX: K is entirely lacking and where also zone VIII: J seems to be only fragmentarily represented, nothing of this increase has been registered.

During the later part of zone K the *NAP* curve slightly diminished, the *AP* curves' development during the periods VIII: J and IX: K is still characterized by high *QM*, *Betula*, *Corylus* and *Alnus*, but among the *QM* components *Quercus* dominates totally. However, *Carpinus* has some influence in the Skede Mose diagrams and there is also some *Fagus* and a marked increase in the *Picea* curve, but none of these two exceeds 1%. The *Fagus* curve disappears in the upper part of the zone IX: K. The *Pinus* curve is still low, and it is a rather unimportant member of the forest components at this time.

The cultural influence upon the landscape is high in the Skede Mose area during the zones VIII: J and IX: K. Below and around the zone limit VIII: J/IX: K there is very much charcoal in the soils and the peaks of its curve are accompanied by increasing values in all three curves for plants, which are possibly connected with the activity of Man. The curve for the Cultivated plants is very well represented and disappears in the zone limit IX: K/IX: L, but together with the gradually, decreasing amount of *NAP* in the upper zone IX: K, the curve for the Synanthropic plants shows an obvious diminishing trend.

In Gladvattnet nothing of this is seen because of the *hiatus*.

Zone IX: L is represented fragmentarily in Skede Mose. In Gladvattnet it is possible that parts of its lowest portion are lacking. The zone has been defined on the Alvar diagrams and in those there are two outstanding characteristics, namely a very pregnant *Juniperus* decrease and a simultaneous *NAP* decrease. The zone can be distinguished in Berglund's diagrams too (1966), and it is for instance very well developed in the diagram from Färskesjön, where the *Juniperus* decrease appears just below the zone limit SA 1/SA 2.

In the diagrams from middle Öland the *Juniperus* decrease is not very pregnant but the *NAP* decrease is very evident, in any case in the Skede Mose diagrams and it is possible to see an accompanying increase in the *QM* in the diagrams from Skede Mose as well as in the Gladvattnet diagram. The zone also seems to be present in the Silverbäcken diagram.

The zone ends with a new increase in the *Juni-*

Gladvattnet, Parish of Högsum, Öland GLV 1-GL

Analyses by Gösta Lundqvist

Fig. 98. G. Lundqvist's diagram from Mossberga Mose (= Gladvattnet). In the original diagram *Corylus* was calculated outside the AP sum but it has been included here and the diagram is recalculated and redrawn to enable a direct comparison with the new diagram from Gladvattnet (GLV 1). The new diagram has been worked out on G. Lundqvist's original samples, kindly put at the author's disposal by the Geological Survey of Sweden. The grouping of the AP components is made in conformity with the division of the Alvar material.

perus curve, which is also accompanied by an increasing amount of *NAP*. In the later part of the zone the curve for charcoal fragments shows a distinct *maximum*, but in the Gladvattnet diagram the

charcoal content was rather high also in the zone's lower part whereas the same diagram sector in S 19 has a charcoal *minimum*.

Zone L means a period with diminishing cultural

influence upon the landscape, which caused a re-afforestation. The charcoal *maximum* in Gladvattnet is then confusing.

The amount of *NAP* again increases and the *Juniperus* curve rises in zone IX: M, and so does the cultural influence. However, from analysis 40 in the upper part of the zone and to the top of the sequence the locally produced pollen amount (from the fen itself) increases very strikingly and presses down the curves, which summarize the pollen from the surroundings of the basin. This is seen in the curve for the Synanthropic plants, which decreases instead of rises at the same time as the curve for the Cultivated plants increases. Much of the pollen, which has been locally produced in the fen's vegetational succession emanates from *Myrica* and *Betula*, which indeed may be expected in a closed up ancient lake.

If one considers this influence from the local pollen production and regards its influence upon the Synanthropic plants' curve, this curve has a real increase or in any case an unchanged representation in the more regionally produced pollen amount. Similarly the amount of the Cultivated plants' pollen has an increase, which in reality is much higher than the one registered in the diagram.

The zone limit IX: M/IX: N has been marked at a new *Picea* increase and it marks in this diagram the beginning of a violent *Juniperus* increase too, which is not accompanied by an increase in the charcoal curve, which instead shows an abrupt decrease. In this diagram the *Juniperus* curve and the charcoal curve act antagonistically.

The vegetation in the area is very difficult to interpret on the basis of such a local pollen diagram, apart from the fact that there has been an enormous *Juniperus* pollen productive vegetational environment very nearby.

The uppermost zone, IX: O, marks the *Picea* immigration to Öland. One may also see that the amount of *Juniperus* pollen diminishes and that the cultural influence increases as the curve for the Cultivated plants rises in the top analyses. Other conclusions of the fen's vegetational surroundings are not possible to make.

G. LUNDQVIST'S DIAGRAM FROM GLADVATTNET (MOSSBERGA MOSE)

Most people who work with pollen analysis today refuse to investigate a material which has not been collected by themselves. The reasons for this may be many, but an important thing is that only the collector can judge what possible errors may be in-

involved in a field material. Additionally it takes so much time for a pollen analyst to complete a *promille* diagram today, that he or she wants to know for certain that all cautiousness has been taken at the coring and sampling.

When I decided to reanalyse G. Lundqvist's original material from Gladvattnet, I had these things in my mind, and although I knew that G. Lundqvist perhaps was the most cautious of all older Swedish geologists as to these things, I was still wondering what result the analysis work would yield.

At the time when G. Lundqvist completed his version of the Gladvattnet diagram, the preparation of samples for pollen analysis was performed according to the KOH-method: A very small portion of the soil sample was put on the slide, a few drops of KOH-liquid (10 %) was added, the whole thing was heated over a flame from a spirit-stove, a cover-glass was put on and the analysis work could start. If the sample was gyttja, the analysis was quickly made and 100 *AP* were counted, if the sample was peat it took more time to find 100 *AP* among the peat detritus left on the glass by the preparation, and if the soil was destructed and the pollen preservation bad no pollen or almost no pollen was found during a reasonable time and the note: "scarce with pollen" or "no pollen" or "pollen destroyed" was given in the diagram.

Diagrams were quickly made and extensive investigations could be completed within fairly short periods.

In our days preparation methods have improved and in most cases almost pure pollen slides can be made if the laboratory work has been made carefully. New optical inventories as high magnification lenses, phase contrast, polarisation and fluorescence microscopy enable us to make more detailed determinations of more pollen or pollen types, and the demand of a sufficient statistical material for the conclusive parts of the investigations force the analyst to register 500, 1000, 2000 or even 5000 *AP* per analysis.

Many of the older age determinations in archaeology have been made with the older type of pollen analysis and much of our knowledge of the Baltic stages, changes in sea-level and land upheaval after the last glaciation rests upon the age figures of such investigations. This reanalysing of an old diagram material from the twenties may serve as an example of the value of older diagrams, but the result must not be taken generally, as the quality of the old works varies a great deal.

General impressions: Because of the greater statistical material the curves of the new diagram are not so jagged as they are in the older. If the sampling

had been performed more densely, the curves can be expected to have become still more even.

Only one zone limit remains on the place where it was originally put. Thus age determinations of certain levels may differ in the two diagrams.

Amazingly much in the old diagram seems to be valid even after comparison with the renewed analysis work. The more marked differences have been found in the peaty part of the stratigraphy. In the gyttja part the differences are more modest.

Minor diagram constituents seem to be overrepresented in the old diagram. Some difficulties have existed in the determination of *Betula-Corylus*. *Myrica* was not known at the time of the analysis work, but G. Lundqvist remarks in the figure text to the diagram (1928, p. 47) that much of the *Corylus* pollen registered in the uppermost part of the diagram could be expected to be *Myrica* pollen instead.

In analysis 44, which was the last one carried out by G. Lundqvist, the destruction degree in the new diagram shows very high values, > 60 %, and this explains why G. Lundqvist stopped his work there. Obviously he believed that the same state of pollen preservation lasted through the rest of the diagram, which is very easy to understand as the soil macroscopically looked very humified.

Conclusions: Old diagrams, if good ones, are fairly reliable in gyttja sequences, less in peat sequences. Zone limits can be expected to alter position upwards or downwards and in discussion of for instance the isolation of a lake basin from communication with the sea, greatest caution must be taken. *Maxima* or *minima*, registered in one analysis only, can not be expected to be reliable curve details for diagram or zone connections.

Notes of the (Interne) Lake and Fen

Development of Gladvattnet and Skede Mose

Gladvattnet

During zone IV the sedimentation starts in Gladvattnet, but not until the zone change IV/V the lime gyttja sequence is initiated. The layer 6, in the middle of zone VII, has more detritus gyttja content than the strata below and above. Evidently a period existed within Atlantic time with a high production of organic material in the lake.

The zone limit VII/VIII has a very sharply developed sediment change, but as far as can be seen in the pollen diagram if this is compared with the Skede Mose diagrams, no *hiatus* of longer duration can possibly be hidden in this change. Above this layer a gyttja with much peat detritus was deposited during

my local zones VIII: H and VIII: J, which means from around 3000 BC to 0 BC or perhaps a little later. The stratigraphical change between this gyttja to peat has a *hiatus* in it, which covers my entire zone IX: K as the lowest part of this peat seems to be synchronous with the first part of my zone IX: L. The next soil change is to a fen peat emanating from a community with much *Betula* and *Myrica*. In the upper part of this stratigraphic sector a considerable amount of *Sphagnum* spores has a distinct *maximum* directly in my zone limit M/N, which coincides with Granlund's RY 1 (1932, p. 169, see also Fig. 97 a). The uppermost layer is a peat, where somewhat drier conditions predominated, according to the amount of terrestrial pollen, possibly in connection with some *Juniperus* growth.

Skede Mose

The position and the extension of the Skede Mose complex is seen on the geological survey map, Fig. 83. The fen is one of the largest on the island, and it has been formed by the blocking up of an ancient lake, dammed against the *Ancylus* ridge. A brief description of its environment and the material extension was previously published by the author (Königsson 1967 c, 1968) and is referred to. However, a summary will be given together with the description of the oldest parts of the stratigraphy and also a summary of the early natural history of Skede Mose (cf. Königsson 1968).

In the bottom part of the stratigraphy in S 11, S 19, S 50 and S 54 a fen peat has been marked, which rests on silt or on moraine *in situ*. This fen peat emanates from a rather moist source community, situated in the basin between a pre-*Ancylus* ridge formed morphological unit of unknown origin and the upper land surface of the island which dips against SSE. As the *Ancylus* transgression started a groundwater rise was the consequence in the areas which were situated near the shores and the basin west of the pre-*Ancylus* ridge became gradually wetter during this period. Finally a lake was formed which yielded the lime gyttja layers (layer 4 in S 50 and layer 3 in S 54). The very locally marked pollen diagram sectors, worked out in the fen peat, transit into more regionally valid diagrams, where the pollen production in the areas around is reflected.

Upon the lime gyttja there is normally deposited a silt layer of varied thickness. This layer has been interpreted as the distal part of the *Ancylus* ridge, and at the time of its formation the *maximum* of the *Ancylus* transgression had reached this level on Öland (The top of the ridge at Skede Mose is 20 m above the present sea-level). Within the silt layer thin

Fig. 99. Contour map of Skede Mose with 0.5 m contours.

lime gyttja depositions may be found, perhaps indicating regressive or stagnant periods within the *Ancylus* stage.

The regression which ended the *Ancylus* stage left the landscape dominating *Ancylus* ridge east of Skede Mose resting upon the earlier existing ridge (Appendix 1: A). Against the ridge the former Skede Lake was formed in a basin where lime gyttjas were deposited. In the southern parts of the basin lake marl was deposited, and this deposition did not end

until the middle of zone VIII: H, when a thin silt layer marks the transition to a sediment type, more rich in detritus gyttja. In the corresponding zones of S 19 and S 32 there is a more differentiated stratigraphy, with alternating detritus gyttja content, and with silt layers in many positions and in particular in the lower parts of the sequences. In the middle of zone VII: G there is a marked change in S 19, which shows an increasing portion of detritus gyttja in the sediments, which for this sampling point lasts during

Fig. 100. Find 270 in Skede Mose *in situ*. Most of the finds had sunk through the detritus gyttja, and they were found in a stratigraphical position, which was much older than the oldest possible age of the Iron Age depositions. This golden arm ring rested upon the gastropod shell layer, which can be dated to the transition between the Atlantic and Subboreal zones, corresponding to the very earliest part of the Neolithic time.

the rest of the zone. In S 32, which was collected some 25 meters to the SSE from S 19, the increased detritus gyttja content has fairly short duration. A similar change, also rather short, was registered in Gladvattnet. In S 19 and S 32 a slight increase in the *Pedistrum* curve accompanies this sediment but this is not the case in Gladvattnet, where instead a *minimum* in the *Pediastrum* curve appears. Thus the diagrams offer no possibilities for the explanation of this sediment.

In the transition VII/VIII there is a gastropod shell layer in many of the diagrams. This layer seems to be synchronous over great parts of Skede Mose, but the transitional layer in the zone change VII/VIII is the most extensive one. The layers may have a considerable thickness and they amount to more than 10 cm in certain cases (Appendix 1: D, 0.5–1.0).

During the later zones the detritus gyttja admix-

ture in the lime gyttja layers increases and the reeds come nearer the lakes central parts. For the interpretation of the archaeological material of Skede Mose, it has been of interest to know when there was still an open water surface in those parts of the fen, where the bulk of the finds was made.

For his book "The Archaeology of Skedemosse. II. The votive deposits in the Skedemosse fen and their relation to the Iron-Age settlement on Öland, Sweden" Hagberg (1967 *b*) got at very preliminary report on the overgrowth of the lake. The report was made when the entire analysis work dealt with in this paper was not completed, and was based upon some of the diagrams of cross section Y = 505 only (Fig. 99). The available C_{14} datings of the soils were drawn into the diagrams and the discussion of the age circumstances was largely attached to these datings. In one of the series, S 22, which was collected very near find 270 (Fig. 100) in the main area of archaeologi-

cal interest, the relatively high *Picea* curve was continuous and just around 1%. The conclusion of the incomplete material treated at that time was that the reeds had reached a line just east of the excavation area already during the Bronze age and that the limno-thelmatic contact, (LTC), at find 270 was very late, and that it probably should be dated to late Viking age or early Medieval time. The summary of my report can be found in Hagberg 1967 *b* (pp. 85–87).

The pollen diagrams S 31–S 38 have been worked on material, which was collected in cross section Y=505 (Fig. 99) with 5 meters between the sampling stations. The section has been diagrammatically compiled in the profile Appendix 1: B, where measurements in every meter have been drawn into it with interpolations. The most easterly diagram is S 38, which was collected at “45 m”. The longitudinal section X=300 crosses this section at “O”. The nearest diagram in that section is S 19, which was collected between “7.0” and “7.5” on the profile in Appendix 1: D.

The limno-thelmatic contact was first determined in the field because of a study of the soils, and the soil column in the pollen diagrams shows the field result. The soils were very humified.

In order to control these results the macrodiaspore analysis was performed on the three diagrams S 31, S 37 and S 38. The material registered in the analysis work is shown in special histograms, which give the absolute numbers of macrodiaspores found, and these diagrams may be compared with the soil column and with certain pollen curves of particular interest: *Gramineae*, *Cyperaceae*, Fen plants, Aquatic plants and *Pediastrum*.

In those parts of the analysed stratigraphy, which were considered as gyttjas, oospores of *Characeae* were abundantly found. In the lower stratigraphical positions, before the greater increase of peat detritus within the sediments, *Najas marina* and one isolated find of *Potamogeton* sp. (very corroded) occurred.

Najas marina is according to Samuelsson (1934, pp. 26–28) most common in brackish water in Fennoscandia and in Denmark, but it is also known from lakes on Gotland and on the Åland islands. Where it has been found in fresh water, it has been in *Chara* lakes, and they have been in such areas which are especially rich in lime. It is however, regarded as a typical brackish water species in our days in Finland and Sweden (Backman 1941, p. 24),

but was during the *Ancylus* period a fresh water plant. *Najas marina* was previously found as a fossil in Gladvattnet on Öland by Hemmendorff (1897, p. 47) and two additional finds were reported by Backman (1941, p. 39, the map) communicated personally to him by R. Sandegren. Finally Martinsson (1961, p. 369) reported finds from Mossberga Mose on Öland. The Skede Mose finds belong to the lower part of zone VIII: J and to VIII: H.

The oospores of *Characeae* and the seeds of *Najas marina* react antagonistically upon the fruits of *Cladium mariscus* in the sequences and the latter replaces the former two upwards in the diagrams. This change occurs together with a simultaneous increase in the pollen curves for *Gramineae*, *Cyperaceae* and Fen plants and with a decrease in the *Pediastrum* curve. The limno-thelmatic contact seems to have been correctly defined already in the field investigation in S 37 and S 38, but should be put a little higher up in the stratigraphy in S 31 and be placed in pollen analysis 13 instead of in analysis 11. On pollen analytical evidences only the LTC is judged to have been correctly defined in the field in S 32, S 34 and S 36, but should be put in analysis 12 instead of analysis 10 in S 33 and in analysis 10 instead of 12 in S 35. In S 22, finally, the contact should be placed in analysis 6 in spite of the amounts of *Cyperaceae* and *Gramineae* curves because of the continuous *Pediastrum* curve and the finds of pollen from aquatic plants.

On Fig. 101 some of the curves from the diagrams S 22 and S 31–S 38 have been put together. The zone limit VIII: J/IX: K has been marked J/K on the figure. The field determined limno-thelmatic contact (LTC) has been marked with a wavy line and the new position for the LTC, which has been discussed above for the series S 35, S 33 and S 31 has been marked with an arrow and a small wavy line.

It is then seen that the LTC is in the middle of zone VIII: J in the most easterly profile S 38 and in S 37. Just below the zone limit VIII: J/IX: K in S 36 and S 35 in the limit in S 34, just above the zone limit in S 33 and S 32 and very clearly above the zone limit in S 31. In S 22, finally, it seems to be just in the zone limit IX: K/IX: L or slightly below it. S 19 has not been marked in Fig. 101, but the LTC in this soil profile is developed just below the zone limit IX: K/IX: L.

In age figures this means that the reed's front was

Fig. 101. Survey of the overgrowth of the Skede Lake and the dating of the limno thelmatic contact (LTC). The discussion in the text, p. 132–134, is referred to.

PINUS

PICEA

ULMUS

CORYLUS

25 meters east of the longitudinal section $x=300$ around 100 AD, that S 19 and S 22, both of them in the middle of the deepest parts of the basin, below the 16 m contour on the map, Fig. 9, show an LTC from 500–650 AD.

In S 11 the LTC is found in the later part of zone IX: K which in age figures can be estimated to 400–500 AD. In S 50 it can be placed around 100 AD and in S 59, finally, which is situated in the Skede Mose proper, the LTC has developed already in the middle of zone VIII: J, which is difficult to date accurately, but which may preliminarily be placed some 1000 years BC.

The rest of the stratigraphy in Skede Mose above the pollen analysed peat layers consists of *Stratum confusum*, which is the ploughed soils worked agriculturally today.

The Vegetational History of the Great Alvar Reflected in the Pollen Diagrams

PREVIOUS INVESTIGATIONS

The pollen analytical exploration of the natural history of the Great Alvar begins with G. Lundqvist's investigations in Möckelmosen and Lunda Mose (1928, pp. 28–32).

In Möckelmosen G. Lundqvist found lake marl locally preserved in joints and because of one single analysis he states the preserved sediment to have been formed during the zones V or possibly IV (VII and lower VIII, Jessen). The upper part of the sequence belongs to zones III, II and I (upper VIII and IX, Jessen).

Lunda Mose is situated on the western fringe of the Great Alvar (cf. Fig. 47 a) and G. Lundqvist has interpreted its sequence to have been deposited with a beginning already in zone X (III, Jessen) and with a fairly well represented Preboreal (IX=IV, Jessen) and a very constricted development in the zones VIII–V (V–VII, Jessen). Zone IV (lower VIII, Jessen) seems to be totally lacking.

G. Lundqvist's conclusions of the vegetational history of the Great Alvar (1928, p. 164) find very few points of support in his Alvar diagrams, but he remarks that "the pollen frequency" is higher in the older of the zones. His remark is however rather an impression than a real registration of facts and he therefore adds that it is impossible to rule out whether this higher pollen frequency is due to greater forest growth in the area or to a changed sedimentation rate. He then evidently decided that the tendency probably was due to the greater forest growth

and stated that this material shows that Öland in general and also the Great Alvar was covered by forests during the warm epoch to a higher degree than it is at the present time. G. Lundqvist's continued discussion concerning the landscape development of the Great Alvar will be further reviewed and discussed below.

Erdtman published an interesting contribution to the vegetational history of the Great Alvar in 1946 (pp. 293–304, the subject was again discussed by the same author in 1948 and 1955). The investigation was originally initiated to rule out what real pollen types were hidden in the *Salix* curve of older diagrams, and G. Lundqvist's diagram from Lunda Mose was chosen for the investigation. It turned out that the bulk of the pollen, earlier registered as *Salix* pollen, was instead *Artemisia* pollen.

The results of the investigation as to the aspect of the vegetational history were that certain main features of the flora on the Great Alvar today can be traced already in the pollen content of the Late Glacial sediments. Erdtman suggested that a certain similarity exists between the "pioneer phase" of the flora's immigration to Sweden after the land ice and with the Alvar flora today, at least partly.

Iversen collected Late Glacial and Post Glacial sediments from the Great Alvar, which have been analysed by Dr. S. Th. Andersen of the Danish Geological Survey. It was published very summarily, without accompanying diagrams in 1954 (pp. 105, 106). Iversen reported that the Alvar during Boreal and Atlantic times was covered by a rather open forest; elements of the recent Alvar vegetation as *Artemisia* sp. and *Juniperus* were present, but scarce. Very little of pollen from *Helianthemum oelandicum* was found, only one grain, while *Ephedra* cf. *distachya* was found with three grains in Atlantic and one grain in Boreal time. Iversen concluded that it is obvious that *Ephedra* cf. *distachya* survived the first part of the Post Glacial time on the Alvar together with other steppe plants. According to Gams (1927) some of the most famous Alvar plants as *Fumana procumbens*, *Globularia vulgaris* and *Hornungia petraea* are associated with *Ephedra* in the Alps. Iversen has recently (1967, pp. 357, 358) reaffirmed his opinion of the survival of *Ephedra* cf. *distachya* on the Great Alvar till Atlantic time.

Finally the present author treated a material from Dröstorps Mose (Königsson 1962). The diagram was not quite modern as the *NAP* registered was not consequently determined, and thus gave more occasional finds of certain pollen types. The original purpose of the investigation was to date the main sedimentological events.

This fragmentary diagram still added new information to our knowledge of the Alvar's history. In lower zone V there was still much *NAP* on this part of the Great Alvar and it seems as if a period with an open landscape existed up to the middle of the early Boreal period. The amount of *NAP* then decreased to increase again after the zone change VII/VIII after which a new period with a more open landscape is being developed. However, as the first analysis work yielded these results, some controls as to other pollen types of interest were made in some samples. Thus *Ephedra* sp. was found in the lowermost sample. The *Helianthemum* curve comprises the two *Helianthemum* types (*Helianthemum italicum*-type and *Helianthemum nummularium*-type, see also p. 164), and it is seen how *Helianthemum* was more frequent in the Boreal than later on and how it increases again very late. But during the forest period, there are continuous finds of *Helianthemum* pollen, which shows that rather open and bright areas existed where *Helianthemum* could survive the forest period.

THE NEW POLLEN DIAGRAMS FROM THE GREAT ALVAR

The following review is based upon the diagrams from Tranekärr TK 1, Linträsk LT 1, Frösslunda Mose FM 1, Norra Kvinneby NK 1, Möckelmosen MM 1, Kritmosen KM 1, Torpmosen TM 1 and TM 7, Triberga Bro TB 1 and TB 3, Västerstad Träsk VT 3 and Stormaren STM 1. The position of these localities is seen on Fig. 47 a.

Preboreal—Zone IV

The lowest part of the Stormaren diagram is the only one reviewed which shows a Preboreal zone. It may be added that the diagram from Ekelunda Mose, which is not reviewed, also shows the Preboreal though only the upper two local zones IV: B and IV: C are present in that diagram.

The lowermost part of zone IV, my local zone IV: A shows very high *Pinus* values together with high percentages for *NAP*. The *Juniperus* curve is continuous but the *Hippophaë* curve, which has a distinct *maximum* in the local zone IV: B, is only represented with a single find in the lowermost analysis and is then lacking and changes to a sudden increase in the uppermost analysis of the zone. As is already pointed out, the *NAP* curve is rather high and among the special *NAP* curves there are very high values for *Gramineae* and *Cyperaceae*. *Artemisia* has a continuous curve exceeding 1% in most of the zone and it amounts to 2% in the zone change.

The landscape was obviously open and the Late Pleistocene tundra vegetation prevailed to a large extent. For the occurrence of the special *NAP* constituents the review of the palaeofloristic material, p. 163 sqq. is referred to.

During zone IV: B the *Betula* curve culminates and together with it the *Juniperus* and *Hippophaë* curves. Corresponding to these plants' *maxima* is a *minimum* for *Pinus*. The *NAP* curve decreases gradually throughout the zone.

It has been mentioned above (p. 124) that the division of the Preboreal performed in this paper may be compared with Behre's from Ostfriesland (1966). The curves in Stormaren do not directly support an interpretation of the Preboreal sub-zones on Öland as the result of climatic oscillations. It rather seems to be a natural vegetational succession from a more tundra like environment in zone IV: A, where an open landscape predominated, to an open birch-juniper-sea buckthorn bush vegetation, which gradually became denser and thus more *AP* productive during the zone IV: B.

In zone IV: C, finally, *Pinus* was established as a pollen producing tree within the area and the amount of *NAP* decreased still more. As far as I can see the forest period on the Great Alvar was developed already in the transition between the zones IV: B and IV: C, which in age figures may be placed around 10,000 years BP (8000 BC).

Early Boreal—Zone V

This zone is found in Stormaren, Västerstad Träsk, Kritmosen and Frösslunda Mose. The transition from zone IV: C to V: D is however only present in Stormaren.

The *Corylus* curve starts with a very even rise and the pronounced *maximum*, which is a striking characteristic for the beginning of the early Boreal in many of G. Lundqvist's diagrams is as invisible in the Stormaren diagram as it was in Gladvattnet.

Besides the rising *Corylus* curve in the first part of the zone it is also characterized by a small *Juniperus* culmination from a *minimum* in the lower zone limit and by a more stable representation of *Ulmus* within the zone. In the upper part of the zone, together with the increasing *Corylus*-curve and the small *Juniperus* culmination, there is an evident and simultaneous culmination in the *NAP* and this increase is largely due to the *Artemisia* curve and to a *Gramineae* culmination. The increase lasts in the first part of the zone V: E but the accompanying *Juniperus* culmination ends already before the zone limit. A similar tendency may also be seen in Frösslunda Mose and in Kritmosen, but the tendency is

so slight that it might not have been observed if the Stormaren picture was not known before. The material is too small for safe conclusions but the picture of an increasing curve for terrestrial plants, *Artemisia* in particular, and of the increasing *Gramineae* together with increased *Juniperus* representation in Stormaren at the same time as the immigration of hazel shows the development of an again more open landscape. (The *Gramineae* in this part of the diagram must be looked upon as deriving to its larger extent from the areas around the Alvar lake as no natural *Gramineae* pollen producing source community has left a corresponding soil in the stratigraphy, and the shores of the Alvar lake can not be expected to offer growth places for more *Gramineae* than it has today. Upwards the amount of *Gramineae* diminishes again.) The increased *Artemisia* growth may perhaps indicate a rising influence from cold continental steppe elements, as remarked by Losert (1928, p. 163). In Erdtman's discussion of the Boreal hazel forest (1931), he reviews the previous discussion of the enormous hazel pollen representation in the early Boreal, and according to Rudolph and Stark (cit. in Erdtman, 1931, p. 158) hazel forests are rather a continental forest type "indicating conditions somewhat similar to those found at the present day in the forest steppe zone of South Russia". The information in the Stormaren diagram is very interesting and a natural consequence of this result would be initiating a special study, exclusively dealing with the immigration of *Corylus* to various parts of Europe and with special regard to the *NAP* accompanying the rising *Corylus* curve.

The zone V: E is characterized by a culmination in the *Corylus* curve, stable curves for *Pinus* and *QM* (*Ulmus* still dominates within the *QM*), and by a minimum for *Betula*. *Juniperus* shows very low values and *Hippophaë*, which had a continuous curve earlier is now lacking in some analyses. The *NAP* amount diminishes again but the *Artemisia* curve remains fairly high and stable and it amounts to around 1 %.

The increase in the *Gramineae* curve seems this time to be, at least partly, due to a local fen community, as the increase coincides with the beginning formation of the *Substantia humosa* layer, which can also be followed in the curve for the fen plants, which acts very antagonistically to the *Pedicularis* curve in this diagram sector.

The landscape became considerably more densely populated by *AP* producers at this time, but the aspect must still have been rather open as *Artemisia* amounts so high values throughout the zone.

All the diagrams from the shore ridges belong to

zone V and most probably to the upper part of V: D. All of them are to a certain degree local diagrams, especially in their peaty sequence parts. They give one important piece of information to the discussion of the forest history of southern Öland as they contain macrofossil *Pinus* needles, which gives evidences of a spontaneous *Pinus* growth in the southern parts of the island.

Late Boreal—Zone VI

The following diagrams have this zone represented: Stormaren, Västerstads Träsk, Torpmosen TM 1 and TM 7, Frösslunda Mose and Möckelmosen. The zone is only fragmentarily represented in Västerstads Träsk, in Torpmosen TM 1, Frösslunda Mose and Möckelmosen but is well represented in Torpmosen TM 7 and in Stormaren.

The beginning of the zone is present in Stormaren, Västerstads Träsk and Frösslunda Mose. The *Alnus* immigration marks the entrance to the zone. In Stormaren the first appearance of *Alnus* is accompanied by a slight increase in the *NAP*, which is not seen in the other diagrams, and by an increase in the *QM* curve, which is a common feature in the diagrams. In Stormaren the *Corylus* curve amounts to some 20 % in the early part of the zone and then diminishes and reaches very low amounts in the upper zone limit, around 6 %. In Västerstads Träsk the values are very low and never exceed 10 % except in the lowermost analysis. In Frösslunda Mose, finally, from a peak of almost 20 % in analysis 7 *Corylus* decreases to 10 % in the next zone. Within the zone the amount of *Corylus* varies considerably from the mentioned 20 % in Stormaren to below 6 % in Möckelmosen. It seems as though those localities which are situated farthest away from the present growth places of *Corylus*, Västerstads Träsk and Möckelmosen, show the lowest values, relatively, of *Corylus* in all the diagrams, which must be due to a sedimentation of much of the *Corylus* pollen carried in the air on the way from the growth places to the Alvar lakes. However, Torpmosen also shows very low values, in fact even lower than those of Möckelmosen. This must mean that the *Corylus* growth on the very nearby Ebbelunda accumulations was very little and that the bulk of the *Corylus* pollen registered in Torpmosen emanates from other growth places, perhaps west of the Great Alvar, and that Möckelmosen and Torpmosen thus offer an excellent example of sedimentational effect upon the pollen content in the air with increasing distance to the pollen producing source community.

Corylus can then be said to have grown very near Stormaren and Frösslunda Mose during the late Bo-

real time, but can not have been a common member of the Alvar vegetation in any of the other Alvar lake's nearest surroundings.

The tendency for *QM* is not so pronounced, but it seems as if those Alvar lakes, which are situated nearer the fringes of the Alvar, have had a *QM* growth nearer to them, and that thus no considerable amounts of *QM* can be expected to have grown in the vicinities of Möckelmosen and Västerstads Träsk at that time. The relative values for *Alnus* seem to be fairly equal all over the Alvar but this is not the case with *Betula* and *Pinus*. The relative representation of *Betula* is higher in Möckelmosen and Västerstads Träsk and this is also the case with *Pinus* but less pronounced. I therefore consider *Betula* to have been the most common Alvar tree and bush during this zone together with those bushes which do not deliver much pollen to the pollen deposition in the sediments and I believe that there has been *Pinus* growth on the Alvar at the same time. It is however quite impossible to estimate the extent of the *Pinus* growth, as the forest was rather open according to the abundant occurrence of *Artemisia* throughout the zone and the presence of *Hippophaë* in this zone in all diagrams, and thus the *Pinus* trees can be expected to have grown in a position very favourable for pollen production. It is also very likely that much of the *Pinus* pollen is long distance transported.

Atlantic—Zone VII

Because of the very high frequency of *hiatus* in the Alvar stratigraphy (Fig. 102) the representation of the Atlantic time is very bad in the material. I have in fact only two examples of diagram sectors, which may be considered to be Atlantic and even those two are, to say the least, very fragmentary.

In Stormaren I have interpreted analyses 66 and 67 to belong to zone VII, and in Möckelmosen analyses 5–8 have also been considered to belong to the Atlantic time. Both diagrams only show the very beginning of the Atlantic time. It is impossible to say anything about the vegetation on the Great Alvar during this period except that the very low amount of *NAP* indicates a fairly dense tree and bush growth in the areas around the two Alvar lakes during the time represented in the fragments of its earliest parts' sediments.

Subboreal—Zone VIII

The Subboreal zone covers my local zones H and most of J. I therefore describe the development during these two zones under a Subboreal heading.

Except in Tranekärr and Linträsk, the Subboreal or part of it is present in all other diagrams.

Zone VIII: H is initiated by the classic *Ulmus* decline. I am not quite sure that I have the earliest part of this decline present in any of my diagrams, as it seems to be connected with a *hiatus*, which has its upper delimitation in the beginning of zone VIII: H. Thus a minor portion of the lowermost zone VIII: H may be missing.

The entrance to zone VIII: H in the diagrams shows many interesting features. The *Ulmus* decline is accompanied by a decline also in the *Tilia* curve and at the same time *Alnus* and *Quercus* increase very markedly. This is to a certain degree also the case with *Corylus*. *Betula* diminishes and shows a *minimum* in VIII: H. Immediately as the *Ulmus* declines there is a beginning and very evident increase of the *NAP* amount and of *Artemisia* in particular. This means that a very clearly seen opening phase develops in the landscape and it can be followed in the diagrams. The opening is accompanied by, among other things, the appearance of *Plantago lanceolata* and in some of the diagrams by the first finds of *Cerealia*. (In the diagrams P marks the beginning of the *Plantago lanceolata* curve, P₁ occasional finds of *P. lanceolata*, S the beginning of the *Secale* curve.) No doubt the development was to a large extent caused by cultural influence and the landscape's response to this in the stratigraphy of the central Alvar lakes as well as in the stratigraphy of lakes of the Alvar fringes was firm. However, the latter show a much stronger relative amplitude in their response.

In zone VIII: J the impression of a stagnant situation is striking in Torpmosen TM 1, Torpmosen TM 7, Möckelmosen and Frösslunda Mose. It may even be the question of a small retrogression in the later part of the zone, where the stagnant or diminishing *NAP* curves are accompanied by increasing *Betula* curves. But at the same time the *Juniperus* curves start their rise. In the uppermost parts of the period a new increase in the amount of *NAP* accompanies the diminishing *Betula* values.

The charcoal has only been registered in Stormaren, Torpmosen TM 7, Frösslunda Mose, Kritmosen and Västerstads Träsk. The Subboreal is entirely lacking in Kritmosen but in the other diagrams a peak in the charcoal curve coincides with zone VIII: H. The amount of charcoal is then not very high in the zone VIII: J, except in Västerstads Träsk, where there seems to be much charcoal also in VII: J. This is, however, not without objections as it has been impossible to determine a limit between VIII: H and VIII: J in this diagram, and it is then not well

established which one of the two zones has been the main formative time for this stratigraphical sector.

In this zone the continuous curve for the Cultivated plants starts in Stormaren, while it is a little earlier in the two Torpmosen diagrams. In Möckelmosen it is later and in Västerstads Träsk the curve is not continuous but the finds occur scattered in the combined zone VIII: H/VIII: J.

It thus is well established that the cultural influence starts in lower zone VIII: H, that the effect upon the landscape becomes very evident immediately, and that the cultural influence during zone VIII: J is lower than in VIII: H but again increases in this zone's upper part. The AP increase in zone VIII: J is to a larger extent composed of *Betula*, in some diagrams accompanied by *QM*. The Cultivated plants do not appear regularly until zone VIII: J and the charcoal curve stresses the cultural influence on the landscape development in the lower part of zone VIII: H.

Subatlantic—Zone IX

The Subatlantic zone on the Great Alvar is represented in all diagrams. In Torpmosen TM 7, however, only the lowest part of the zone is present as is the case with the Tranekärr diagram, which was worked out for other purposes than for the establishment of the Alvar's vegetational history. In some of the other diagrams the uppermost part is not present, because of difficulties in connection with the sampling.

In zone VIII: J the amount of NAP was increasing in the zone's uppermost part. This trend continues in zone IX: K and the increase is rather even and without pronounced peaks. In the uppermost part of IX: K the trend changes to diminishing. The *Juniperus* curves show exactly the same course as the NAP curves. These features are almost equally developed in all diagrams. The *Betula* culmination in the preceding zone has turned over into a *minimum* and in most diagrams a *Pinus* increase supersedes. In those diagrams where charcoal has been registered, no particular features can be seen in its curve. The *Cerealia* in the curve for the Cultivated plants are continuously represented in most of the diagrams.

Zone IX: K is obviously a period with very strong cultural influence upon the landscape and the small "reafforestation" period with birch, which is indicated within the early and middle parts of zone VIII: J seems to have been entirely neutralized.

During IX: L the picture changes markedly. In the Stormaren diagram, for instance, the *Juniperus*

curve decreases dramatically and together with it the NAP curve diminishes. The curve for Cultivated plants, which was continuous before, now disappears in many analyses and the increasing trend in the curves for Synanthropic and Hemerophilous plants changes. The very same picture can be followed in the diagrams from Torpmosen TM 1, Möckelmosen, Frösslunda Mose and Västerstads Träsk. The charcoal curve is a little confusing. It does act antagonistically upon the decrease in the *Juniperus* and NAP curves instead of the opposite, which was expected, and it shows marked *maxima* instead of simultaneous *minima* (as is also the case in Gladvattnet).

When this period with accentuated NAP decrease appears and consequently some "reafforestation" takes place, the increased amount of AP is difficult to differentiate. In the Möckelmosen diagram, for instance, there is a slight rise in the *Pinus* curve. In Torpmosen TM 1, *Betula* is increasing. In Stormaren *Pinus* and *Corylus* show slender rises, in Frösslunda Mose *QM* and this is also the case with the diagrams from Linträsk. Västerstads Träsk, finally, shows an increase in the *Pinus* curve. No common significant changes among the AP producers have been observed and it seems as though merely a common overgrowth existed during zone IX: L, and that, locally, different species could increase their representation. Still the charcoal *maxima* and their significance remain unexplained.

The decline of the *Juniperus* and NAP curves in IX: L have been restored above the zone limit IX: L/IX: M and the *Juniperus* curve even increases above its highest value in zone IX: K. The curve for the Cultivated plants is also restored. No particular features in the AP curves have been observed.

The cultural influence upon the landscape has caused the repeated development of a more open landscape.

The transition to zone IX: N shows again increased NAP curve. At this time very evident diminishing trends in many curves appear, particularly for *Corylus* and *Quercus* but at the same time the *Picea* curve rises as does *Pinus* in many diagrams. It is possible that these increases are only due to a more open landscape, where those pollen, which are well suited for long distance transportation, raise themselves, and that no corresponding increase in their growth accompanies the change. In any case the amount of *QM* and *Corylus* has diminished, which is due to decreased representation of these trees in the areas edging the Alvar. In Stormaren, Linträsk, Västerstads Träsk and Frösslunda Mose nothing seems to have happened to *Betula* and *Juniperus* together with the NAP increase, and that must mean

that the two in reality have decreased their pollen production slightly. In the remaining diagrams from Möckelmosen, Torpmosen and Kritmosen the curves for *Betula* and *Juniperus* have decreased and this consequently means a still greater relative decrease for their pollen production in the areas surrounding the three mentioned Alvar lakes.

In all diagrams except in Västerstads Träsk the curve for the Cultivated plants rises and becomes stable above the zone limit.

The zone IX: N thus must be considered to be a period with strong cultural influence upon the landscape, which during this zone became still more open.

During zone IX: O, finally, this trend is accentuated and an extremely open landscape, reflected in the diagrams from Stormaren, Kritmosen, Torpmosen TM 1 and Linträsk develops. The curve for Cultivated plants remains fairly unchanged from the preceding zone. In some of the diagrams, Stormaren and Linträsk, a diminishing trend in the *NAP* curve in the uppermost part of the diagram can be observed. This trend is also characteristic for the Cultivated plant's curve in these two diagram sectors. This indicates a very late phase with less cultural influence upon the landscape and a tendency to a renewed overgrowth. However, this tendency is present in so few localities that its regional character can not be said to be safely established.

A Comparison between the Alvar Diagrams and the Diagrams from Middle Öland

The comparison between the diagrams from the Great Alvar and those from middle Öland will only deal with the general impression of the *AP* section. The cultural development and those diagram features, which are connected with the activity of Man will be specially treated in a following chapter.

The most striking difference between the diagram types is the development of the *QM* curve. Its *maximum* in Gladvattnet amounts to just below 30 % in zone IX: L, which corresponds to less than 10 % in Stormaren and around 4 % in Möckelmosen for the same period. The later part of the *Corylus* curve, from zone VII: G and upwards amounts to less than 10% in Stormaren and Möckelmosen (but is higher in Möckelmosen than in Stormaren) and is considerably higher in Gladvattnet with some 10–15 % and just below 20 % in Skede Mose S 19.

The *Pinus* curve is rather even in the Stormaren diagram and it can be generalized to an average of 50 % for the whole diagram, in the subzones VIII: H–IX: K of 40 %. In Gladvattnet from the zone VI:

F the average is around 35 % and for S 19, apart from VI: F itself, with an average of 40 % the curve is clearly below 30 % till zone IX: L, during the Atlantic time still lower. The *Juniperus* curve, finally, apart from the local *Juniperus maximum* in zone IX: N, Gladvattnet, shows a quite different development in the diagrams from middle Öland, where the *Juniperus* curve in zones VIII: J and IX: K never reaches 2 %, and in zone IX: M amounts to 1–2 %.

In the diagrams from the Alvar the corresponding zone IX: K values from Möckelmosen are 4 % and in Stormaren they have a *maximum* of 6 %. In zone IX: M the values for Möckelmosen exceed 6 % in a *maximum* and amount to just below 10% in Stormaren.

The difference between the two diagram types is significant. The diagrams from the Great Alvar show a general picture of a more open vegetation type where the *Pinus* pollen has an opportunity to dominate in quite another way than in the deciduous wood area of middle Öland. The more abundant occurrence of *Juniperus* in the Subboreal and Subatlantic shows that an Alvar like landscape was created very early in these zones. This landscape type lasts in the rest of the two zones with a few periods of beginning and then ceased overgrowth involved, but the general trend was against a more and more open landscape. The diagrams from middle Öland unfortunately do not cover the whole period, but in those diagram parts, which can be directly compared with the Alvar diagrams, it is evident that the *AP* has a much more dominant position. This is especially true of *QM*. The general impression is also that *Betula* on the whole is percentually much more strongly represented on the Alvar than it is on middle Öland.

Remarks on the Stratigraphy

On Fig. 102, the soil thicknesses and the pollen analytically observed *hiatuses* have been compiled. It should be stressed that there may be additional *hiatuses* in the stratigraphy, but it has not been possible to define them by using the pollen analytical evidences. In fact the figures of the soil thicknesses in some of the zones indicate that this is the case. In the stratigraphy of Dröstorps Mose the pollen diagram is too summarily established to permit safe conclusions of *hiatuses*, but I consider that a renewed investigation of this Alvar lake would reveal at least one *hiatus* in the zone limit VII/VIII covering most of the Atlantic period.

In the Alvar diagrams the Subatlantic shows high figures of soil thicknesses, mostly sediments with

Fig. 102. Survey of sediment thicknesses in the investigated fens and Alvar lakes, and a diagrammatic compilation of the *hiatuses* found. The gastropod shell layer in Skede Mose is marked in the diagram. Additional *hiatuses* may occur, and some indications of such have been observed, but in this diagram only those have been drawn which are considered to be safely established.

high content of peat detritus and other organic material. The Subboreal shows average values, which are lower than for the Subatlantic and in four diagrams much of the zone's soils are constituted of *Substantia humosa*, which seems to derive from some peat forming plant community.

The Atlantic period is very badly represented and only three diagrams, Dröstorps Mose, Möckelmosen and Stormaren, have sediments from this zone present, and even there very fragmentarily. The soils are lime gyttjas in Dröstorps Mose and Möckelmosen and *Substantia humosa* in Stormaren.

In zone VI the values of soil thicknesses vary a great deal and the most abundant occurrence is in Dröstorps Mose, Torpmosen and Stormaren, part of it lake marl as in Torpmosen and Dröstorps Mose. In Stormaren all of it is *Substantia humosa*.

In zone V rather even and high figures occur and lime gyttjas or lake marl constitute the stratigraphy,

in Stormaren with some *Substantia humosa* still on the top.

Zone IV finally, is only present in Stormaren, where 55 cm of lime gyttjas and lake marl constitute the soils.

It is then evident that the sedimentation rate can hardly be calculated to yield any useful results, anyhow in the zones VII and VIII. The visible *hiatuses* cover great parts of the stratigraphy and other *hiatuses*, however invisible, can be suspected to occur in zone VIII.

The occurring *hiatuses* are, however, very interesting and it may be observed on Fig. 102, that most of them occur covering zone VII. I have marked the limits with spines, thus indicating that the limits are a little diffuse.

Two things are striking in this picture. The first is that so many of these *hiatuses* have their upper limits very well concentrated within the very same

diagram part. The second is that their lower limits are amazingly synchronous.

A *hiatus* may be one of two things. For the first it may be a period when no sedimentation or other soil formation existed. For the second it may be the result of a period when older soils were removed from their *situ nascendi* by the activity of erosion or any chemical effect. It seems very incredible to me that the Atlantic period should not have been soil producing on the Great Alvar, and I thus consider the removal theory to be the most reliable of these.

If the more or less synchronous upper limits are first regarded, this means the beginning of a new period of undisturbed soil formation. The limit then is a *terminus ante quem* for the *hiatus*. The lower limits and rather the uppermost of them then show a *terminus post quem* for the *hiatus*. The duration of those processes, which removed the Atlantic soils may not be determined more exactly.

If the present soil formative situation is regarded, most Alvar lakes show very similar sediments, which are peat detritus containing gyttjas with some lime gyttja content. The more or less synchronous lower limit of the *hiatuses* has then been interpreted as the result of the removal effect upon an almost identical soil type formed in all the Alvar lake's basins during Atlantic time. This explains the conformity of the lower *hiatus* delimitation.

The soil removal processes may be erosional or perhaps chemical.

In the later part of the Atlantic time a colder period seems to have existed (Frenzel 1966). A colder period may also have been wetter thus offering more abundant water flow and more erosion active surface hydrography on the Alvar.

The first part of the Subboreal period was climatically rather continental, thus bringing less water flow and less erosion active surface hydrography to the Alvar. The water table of the Alvar lakes can be expected to have become considerably lower than before and the rate of oxidation of their organic sediments must have increased. If the Atlantic period is taken to have yielded organic sediments of gyttja types or perhaps some peat types, these might have been oxidized during the most continental parts of the Subboreal period and so removed.

The present Atlantic soil in Stormaren is a highly humified one, probably originally some kind of a peat.

Additionally it may be stressed that the Atlantic sediments in Skede Mose (S 19 for instance) show an increasing amount of detritus gyttja which above the zone limit VII/VIII again diminishes. In Gladvattnet there is a period of higher detritus content

in the lime gyttja in zone VII (layer 6). It then seems possible that the increase of organic production in the lakes of middle Öland during Atlantic time was also present in the Alvar lakes.

I consider the oxidizing theory as the most believable of the soil removing theories.

Some very important climatic change was obviously connected with the zone boundary VII/VIII. As has been marked on the Fig. 102, a gastropod shell layer in S 19 coincides with the boundary. The shell layer is very extensive in Skede Mose and in all dated examples it has turned out to be synchronous. The occurrence of the layer then emphasizes the impression of a very important climatic event at this time.

Of the other observed *hiatuses* the one covering zone K in Gladvattnet should be compared with the stratigraphical situation in Linträsk. The sedimentation there starts in zone IX: L. However, Linträsk must have had sediments earlier too, which have been removed before the latest sedimentation period. The beginning of the soil formation thus can be regarded as a *terminus ante quem* for a hiatus, which covers the rest of Linträsk's late Pleistocene and Holocene sedimentational history. It is possible that this *hiatus* too indicates a period of climatic oscillation, but the material from the two localities is too small to permit safe conclusions in this respect.

The Human Influence upon the Landscape Reflected in the Pollen Diagrams

The following summary of the observed human influence upon the landscape in the treated areas of Öland may be made. It should be stressed that the tendencies are due to agricultural activity of different kinds, grazing in particular, and that other types of human activity can hardly be read from the diagrams.

Skede Mose. The influence upon the landscape following immediately upon the *Ulmus* decline was very modest and the first period with landscape-changing character came much later, in the middle of zone VIII: J. The *Ulmus* decline has been placed at 3300 BC, and it may consequently be said that the activity of the Stone Age people did not change the natural vegetation in the area much.

The increased activity, which resulted in a more open landscape in the middle of zone VIII: J is a little difficult to date accurately. An estimation built upon a judgement of the sedimentation rate thus must be looked upon as preliminary and it needs further investigation for a safer determination. The age figures received are some 1100–1000 BC, which

would then correspond to the middle of the Bronze Age in Sweden.

The human influence upon the landscape increases and during the centuries following the birth of Christ the expansion culminates during the Roman Iron Age. During the rest of zone IX: K, the Migration period, a slightly decreasing human influence upon the landscape is observed, which in the zone limit IX: K/IX: L decreases still more. It however, never disappears, anyhow not in those parts of the zone which are present in the Skede Mose diagram material. The zone limit was placed between 500 and 600 AD, which in Archaeological periods means the transition between the Migration period and the Vendel period.

Unfortunately no later periods are covered by the Skede Mose material.

Gladvattnet. The picture of the human influence upon the landscape differs markedly from the one shown in Skede Mose. Immediately after the *Ulmus* decline the landscape becomes more open but the tendency is rather slight. During the rest of the zones VIII: H and VIII: J nothing more seems to happen to the area around Gladvattnet in respect to increasing activity of Man. A *hiatus* covers zone IX: K and the picture of cultural influence rate in zone IX: L is very little diverging from the one in VIII: J. Thus it seems as if the first *landnam* phase created a landscape, which prevailed through the Stone Age and the entire Bronze Age, and also during the oldest parts of the Iron Age.

It is, of course, possible that there might have been an increased influence during the missing zone IX: K, which had already ceased again before the entrance of zone IX: L. Nevertheless the described development differs from the one shown in Skede Mose, and nothing or almost nothing is seen of the increased human influence upon the landscape during the later part of the Bronze Age and the early Iron Age which was so evident there.

Instead an increase comes in the upper part of zone IX: L, which means the Viking Age archaeologically, and new increases follow both early and a little later during the Medieval period.

Stormaren. The first signs of human influence are seen immediately after the *Ulmus* decline, and already during zone VIII: H this influence increases remarkably, and the open landscape is a reality. All through the Stone Age and the Bronze Age the established situation remains fairly unchanged, and it is only during the latest parts of zone J, that nothing is known of this development as an *hiatus* covers this stratigraphical sector. During zone IX: K the human influence increases but then again diminishes

very markedly in the zone IX: L. In archaeological terms this means that there was an increased activity during the Roman Iron Age and the Migration period on the Alvar around Stormaren, but that this influence decreased in the end of the Migration period. During the later part of zone IX: L (the Viking Age) the influence increased again, and in the later part of the Medieval time a new increase followed, which changed approximately after 1500 AD to a diminishing trend.

Möckelmosen. The same picture as in Stormaren appears in the earliest parts of the Subboreal period, and during the Stone Age the Alvar around Möckelmosen became an open land. The very even continued development of Stormaren all through the Bronze Age and the early Iron Age does not have an equivalence in Möckelmosen, where there is seen a tendency to increased cultural activity in the middle of zone VIII: J, which means the middle of the Bronze Age or at the same time as the human influence becomes clearly visible in the Skede Mose diagrams for the first time. Then there seems to be some decrease in the influence during the later part of the zone VIII: J, which corresponds to the earliest parts of the Iron Age, and during the Roman Iron Age the same increasing character is seen as in Stormaren and the decreased cultural activity of the early Vendel period is also very well developed in the Möckelmosen diagram. The later development with a Medieval increase is also present. The uppermost part of the stratigraphy is lacking in Möckelmosen.

Torpmsen. The development largely follows the one of Stormaren.

The diagrams from Skede Mose and Gladvattnet differ markedly from each other. This will be further discussed later in a following chapter but I want to draw the attention to the fact that these two areas differ very much according to their edaphic conditions. Skede Mose is situated within an area of dominating littoral deposits of prevailing sands and gravels, usually well drained, and Gladvattnet is situated in the morainic region and has additionally some areas of exposed bedrocks very near it.

As to the three summarized Alvar diagrams I have chosen one from the western edge of the Great Alvar, one from the middle, and one from the eastern fringe. A generalized picture of the human influence in the three mentioned areas is drawn on Fig. 103.

The Cultural Influence Upon the Landscape in other Swedish Provinces

Berglund (1966, p. 155) summarizes the following stages of increased human influence in Blekinge:

Stage 1. Early Neolithic *landnam*: 2800–2500 BC, Stage 2. Expansion in the middle and late Neolithic time: 2000–1700 BC. Stage 3. Expansion in early Iron Age: c. 300 BC. Stage 4. Expansion in the late Iron Age: 800–1000 AD. Stage 5. Expansion in modern time: 1600 AD. Additionally it may be noticed that Berglund's diagrams often show a decreased human influence upon the landscape just below the zone transition SA 1/SA 2, with decreasing amounts of *NAP* and *Juniperus* (see for instance the Färskesjön diagram). The zone transition can be placed c. 650 AD.

Helmfrid (1958, the diagram p. 248) has an increased *Juniperus* curve which starts this increase below a C_{14} dating of 1050, which means an increased *Juniperus* growth from the later part of the Viking Age in western Östergötland. At the same time the amount of *Cerealia*, *Secale* in particular rises. The *Secale* curve is dated to c. 100 BC (cf. p. 120).

Magnusson (1964, the diagram), who has also treated a material from western Östergötland, shows a *Secale* curve, which he considers to derive from approximately 300–400 AD in its lowest part. Above this his diagrams show an evident tendency to decreased human influence upon the landscape, which is accompanied also by diminishing curves for *Secale*, other *Cerealia*, *Plantago lanceolata*, and *Artemisia*, *Juniperus* is not drawn into the diagram. In the stratigraphy column there is marked *Spagnum* peat and the signs indicate an uneven rate of its formation. It is then rather possible that the decreased human influence can be placed in the Vendel period and that the recovery of the influence took place in the later part of the Viking period and earliest part of the Medieval time. The dating of the *Secale* curve seems a little high if compared with Helmfrid's dating not far from Magnusson's area, and I consider it very probable that Magnusson's period of increased influence should be dated to the same age as the *NAP-Juniperus* decreases in Blekinge and on Öland.

Fries (1958) in his paper from Västergötland in one diagram has an evident decrease in the curves for *Cerealia* together with a simultaneous short *Juniperus* decline (The diagram 2 a, Spångsjön). As these features seem to have developed in this diagram only, it is possible that it should rather be looked upon as an incident. It is, however, to be found in a diagram sector, which has been dated to Viking Age.

Fries (1961) has found similar features in a diagram from the Åland islands in Finland, where a C_{14} dating of the increased *Secale* curve (not the beginning of it) has given 340 ± 90 AD. Fries discusses a very marked decline in the cultural influence on the diagrams, and he concluded that with an even

Fig. 103. Schematic diagram showing human influence upon the landscape, which has been observed in the diagrams. It should be stressed that the picture is relative and that the influence ratio in the diagram is an interpretation and that it does not show the actual situation in absolute values.

sedimentation rate throughout the diagram, the *Secale-Juniperus-Gramineae* (*spont.*)-*minima* should be expected to have happened in the Viking Age. However, he remarks that the dating of the *Secale* curve is too old, as the common archaeological knowledge about the beginning of Iron Age cultivation on Åland places it in the time c. 500 AD. If this picture of the archaeological development is correct, the *Secale* curve can hardly be older and consequently the *minimum* for the cultural decrease should be put forward in time. However the dating of the *Picea* curve, which is also included in the diagram, is also considered to be too old, which is supported by other datings of the *Picea* curve from Åland. The age of the cultural *minimum* then seems to be unsafely established but it cannot be totally excluded from the discussion.

*The Archaeological Succession on Öland
and the Pollen Diagrams*

The review follows the description of the archaeological succession on Öland given by Stenberger (1948), which is the latest compilation of available material from the island. Where information from other sources has been added to the description, this is quoted.

The oldest traces of Man on the island derive from the *Ancylus* period, the Maglemose time some 7000–5800 BC. The finds are bone tools suited for fishing and hunting. Only three finding places are known, two from the eastern parts of southern Öland (Hulterstad and Stenåsa) and one from the area just north of Skede Mose. According to Stenberger during the Maglemose period Öland was an area where only very occasional impulses of human influence could penetrate. Together with the three tools, a few stone axes of the Lihult and Limhamn types (see Stenberger 1964, p. 53, Fig. 15) constitute the Mesolithic material on the island.

In the latest part of the Mesolithic time another axe type appears, the simple rounded axe (Stenberger 1962, p. 38), which especially often has been found on middle Öland from Borgholm in the north and down to Mörbylånga.

With the Neolithic time a very important phase in the human usage of the landscape in Sweden started. Agriculture and cattle were introduced. The evidences of the Neolithic on Öland are interesting as we find some examples of Megalithic Passage graves on the western fringe of the Great Alvar. These graves are otherwise found in western Sweden. Besides the Passage graves some other Stone Age graves are known from Öland. Very few dwelling-sites are known, one of them, at Köpingsvik, belongs to the Pitted Ware culture (Stenberger, 1962, p. 48). The people from this site evidently combined fishing and keeping of domestic animals (e.g. pigs) in their household (Hagberg 1966, p. 53). The boat axe culture is represented on the island by finds of axes. One grave from Bårby, parish of Mörbylånga is also known. Stenberger presumes (1948, p. 313) that both the boat axe people and the Megalithic people were relatively few on the island, but our knowledge of the Stone Age on Öland is still very fragmentary.

It is only from the latest part of the period that the finds indicate that some regions of importance existed. Many flint daggers and spear heads have been found and from Torslunda even a little grave field is known. Hagberg (1966, pp. 53, 54) assumes that Torslunda was a very rich district during the Stone Age.

If the compiled picture of isolated finds from the Stone Age on Öland (Åberg 1923, Maps II, III, IV, and V) is regarded, the oldest period is best represented on middle Öland and both the northern parts and the southern are almost lacking in finds. The following periods change this picture a little and also the southernmost part shows some finds. However, maps of this kind may be misleading, which is perhaps indicated (for these maps) by the richness of finds in the parish of Smedby, where one of Öland's most active private collectors of archaeological specimens lived.

The Bronze Age was, according to Stenberger (1948, p. 329), a time of prosperity on Öland as the finds from this age are so many and so rich, and the island seems to have been a very important part of the Baltic area at that time.

The transitional time between the Bronze Age and the Iron Age and the first part of the Iron Age have long been mysterious periods and have been considered to have been a time of cultural decline. According to Hagberg (1966, p. 65) the older Iron Age on the island instead had a position of great power, which in particular is valid for part of the Pre-Roman Iron Age and the Roman Iron Age at approximately 150 BC–400 AD. The Roman Iron Age was very wealthy according to the contents of the graves, where precious gifts were very often deposited together with the dead. Especially rich is the second century after Christ. The latest part of the Roman Iron Age shows less richness.

During the following period, the Migration period, Öland had a new time of great richness and many gold finds from the fifth century AD are known from the island. The finds of Roman golden coins, *solidi* have been very important for the discussion of Öland's cultural development. The *solidi* which have been found on Öland remain from a very restricted period, 450–490. The corresponding figures for the Island of Bornholm are 475–525, and for the island of Gotland 500–560. Hidden treasures are considered to indicate periods of war and ravages.

On Öland there are more than 900 fundaments of ancient houses from the middle of the Iron Age. Gotland shows a similar situation and excavations there indicate (according to Stenberger) abandonment of these houses in the first part of the sixth century AD, and for the few excavated house fundaments on Öland he found the same tendency. Stenberger believes that some catastrophe, perhaps war, was brought to Öland and almost annihilated all houses on the island.

On Öland there are many strongholds (ring fortresses), which are considered to remain from ap-

proximately the same period as the house fundaments. The stongholds have been taken as coinciding with the catastrophe.

After the fifth century AD there follows a period of cultural stagnation, and it is first during the Vendel period (550–800 AD) that Öland has again recovered from the catastrophe. The houses seem to have been rebuilt in other places than before and largely on the sites of the present villages. According to Hagbergs's investigations (Hagberg 1966, p. 71) this was, however, not always the case. Anyhow at the site Sörby Tall, parish of Gärdslösa, the same dwelling place was again used during the seventh century AD (Hagberg 1966, p. 70, 1967 *b*, pp. 95, 96). At the Örmöga settlement, parish of Bredsättra, the finds emanate from the first, sixth and eighth centuries AD (Hagberg 1966, p. 70, 1967 *b*, pp. 104, 105).

According to Stenberger (1948, p. 391) the Viking period was a new period of great power on Öland. The finds are again very rich, this time not of gold but of silver, and many hoards have been found which indicate new periods of troublous days.

How does the archaeologic succession and the picture of the human influence seen in the pollen diagrams fit together?

For the first it must be said that the archaeologic information of the Stone Age does not allow any conclusions of the degree of the cultural influence during its various periods, except perhaps the last one; the really useful information then starts with the Bronze Age material, as this is the first period from which a rich material exists to work with.

As has already been shown schematically on Fig. 103, there are clear differences in the picture of human influence upon the landscape between middle Öland and the Great Alvar, but also between Gladvattnet and Skede Mose. These two localities were originally only planned to give two examples of the "normal" landscape development in the island's today forested areas *contra* the deforested Great Alvar. Thus the material from middle Öland does not offer a complete picture of the cultural landscape development in the area of the deciduous woods, but they yield some tendencies.

In Gladvattnet an immediate response to the first part of the Stone Age is registered and during the first centuries just after the *Ulmus* decline, the curves for the Synanthropic as well as the Hemerophilous plants rise together with a small culmination in the charcoal curve. It may, however, be noted that the influence upon the landscape was rather modest and that it remains fairly unchanged till the upper part of zone IX: L (late Vendel time to early Viking time),

when the increase follows. During zone K, part of the Pre-Roman Iron Age, the whole Roman Iron Age and the Migration period, a *hiatus* causes a complete absence of knowledge of the cultural development in the Gladvattnet area. Later on, in Medieval time, an increasing human influence is seen, but as to the latest period it is impossible to rule out the complete picture. The curve for the Cultivated plants, however, gives the impression that the human influence increases also after the sixteenth century AD.

In Skede Mose the influence is exceedingly small till the middle of the Bronze Age, when the open landscape gradually develops. A very even increase in the influence culminates in the Roman Iron Age according to the curves rather in the third and fourth centuries AD and then becomes stagnant or even diminishes. The diagrams unfortunately give almost no information later than the transition between the Migration period and the Vendel time.

In his classic book on the older Iron Age of Öland, Stenberger also gives some facts about the Place names on Öland (1933, pp. 81–85). Names ending in *-lösa* and *-inge* seem to be older than those ending in *-hem*, *-stad* and *-by* and still younger are names ending in *-torp*, *-ryd*, *-rum* and *-hult*.

The oldest name types are most common on eastern Öland (Plate 11:5) and the youngest types are very common on middle Öland west of the eastern shore ridge region. The later group seems to be fairly late, probably of Viking Age.

Names ending in *-ryd* and *-rum* indicate forest clearance. These names are lacking or almost lacking in those parts of the island where no woods exist today, while they are frequent in the wooded area of middle Öland. I think that this might be interpreted as if the present area of wood cover on Öland largely coincides with the situation when the places ending in *-rum* or *-ryd* were founded. The absence of older types of names (there are a few exceptions, for instance Glömminge) may indicate a gap in the usage of the land on the middle of Öland, west of the eastern shore ridges from the time when the older Iron Age houses were abandoned around 500 AD and until the new forest clearance indicated in the place names and perhaps remaining from the middle of the Viking Age. On eastern Öland with its older names, amazingly few house fundaments have been found (Stenberger 1933, Plate II: 4) and it is possible that the present villages rest upon the older Iron Age settlements to a great extent.

The picture of the whole period of catastrophe (p. 144) is unfortunately not covered in Skede Mose but of the present material from the beginning of the period it seems as if the catastrophe was not total.

The period of cultural culmination is not present in Gladvattnet but it can probably be found in renewed investigations there. Still the difference between the two area's early development remains to be explained.

Skede Mose is, as has been pointed out before, situated within an area of rather well drained sandy soils. Gladvattnet on the contrary is in the badly drained parts of the morainic region and around the site exposed bedrock is frequently found in restricted Alvar areas. It is possible that the first limited influence of the various Stone Age peoples was just enough to open these Alvar areas, which then are represented by the increased *NAP* production in Gladvattnet, and that the Alvar areas largely have remained with an open aspect afterwards. During the "dark" period covered by the *hiatus*, forest clearance must have appeared in the neighbourhood of Gladvattnet as Iron Age house fundaments can be found both to the south and to the east of the lake. One of the ancient strongholds is also situated nearby. But the increasing human influence upon the landscape nicely demonstrated in the Skede Mose diagrams, which starts in Bronze Age and culminates in Roman Iron Age, is not at all seen in Gladvattnet. And the zone IX:L, the transition between the Migration period and the Vendel time, is very pregnant in the Gladvattnet diagram. I want to see the many abandoned houses and the younger place names occurring in this region as a possible explanation of the very low human influence during this time.

In the Skede Mose case the culmination during the later part of the Roman Iron Age is very interesting. During this time much of the very rich votive deposits (Fig. 100) in Skede Mose were made and Hagberg has recently concluded that Öland during the Roman Iron Age had a very high leather production and probably also leather export (1967, pp. 115 sqq). Hagberg's conclusions were partly based upon a very abundant occurrence of half-moon knives (a leather cutting tool) on Öland during this period, and if he is right, this production must have increased the landscape influence by grazing cattle widely, which may have resulted in a similar influence rate as is seen in the Skede Mose diagrams during the very period of the supposed leather production.

It is also very probable that the island at this time became overpopulated, which may have resulted in the establishment of settlements in marginal positions, very sensitive to any kind of change, economic, military or climatic. Many of the fundaments of houses on western middle Öland perhaps emanate from such marginal settlements.

The information from Gladvattnet and Skede

Mose has given tendencies of the landscape development on Central Öland. The results offer possibilities of defining well delimited special investigations for the working out of a detailed landscape history of middle Öland and the coming investigations should preferably be directed to the Roman Iron Age, Migration, Vendel and Viking periods.

The comparison between these two localities also shows how the natural environment very pregnantly can influence the landscape development within a restricted area, and that thus local trends may serve to elucidate greater problem complexes. The lack of regional validity for pollen diagrams within forest areas is also demonstrated.

Among the Alvar diagrams there is a slight difference too, as there is one feature in the diagram from Möckelmosen, which has not been found in any other diagram namely a small culmination of the *NAP*, which can be dated approximately to the middle Bronze Age, the same time when the "opening" of the landscape in the Skede Mose region began. Otherwise the development largely follows the same pattern as in all diagrams.

As in Gladvattnet, there is an immediate response to the culture's entrance together with the *Ulmus* decline, but as distinguished from this diagram the *NAP* amount increases together with the zone change VIII:H–VIII:J, which according to age figures, Fig. 97 a, would correspond to approximately 2500 BC. The start of the Megalithic passage grave culture in Sweden can be put some 2300 years BC, and the so-called "Ramsey's Stone Age transgression" has also been placed in roughly the same time. The development, apart from the described oscillation in Möckelmosen, remains fairly unchanged till the beginning of zone IX:K, when a new increase in the amount of *NAP* corresponds to the Skede Mose culmination and to the Roman Iron Age and the Migration period.

It thus seems possible that the first Alvar forming period of importance coincides with the Megalithic passage grave period, and it is then important to recall the presence of the Resmo passage graves on the western fringe of the Great Alvar.

During the rest of the time from this period and up to the beginning of the Roman Iron Age the landscape seems to have remained with sufficient and rather constant pressure of human influence. The picture reminds of the development in the Gladvattnet diagram, and it is possible that the initial "opening" phase was just enough to create the open landscape. If this creation for instance was accompanied by repeated burning of the area the effect upon the landscape may have become very strong and lasting.

During the Roman Iron Age it is evident that a new period of increased cultural press upon the Alvar was initiated, and the result was a still more open landscape. In the following and in the last chapter I will return to this and to the next period (IX: L).

Zone IX:L, corresponds roughly to the very latest part of the Migration period, the Vendel period and the Viking Age. This zone covers a time of decreased cultural influence on southern Öland and during the first part of it the tendency is very clear.

In the period's later part the influence recovers both in Stormaren and in Torpmosen but in Möckelmosen the situation remains unchanged throughout the period. Thus the development in the diagrams nearest to the Alvar's edges shows a similar picture, which has also been seen in the Gladvattnet diagram, where the influence again increases during the Viking Age. The late development indicates a strong influence during the Medieval time, possibly even increased in its later parts. A decrease enters around 1500 AD and remains during the uppermost parts of the diagrams.

The archaeology of the Great Alvar itself is very fragmentarily known. Most knowledge goes back to stray finds in the fields of the Alvar villages; one runic stone is known from the northern Alvar and the rest of our learning is based upon the inventory of ancient monuments made by the Central Office of National Antiquities together with the making of the economic photographic maps of the island.

This knowledge, however, only shows the abundance of the various monument types (Fig. 104) and does not normally allow conclusions of their age circumstances. In addition to this the excavation of the ancient stronghold at Eketorp, which is still in progress, gives information of a very active Viking Age and early Medieval time in this part of the Alvar (Stenberger, 1966 a, 1966 b).

If the entire material from the pollen diagrams is compared with the archaeological succession in general it is an amazingly harmonious picture we meet. However local differences are also traced which seem to be due mainly to edaphic conditions.

Fig. 104. Map showing the archaeological monuments within the Great Alvar of Öland. Designations: 1. Area outside the Great Alvar or within the Alvar villages' cultivated parts. 2. The strongholds. 3. Group of house fundaments. 4. Grave or grave field.

The map is a compilation of the information given on the economic photographic maps of Öland. It was originally given by the Central Office of National Antiquities through a systematic inventory.

Notes on the Palaeoclimatology, the Pollen Diagrams and the Archaeologic Succession

This chapter only deals with a couple of tendencies, and it thus does not claim to give the whole palaeoclimatological picture. As the continued investigations eventually will be completed and the entire palaeofloristic material will be given, the possibilities of establishing a climatologic development for the Alvar increases.

The periods to be treated in this respect are the zone transition VII/VIII, the local zones IX:K and IX:L.

The zone transition VII/VIII. The outstanding characteristic for the zone transition is the *Ulmus* decline. This event has long been looked upon as a mainly climatic one (Iversen 1941, pp. 34, 37). Simultaneously the amount of *QM* decreases, which Iversen considered to be due to Neolithic forest clearance. Faegri (1940, pp. 122, 123) remarked that it is possible to assume that a common usage of the *Ulmus* leaves for cattle food would restrict its reproduction and pollen production largely, and that this would be a possible explanation of the *Ulmus* decline. The decline was placed somewhat up in the Subboreal.

T. Nilsson (1948, p. 48) summarizes his opinion and states that the entrance of the Neolithic time was simultaneous with the big climatic change and suggests that the climatic changes "perhaps provoked the migrations of the Megalithic people and the introduction of agriculture to Scandinavia".

Later the explanation of the *Ulmus* decline as merely caused by human influence has become frequent, the beginning made by Faegri (1940). Troels-Smith has in particular used this explanation for the *Ulmus* decline (e.g. 1953, p. 17) and he is the one who has tried to investigate and elucidate the problem from various points of view. In Swedish material M.-B. Florin adopted the theory (1957, p. 22). The theory was very penetratively discussed by Magnusson (1962, pp. 50–57), who on the basis of the discussion rather supported T. Nilsson's opinion (1948). Later Iversen has again treated the problem and he supports Troels-Smith's theory (1960, pp. 15–20, 1967, pp. 407–409).

Tauber (1965, pp. 54–61) suggests alternative explanations based upon his works on the differential pollen dispersion. He emphasizes that vegetational environments around a lake may be very sensitive to local ground water changes, which will "upset the ecological equilibrium" and "result in aerodynamic changes, which will influence the pattern of pollen dispersion" (p. 55). Tauber points out that the *Ulmus*

decline also appears in areas where early agricultural activity would not be expected. He mentions elm falls in pollen analytical literature from outside northern Europe, among them one particular case in Wisconsin, which is dated approximately to 3000 BC some thousands of years before the first agricultural activity in these areas started. On the basis of the knowledge that the *Ulmus* curve again recovers after its decline in some oceanic European areas, Tauber (p. 61) intimates an entrance of a continental climate as a possible explanation of the *Ulmus* decline in the zone boundary VII/VIII.

Frenzel has summarized the available palaeobotanical evidences of a climatic change in the Atlantic/Subboreal zone boundary on the northern Hemisphere (1966, p. 99 sqq.) and he finds a very "short-term cold spell" at the very end of the Atlantic period, or in age terms 3400–3000 BC, which is really the beginning of the Subboreal period according to Nilsson (1964) and Berglund (1966) and which largely coincides with my local zone VIII: H. Later continentality of climate increased in several parts of the world, but there were interrupting minor oscillations (as shown in Västergötland by Fries 1951, pp. 144–147). At about 1500 BC and still more since about 900 BC the climate deterioration began. Summer and winter temperatures lowered, rainfall seems to have increased in Central Europe. The real vegetational events caused by these oscillations, whose intensity was rather weak, are often hard to discover as the activity of Man caused other vegetational changes, which "suppressed, camouflaged, enhanced or retarded" the natural changes.

In the material from Öland it is for strictly stratigraphical reasons evident that in the zone transition VII/VIII or slightly later some important climatic events occurred, which caused the *hiatuses* summarized on Fig. 102. At the same time as the soil formation again began the *Ulmus* decline appeared or had just appeared. No doubt a locally very serious climatic change struck the island at that time.

However the *Ulmus* decline is accompanied by evidences of some cultural activity on the island, and in many of the pollen diagrams (but not in all) the increasing amounts of *NAP* indicate some initial forest clearance already at this time. In my opinion the climatic change is the primary reason for the *Ulmus* decline, but it is at the same time quite possible that the Neolithic farmers used the elms for cattle food. The explanation of T. Nilsson (1948) quoted above well corresponds with my opinion.

The Zones IX: K and IX: L. In the brief description of the Bo settlement Hagberg (1967 *b*, p. 97)

remarks that the early Roman Iron Age settlement just east of the Ancylus ridge was abandoned owing to increased wetness and moved to somewhat higher grounds. The moving took place in the late Roman Iron Age or in the Migration period. The Roman Iron Age has been defined by Stenberger (1964, p. 361) to have lasted between 50 and 400 AD with a limit between an older and a younger part around 200 AD.

Granlunds Ry II was originally placed in the same time (1932, p. 170) but is now considered to have been formed rather around 300 AD. It can according to Granlund (1932, p. 170) be assumed that RY II represents a time with decreasing temperatures, increasing rainfall and rising groundwater table.

Berglund (1966, pp. 155, 157) emphasizes a few C_{14} datings, which show climatic changes of interest. One of these, U 447, gives the age 320 AD ± 80 for a change to a more humid climate.

In Fairbridge's review on the world sea-level and the climatic changes (1962, 1963) the known late transgressive movements have been plotted against the sunspot *maxima* for the past 2000 years. The present rise of the sea level (1962, p. 118), which amounts to 1 mm per year, has been going on for about a century and during the same period there is a mean rise of temperature at the long-established midlatitude climatic stations of nearly 1°C. According to Fairbridge, there is a good correspondence between sea-level fluctuations and the temperature curve. Transgressions are connected to warmer periods and regressions to colder. "A climatic change of minor order is reflected faithfully by the eustatic curve" (Fairbridge 1962, p. 118).

On the curve given by Fairbridge (1962, p. 119, Fig. 6, 1963, p. 238, Figs. 5 and 6) a regressive period lasts from 0 BC and upwards. It shows a *minimum* in the so-called Roman or Florida Emergence in the later part of the second century AD. Then the curve changes and the so-called Post-Roman submergence appears with a *maximum* 500 AD or slightly earlier. As to later events there is an emergence with a *minimum*, however not so accentuated as the Roman (Florida) emergence, around 700 AD, a submergence with a *maximum* slightly later than 900 AD, a new emergence 1000 AD, a submergence (the Rottne submergence = Younger Dunkirke or Mya stage) with a very accentuated *maximum* 1150 AD and then a long lasting and deep emergence (The Paria emergence) at 1500 AD.

Translated into temperature terms this means a colder period during the Roman Iron Age, a warmer period in the later part of this period and in the Migration period, slightly colder in Vendel time,

warmer but with fluctuations of rather high amplitude during the Viking Age and the early Medieval time, with a temperature *optimum* 1100–1150 AD, then considerably colder again and a new warm period finally starting around 1600 AD.

It is of course very difficult to control the validity of the later part of the Fairbridge-curve and its climatic significance. The curve itself has been much discussed and some grouping of scientists, who work with the eustatic movements of the sea, occurs. Besides what should be called the Fairbridge group, which then works on the theory of an oscillating sea-level after 6000 BP, there is another group working with the theory of a standing sea-level after 3600 BP. A third group denies any sea-level higher than the present during the Holocene and also a standing sea-level after 3600 BP (Jelgersma, 1966, p. 55, with a summarizing discussion).

However, most geologists working in the Baltic area find abundant evidences corresponding to the results of Fairbridge, especially during the Litorina period (cf. S. Florin 1963, and the literature discussed there). The Fairbridge-curve is the best summary available of our present knowledge about the eustatic movements of the sea.

If the Fairbridge-curve is taken to be fairly credible, then the validity of the close connection between the temperature curve and the eustatic movements has not been discussed. Lamb (1965) discussed an early Medieval warm period on the basis of historical, botanical and meteorological facts. He found that a "notably warm climate" lasted a few centuries around 1000–1200 AD, which was followed by a decline of the temperature till between 1500 and 1700, which seems to have been the coldest phase since the last Ice-Age (Little Ice Age).

This outline of the climatic history of the last nine centuries, which is built upon very convincing facts, coincides remarkably well with the climatic interpretation of Fairbridge's curve (1962, p. 119, Fig. 6) related above. It is then quite possible that the older parts of the curve can also be used in a theoretic paleoclimatic discussion.

It should, however, also be remarked that local or semi-local conditions may cause changes of climatic conditions, which may be very important and perhaps landscape forming. A shift in the depression tracks may thus yield a moister weather type for certain areas. If, for instance, a longer period with a high frequency of cyclons (depressions) of van Beber's type V:b should prevail in Europe, the result would be an increased precipitation in central Europe, on Öland and Gotland, without an accompanying general climatic change (Professor G. Liljequist,

Fig. 105. Aspect from the Södra Bårby karst area with *Juniperus communis*, *Rhamnes cathartica* and *Rosa* sp. growing in the open joints. Parish of Mörbylånga, June 1966.

Uppsala, personal communication, cf. Liljequist 1962, pp. 335, 374, 375).

During my local zone IX:K, a remarkable high *NAP* curve in Skede Mose and in the Alvar diagram indicates an open landscape. The accompanying culture indicating curve points out a high degree of human influence at the same time.

The Great Alvar today is a very poor area, where even grazing flocks of sheep have difficulties in finding food. During the older Iron Age the Great Alvar was inhabited and no less than 48 groups of house fundamentals datable to this period are known from the area. It is very difficult to understand how the people, who lived there, could survive if one only considers the present natural environment of the Great Alvar.

I have above quoted some words of Frenzel (1966), where he stresses the difficulty of tracing the climatically caused vegetational changes in the landscape development after the appearance of Man in a region. In this case, I can only see a changed climatic situation enabling people to live and survive within the Great Alvar, and consequently the degree

of human influence must be closely compared with the climatic development to be understood.

The evidences of Hagberg with a flooded settlement, abandoned after 200 AD (1967 *b*, p. 97), the climatic change indicated in the RY II of Granlund 300–400 AD (1932, p. 170), the increased humidity found by Berglund (1966, pp. 155, 157) 320 ± 80 AD together with the discussed climatic interpretation of the Fairbridge-curve, speak for a period of slightly colder and perhaps (but not necessarily) increased precipitation rich climate between 0 BC and 450 AD. This means that a somewhat changed hydrography must have existed, and if the precipitation did not increase, the evaporation must still have been lower. Thus moister conditions can be expected to have existed, and this means for a semi-arid area as Öland (cf. p. 19) increased grass growth and thus better possibilities for keeping cattle. The succeeding warmer period can then be expected to cause the opposite situation.

I want to see the development of the Alvar "farms" as a consequence of the climatic change, which enabled people to establish marginal settle-

Fig. 106. The ashes and sorbs of the now ruined ancient village of Dröstorp, show how the gravelly accumulations on the Great Alvar have once been covered with tree growth. On the most extensive deposits, as this one, groves may be possible, on smaller ones spinneys or rows of trees and bushes constituted the cover. Parish of Sandby, June 1957.

ments outside perhaps overpopulated areas. It is also possible that the increased human influence on the sandy soils of eastern middle Öland and the increased open landscape there during the same period should be looked upon in the same light.

During the Roman Iron Age the real Roman influence upon the cultural situation on Öland increased, which can be seen in the rich archaeological material from this period. Hagberg suggests that this may be due to trade connections with the Roman legions in southern Germany, which concerned leather needed by the Romans (1967 *b*, pp. 121 sqq.). However, this trade may as much be due to an overproduction of cattle and leather on the island, which forced the inhabitants to try to sell their products to the legions, as the legions' conscious search for new leather supplying countries.

The following warmer period may have been less favourable for the people settled down on the Alvar. A changed climatic situation can be expected to be much more evidently seen in a marginal zone than in adjoining areas. If for instance a plant is living close to its northern limit and a more severe climate

type enters, this will very quickly cause a common dying out of the plant near this frontier.

As the Alvar people lived in a marginal position, probably due to overpopulation of the island (cf. Stenberger 1964, p. 430), which had forced them to find new land and new dwelling sites, they were the last to settle down and the first to break up. Moister conditions must have been the conditions precedent for their existence on the barren Alvar.

Stenberger discussed the annihilation of the Iron Age houses on Öland and Gotland (1933, pp. 201 sqq. 1955, pp. 1065 sqq.), and he considers that a period of war led to a catastrophe for the islands. He again summarizes his point of view 1964 (pp. 553–557) and also reviews available literature from the same period in Scandinavia: Öland was destroyed 450–490, Gotland and perhaps also middle Sweden (the Mälar valley) 500–560, Bornholm and parts of Scania 475–525.

Ambrosiani (1964, pp. 210–212) intimates that some alteration in the colonization seems to have occurred approximately in the transition time between the Migration period and the Vendel period.

Fig. 107. Air photograph over the Penåsa area, parish of Kastlösa. The Penåsa stream is seen in the lower part of the picture. South of this are the ruins of the ancient Penåsa village, and north of it the Penåsa grove. The Alvar lake is Rosenkärret. West of this a row of black dots can be seen (The arrow), which is a row of birches. The more extensive gravel accumulations north of the village have become covered with trees, but the row of birches grows in a joint system and little or no gravel is attached to it. To the east of the birch row patches of greyer shade are seen. These patches indicate abundant growth of *Potentilla fruticosa*, which is also seen to the west and to the south of the row.

In the lower left corner, the scarps have developed in a semicircular pattern. I have not investigated this particular site, but in other similar ones which have been studied the pattern has indicated a dôme (p. 30). Photograph by Rikets Allmänna Kartverk 1964. Published by permission of the Swedish Defence Staff.

Recently Lindquist in his work on the cultural landscape in eastern Östergötland (1968) finds a period of stagnant and even annihilated cultivation and colonization, which he dates to early in the Migra-

tion period (400–475 AD). He wants to see the increasing power and expansive force of the early Swedish realm in the periods of war discussed by Stenberger, and he considers that eastern Östergötland

Fig. 108. Photograph showing the birch row on Fig. 107. The picture is taken in the central part of the row and towards the east. Note the flowering *Potentilla fruticosa* stands fringing the Alvar swamp in the foreground. Penåsa Alvar, parish of Kastlösa, August 1966.

first, then Öland, Scania, Bornholm and ultimately also Gotland were defeated by the Swedes. The main point in Lindquist's discussion is that after the war periods, a new colonization appeared, and that the conquered areas already at that time became organized according to a very strict administration as members of the ancient Sweden.

Arrhenius (1955, pp. 1053 sqq.) worked with phosphate analysis in the Vallhagar excavations on Gotland. On the basis of phosphate investigations on Gotland in general and on an analysis of the geographical distribution of the Iron Age settlements on Gotland he concludes that they mainly lay in the clay regions, while the later colonization appeared on lighter soils. He also maintains that a period of increasing rainfall started about 400 AD and he means that a climatic change in this direction would have meant a complete catastrophe for agriculture in the clay regions.

Also in the Vallhagar publication Pettersson (1955, p. 56) suggests the pauperization of the soil as the most probable cause for the ultimate abandonment of the settlements, and he also emphasizes (p. 52)

how a period of wet summers may have "a favourable effect on the dry conditions of Gotland, since the moisture encourages the production of pasture, fodder and grain on the easily dried soils of the island".

Nylén (1962, pp. 169 sqq.) summarized the literature and he states against the war theory that it is remarkable that the annihilation became so total. He also point out that Björnstad's (1951, Fig. 395) analysis of the entire finds from all investigated Iron Age houses on Gotland shows a decreasing frequency for those finds, which can be dated to the later part of the houses' usage period. Nylén stresses (p. 173) the fact that the war period indicated by the frequent *solidi* hoards may have been part of the causality of the abandonment of the houses, but the question is how great this part has been. Nylén's final conclusion is that the wealthy Iron Age settlements suffered from the war, but they survived; the poorer settlements, instead, were annihilated. This conclusion was also in the spirit of Almgren's discussion of the Vallhagar publication (1957, p. 243) where he also points out climatic and other natural circumstances as

Fig. 109. The picture shows a typical aspect of the more luxuriant stands of trees and bushes on the present Alvar. The trees are *Betula* and *Populus*, and in the foreground *Juniperus* grows. This type of bush/tree vegetation seems to me to be a potential "forest" type on the Alvar, which may be thought to have covered much of the gravelly deposits before the *landnam*. Södra Bårby Alvar, parish of Mörbytinga, June 1966.

possible reasons for the abandonment of the settlement.

In my discussion of the local zone limit IX:K/IX:L have found parallels, which may be approximately dated to the same time as the zone has been on Öland

(pp. 122, 123, 142, 143). In Blekinge and Östergötland the same picture appears and it is possible that this is also the case on Åland. Additionally a weak tendency may be referred to in one Västergötland diagram. In an unpublished pollen diagram from a sub-

Fig. 110. Example of "curtain forest" which may have been the common aspect on the Great Alvar before the *landnam* phase. These rows of bush/tree forests greatly restricted the wide Alvar view, which is today the typical Alvar picture. In this particular row pines, birches and aspen trees occur. Solitary spruces may also be seen. Bjälkäsen, parish of Mörbylånga, July 1967.

merged peat in Huskvarna bay, Lake Vättern, a similar picture has been found. This diagram has been worked out by the author.

Compared with the climatic discussion of the Fairbridge-curve (p. 149) this one indicates a somewhat warmer and so possibly drier period existing from 400–600 AD.

It then seems natural to me to accept the Almgren-Nylén theory of the poor settlements, which, according to Pettersson's remark, in time became gradually pauperized, and when the climate changed the drier conditions served to make the settlements still poorer.

The obviously coincidentally occurring war time may have caused the people in these marginal settlements to abandon their homes, but the ultimate cause of the annihilation of all these settlements was, according to my interpretation, climatic, and it seems very reasonable to build in a pauperization factor in the complex.

An Outline of the History of the Great Alvar

"When the field has been farmed in the spring, it will give off dust during the summer, when the

weather blows, and the most fine, black mould, the best and the real food for the plants, blows away and this almost invisible dust will rest along the fences, as does the sand drift and the snow in the winter; and hence the grass growth is always most exuberant along the fences. The most superb dust then blows away, as it lies open for all winds, and it often does not rest, until it is thrown into the sea. In this way it has happened to Öland's Alvar and many other places ..." (Linnaeus, 1751, pp. 239, 240).

The discussion of the history of the Great Alvar has been going on ever since Linnaei days. Additional to the Great Alvar on Öland minor Alvars occur scattered over the rest of the island, on Gotland, in Västergötland, in Estonia and in Latvia, and the literature includes some contributions from the latter two countries.

Notes about the Alvar history have thus been found in the following papers: Linnaeus (1745, 1751), Wahlenberg (1821), Sernander (1894), Hemmendorff (1897), Witte (1906), Hesselman (1908), Falck (1913), Danielsson (1918), Du Rietz (1921, 1923, 1925), C. Samuelsson (1924), Thomson (1924), Sterner (1924, 1925, 1938, 1948, 1955), Vilberg (1927,

Fig. 111. An example of a row of birches and aspen trees covering gravelly ridges NE of the church of Resmo. Parish of Resmo, August 1964.

1930), G. Lundqvist (1928, 1934, 1955), Stenberger (1933), Albertsson (1940, 1946, 1950, 1951 *a*, 1951 *b*), Selander (1941), Pettersson (1945, 1946, 1948, 1949, 1958), Sjöbeck (1946), Erdtman (1946, 1948, 1955), Iversen (1954, 1967), Horn af Ranzien (1955), C. Fries (1957), Steen (1958), Larsson (1959), Königsson (1962 *b*), and Martinsson (1965).

Two principle opinions have been maintained. (1) The Alvar has always been what it is today and (2) the Alvar is an extreme culture product.

The Alvar today is in a very dynamic stage. During the last hundred years the grazing has been more and more discontinued (cf. Hofrén 1939), and the overgrowth has increased rapidly.

The natural conditions for the landscape have been shown on the physiognomic map accompanying this paper. The picture shows exposed bedrock areas or areas with a very thin cover of weathered soil upon the bedrock alternating with gravelly deposits, most of which are rather shallow. In many of the

bedrock areas open joint systems, partly soil filled, occur.

The natural history of this distribution pattern of the soils on the Great Alvar is only known in fragments. E. Nilsson has summarized his available facts 1958 (pp. 179, 180), and he emphasizes the Kalmar line (a terminal moraine system, cf. pp. 12, 13) as very important. According to him it is one of the main stagnant stages in the ice recession. (This is also shown on plate I, E. Nilsson 1968). The glacial striae on Öland are said to support this theory as they alter direction to NW-SE north of the line from prevailing N-S direction south of it. He also considers that the roughly NW-SE directed ridges, which cause the jagged contour of the eastern coast of northern Öland, indicate the same ice movement direction. As is seen on the map with glacial striae, Fig. 3, only four striae are known from north of the Kalmar-line, and it has been shown (Königsson 1964 *a*, 1967 *a*) that the mentioned ridges must rather be interpreted

Fig. 112. This picture shows some old roads on the Alvar. Old roads have been discovered, which are not used any more, and one of these can be seen as a withish shade starting in the lower left corner and running towards ENE. Just below the central part of the photograph it divides into two roads; the one continuing towards NE, the other towards ESE and finally reaching the Träby strong-hold. The northern road is directed towards the church of Segerstad.

The roads were discovered when I once found one of them crossed over by a stone wall, and when the road was looked for on the air photographs it was easily found. Additional similar patterns, which before that discovery had not been observed at all, were afterwards seen and controlled. By the use of air photographs it seems to be possible to discover many forgotten roads on the Great Alvar, which must be of great importance for the understanding of the cultural situation on all southern Öland. See also Fig. 113 and 114.

On this map the scarp dammed persistent Alvar swamp in the upper left corner should also be observed.

Air photograph by Rikets Allmänna Kartverk 1964. Published by permission of the Swedish Defence Staff.

as shore ridges according to available exposures. Still the Kalmar-line may be the result of a main stagnant period, as material from Kalmarsund proper obtained by coring on the bottom does not contradict the theory.

E. Nilsson considers that a relative absence of boulders on the Great Alvar is due to the Baltic ice stream, which he maintains covered southern Öland, and which perhaps was carrying a local moraine with limestone boulders, which have been ground into pebbles and sand by the waves.

The reality is that especially on the western Alvar side there may be found areas with very striking boulder richness, and in these collections the erratic boulders predominate. In other areas very few boulders are seen.

The present cover of gravel and sand is thin

and restricted to ridges (cf. p. 42 sqq). E. Nilsson considers the various transgressions of the Baltic stages as the cause of the poverty of soils on the Great Alvar. This seems very reasonable, as the many shore ridges in the area support the theory. Because of the rather modest proportions of the ridges, including the *Ancylus* and *Litorina* ridges in many areas, I want to add, hypothetically, to the picture that the moraine cover may have been rather thin as it has been removed to such a great extent.

The distribution of the gravelly deposits must be the basis for the discussion of the vegetational cover of the Great Alvar. Its present pattern has been reviewed above (p. 24 sqq.), and the bush and tree members of this pattern have been described briefly.

It has been shown in the pollen diagrams that a "forest period" has existed on the Alvar. It has also

Fig. 113. Very often only little is left of the roads as lichens and mosses cover them, and they are difficult to discover on the ground. In this particular case the road has been rubbed down in the bedrock, and it may be traced in the distance in the gravelly ridge, as a diffuse shadow. Träby Alvar, parish of Segerstad, August 1966.

been emphasized that the character of this forest must have been rather open, and that light demanding plants as *Artemisia* and *Hippophaë* were important members of the plant communities.

Unless a formerly existing soil cover, now disappeared, enabled an extended bush and tree growth, the possible extent of these plant types during the "forest period" can be seen on the physiognomic map.

In areas with open joints some growth may be considered as possible. Present examples of very luxuriant bush growth offer the *Corylus* stands in the Ekelunda hazel karst (Fig. 24) and the *Rhamnus cathartica*, *Prunus spinosa* and *Rosa* sp. growth in the Sa Bårby karst (Fig. 105), which is situated south

of Möckelmosen, half way between the two roads crossing over the Great Alvar.

On gravelly areas, according to the present climatical situation, mostly *Juniperus* growth dominates, but in such areas where nearby marsh zones indicate more abundant water supply in superficial layers, *Betula* and *Populus* predominate, often with a lower bush layer of *Potentilla fruticosa* below them. The border zones of the Alvar, where soil depth and water supply in many cases permit bush and tree growth, the inhibited grazing has resulted in increased growth of *Betula* and in certain areas *Juniperus*.

On the most extensive gravelly deposits, the Alvar villages' areas, also other trees occur as *Ulmus* and

Fig. 114. From Resmo church towards Triberga stronghold another road runs. Part of it is built of stones, and part of it is only marked with stone pillars, like the one on the picture, which occur within sight of each other. All ancient roads, which have been observed up to now seem to run between the churches or between these and the strongholds. From the stronghold at Eketorp, there is one ancient road directed roughly towards NW. It is possible that this road can be followed over the Alvar and it may end near the church of Södra Möckelby.

Fraxinus and other members of the *QM*. This is, for example the case in the Gösslunda and Dalby/Lunda areas (cf. Fig. 106).

As far as I can see from my diagrams, the *Betula* growth is what becomes registered as more abundant during the forest period perhaps together with some *Pinus* trees. However, as the Atlantic sediments are lacking or almost lacking it is not possible to say anything about the vegetational situation during this zone on the Alvar. Theoretically a more extended tree and bush growth is assumed, and the abundance of the *QM* component is supposed to have been considerably higher also on the Great Alvar proper.

According to my map, chiefly the brown areas and many of the strongly green areas are considered as potential areas for abundant tree and bush growth. Consequently a very considerable amount of the Alvar area may not have been covered by the mentioned vegetation. A soil cover, probably a humus layer, which has now disappeared, may have occurred and perhaps widened the area of bush and

tree growth somewhat, but the main picture of the ratio between potential tree-bush growth areas contra such areas with almost no potential in this respect must be considered to have been very much the same throughout the Holocene. The survival of light demanding plant species through the forest period until our days supports this statement.

The Alvar forest was thus restricted to certain areas and the bushes and trees appeared in spinneys or rows (Figs. 107, 108) and the wide horizon of the present Great Alvar was greatly restricted by this pattern.

The prevailing species may have been *Betula*, *Populus* (Fig. 109), *Pinus* and those members of the Alvar vegetation to day, which yield little or no pollen to the recent pollen sedimentation, eg. *Rhamnus cathartica*, *Rosa* sp., *Prunus spinosa*, *Crataegus* sp. and *Salix* sp. Some *Juniperus* growth fringing the Alvar patches complete the picture (Figs. 23, 34, 107, 108, 110, 111).

The more abundant growth of bushes and trees must have meant increased humus formation in the

Fig. 115. Air photograph showing the excavation site of house fundaments from the middle Iron Age near Möckelmosen. Apart from the fundaments the richness of boulders in the area is of interest and is well demonstrated in the white dots on the ground. A few small areas with open joints may be seen, so called karst windows. The abundant growth of *Juniperus* can also be studied. Helicopter photograph by Rune Hedgren, Royal Swedish Air Force. Published by permission of the Swedish Defence Staff.

thus “forested” areas. The humus formation may have been gradually extended over areas outside the bush and tree covered ones, and especially during the Atlantic period one would expect potentialities for such soil formation.

The question of the wind eroded Alvar soils has been much discussed, and already Hemmendorff (1897, p. 30) on the basis of a personal communication to him from Areskog, the famous botanically learned reverend on Öland, points out the particle transport over the Great Alvar. He also referred to this phenomenon as a possible reason for the area’s soil poverty. Sjöbeck (1952, p. 14) shows how large

regions in southwestern Sweden were cleared and burned for cultivation, which, according to him, took place in Megalithic time, and which resulted in soil deflation. He also points to the possibility of a similar development for the Great Alvar.

C. Fries (1957, p. 189) adds a detail of particular interest: “. . . under the grave mounds made by the peasants of the Bronze Age the soil was left; around the mounds it is gone—gone with the wind”. Unfortunately he does not refer to any defined locality on the Alvars.

A similar observation, however, has been made by Stenberger (1942, p. 104) in an Alvar-like area on

northern Gotland, where a Bronze Age crater cairn was found to concrete a layer of silt in its middle parts. Stenberger did not finish the investigation of the grave at that time, but it was instead made very recently by Dr. E. Nylén and Mr. A. Hallström, Visby. In cooperation with Dr. Nylén, I studied the profiles in the cairn, Kauparve, parish of Lärbro, and the layers were sectioned and sampled. In a cleft in the northern parts of the grave a silty humus rich soil of about 30 cm thickness was found underlying the walls. In the other parts of the cairn the soil layer was very modest. The heavy silt layer reported on by Stenberger (1942) had probably been removed in connection with his investigations. Because of the new evidences from Kauparve it does not seem to be possible to conclude anything about the extent of earlier existing soil layers in this particular area.

C. Samuelsson (1924) treated the wind erosion in Sweden, particularly in fields and in fens, and he considered that the development of the Great Alvar greatly depends on wind erosion (pp. 92, 93).

It seems very probable that burning has been used in connection with some clearance of the Alvar forests, when the first grazing cattle were entering the area, and it seems very reasonable to assume that the humus layer suffered greatly from every repeated burning. During my zone VIII:H both in Stormaren and Torpmosen 7 pregnant culminations in the charcoal curve indicate that fires struck the Great Alvar at that time. The period largely coincides with the Passage grave culture, and it may thus be possible that Sjöbeck's theory has full validity (Sjöbeck 1952, p. 14).

The question of the effect of grazing in the area has long been discussed, with a start in Hesselman (1908). He and Vilberg (1927, p. 135) considered that the formation of the Alvar had an edaphic background, where climatic situation and grazing effect were important components in the complex. Vilberg (1930, p. 108) develops the theory and points out that a reafforestation begins in the Alvar areas as soon as the grazing decreases.

Recently the effect of overgrazing has been seen on Öland, as too big flocks of sheep have grazed in the Alvars. *Juniperus* and *Betula*, sometimes also *Pinus* and very often *Potentilla fruticosa* suffer much from the overgrazing and will die within a couple of continued grazing years. At the same time several examples of beginning wind erosion have been discovered (Fig. 39). A summary of the wind circumstances is given in Figs. 5, 6, 7 and 8.

There is no doubt that the Alvar landscape formation is very closely connected to the grazing activity, and that earlier existing humus soils may be assumed

to have been removed with the aid of grazing to some extent, perhaps in connection with clearance burning.

It has been pointed out that the development of the Great Alvar landscape has a culminating human influence connected to the older and middle Iron Age. The archaeological picture then is very important for the understanding of the landscape development during this time. A map of the known archaeological remains on the Great Alvar is given in Fig. 104. It summarizes the information from the inventory of the archaeological monuments, which was performed when the economic maps were made. The great number of monuments is amazing, and still more amazing are the 48 groups of house fundamentals, which have been found on the Great Alvar, and which are considered to be from the older Iron Age. Evidently the inhabitants of these houses must have had an immense influence upon the development of the landscape. It was because of this that it was desirable of knowing from what time the fundamentals were, and if possible to get to know about their inhabitants' living and household conditions. The research team "*Ölands Stora Alvar*" was constituted to investigate this and other problems and since 1965 the excavation of the house fundament complex SSW of Möckelmosen (*Boplats* on the physiognomic map) runs. The house fundament group remains from the later part of the Roman Iron Age and the beginning of the Migration period according to the find material (Fig. 115), and the C_{14} datings which are available now (100 ± 80 , 190 ± 70 , 260 ± 70 and 470 ± 70 AD) indicate a habitation of the settlements during the very period of slightly colder climate, which corresponds to the Roman (Florida) emergence *sensu* Fairbridge (1962). The excavations are continuing and the results should therefore be looked upon as preliminary (personal communication by Mrs. Ebba Stina Königsson, FK, Institute of Nordic Archaeology, Uppsala, see also Königsson & Königsson 1967).

Nearer Möckelmosen another excavation is in operation and from this one finds, preliminarily placed in later Viking age or early Medieval time have appeared (personal communication by Miss Monica Wennersten, FK, Institute of Nordic Archaeology, Uppsala).

The excavations of grave mounds supposed to remain from the Bronze Age, to look for preserved soil layers, failed in this respect in the first investigated grave, which yielded only finds from the Migration period. The second excavation is still in progress, and finds have put the Gösslunda Rör at least back to the middle of the Bronze Age. The excavations will continue in 1969, when eventual soil layers be-

low the mound will be examined (personal communication by Mr. Ingmar Jansson, FK, Institute of Nordic Archaeology, Uppsala).

It is then shown preliminarily that the Alvar houses very probably were inhabited during the Roman Iron Age and the first part of the Migration period. These marginal settlements must have been very exposed to climatic events and to pauperization of the soils. It does not seem possible that these people could live very long on the barren Great Alvar, which with the time grew still more barren. When the climate finally again changed they had to leave their dwellings, but during their stay on the Alvar plain they created the landscape, which during this period seems to have become an Alvar in our sense for the first time.

Later on, during periods of overpopulation or temporary climatic changes, new attempts were made to settle down within the area. The site near Möckelmosen with finds from the later Viking Age and the early Medieval time (Wennersten), was perhaps one of these attempts. Others were made during the eigh-

teenth century, when at least two now ruined villages were founded.

The Great Alvar during the Historical time is the subject for the investigations by Dr. Sölve Göransson, Institute of Human Geography, Uppsala, within the program for the research team.

For the later periods the pollen diagrams have shown an increased human influence around 1500 AD, which then decreases. It should be added that there is a coinciding climatic *minimum* during the time 1500–1700 AD, the so called Little Ice Age.

With this study an outline of the Holocene history of the Great Alvar has been presented. Some periods have been fairly well investigated, others less well. The Atlantic period, lacking in preserved sediments of the Great Alvar belongs to the latter category.

Many details remain to be elucidated. Some of these problems will be treated in connection with the continued team-work, and this involves extended studies of the late Pleistocene and Holocene geology of the Great Alvar of Öland.

APPENDIX

The Pollen and Spores Material, Determination and Classification Notes

As has been stressed above, this study mainly concerns the landscape development within the Great Alvar and the human influence in connection with the development. Thus the palaeofloristic material is of minor direct interest at this point, and it will instead be treated together with the more extensive material which will appear in the continued investigations.

However a brief summary of the more exclusive finds and those finds which have a direct interest within the scope of the present study will be given. In connection with this some species or types determinations need some further comment.

The grouping of the different pollen types and spores in the Hemerophilous and Synanthropic curves was made according to Sterner's information on this subject. In an enumeration of all pollen and spores types identified the performed grouping is given with the following designations: Hemerophilous—H, Synanthropic—S, Cultivated—C, Terrestrial—T, Aquatic—A, Fen plants—F, Others—V, Tree and bush pollen—AP.

Acer—AP.

Allium—T, H.

Alnus—AP.

Anemone type—T.

Artemisia—T, S, H.

Attempts have been made by several authors to distinguish types or species among *Artemisia*. Straka has, for instance, determined *Artemisia campestris* (in Fries 1958, p. 49) and J. Lundqvist recently (1967, p. 221) reports of finds of *Artemisia norvegica*. As to the latter of the two, in a type sample as the one at our disposal within the Institute of Quaternary Geology at Uppsala, a big percentage of the pollen have "the spinuloid processes" "considerably larger than in the other species" (Erdtman, Berglund and Praglowski 1961, p. 25) but there are also pollen without these larger processes. On the other hand *A. norvegica* (according to this definition) can be found for instance in reference samples from *A.*

rupestris and *A. vulgaris*. By the analysis work *A. norvegica* like pollen have been observed from Öland.

According to my opinion, it is a statistical problem in determining *A. norvegica* and other *Artemisia* types.

The first thing to be done is to investigate a great number of individuals of the *Artemisia* type of interest as to the percentage of the ideal pollen type to be found in each individual. According to this and to the observations remarked above about the reference samples' content of various *Artemisia* types in the same individual, it must always be the question of an *Artemisia* pollen type and never of a fully determined *Artemisia* species. Thus it is very problematical to distinguish *A. norvegica* in fossil material. This also seems to have been in the spirit of Erdtman (1967, p. 28), where he mentions the determination as "the identification of fossil pollen grains indistinguishable from those of *Artemisia norvegica*".

As no investigations in the referred respect have been made and reported on, and as in our reference material no trends have been seen to justify detailed species determinations within *Artemisia*, no attempt has been made in my analysis work to differentiate determinations.

Avena—T, C.

Betula—AP.

Botrychium—T.

Calluna—T.

Caltha type—V.

Campanula type—T, H.

Caryophyllaceae—V, H, S.

Carpinus—AP.

Centaurea cyanus—T, S.

Centaurea jacea—T, H.

Centaurea scabiosa—T, S.

Chamaenerion—T, H.

Chenopodiaceae—T, H, S.

Cladium type—F.

Compositae, *Cirsium* type—V, H, S.

Compositae liguliflorae—V (own column, see p. 106).

Compositae tubuliflorae—V, H, S.

This group collects the *Aster* type and the *Achillea* type but not the *Artemisia* type and the *Cirsium* type.

Corydalis type—T.

Corylus—AP.

Cruciferae—V, H, S.

Cyperaceae—V (own curve).

Empetrum type—V.

Ericaceae—V.

Ephedra.

E. has not been combined with any of the groups. The finds in the present analysis material are from the Great Alvar of the Preboreal, Boreal and Sub-boreal periods. In the Dröstorps analyses the *Ephedra* find belongs to the Boreal period. Iversen reported 1954 (p. 105) one find from Boreal and three finds from Atlantic time. Together with my new finds altogether nine pollen grains of *Ephedra* are known from the Great Alvar, and additionally two finds from middle Öland comprising 4 grains, three of them from the Preboreal period, should be included in the picture.

Iversen suggests that the *Ephedra* pollen derives from growth places on Öland, and he repeats this in a recent publication (1967, p. 358).

On the basis of surface sample analyses Welten (1957) concluded that *Ephedra* could be expected to grow locally if the pollen amount in an analysis was 0.5–1.0% of the pollen total in the sample, and he considered it quite possible for the *Ephedra* to grow in southern Scandinavia in Late Pleistocene time.

Vinje and Vinje (1955) found *Ephedra* far away from its nearest growth places in the air over Davenport, Iowa, USA, on glycerin-coated slides exposed above the temperature inversion on the heights at 1350 and 1500 m, and Maher (1964) shows a very interesting map including *Ephedra* finds in the sediments in the Great Lakes region and *Ephedra* finds in the atmosphere compared with the present distribution of *Ephedra* in the USA. From the finding place for atmospheric *Ephedra* of the present time, which is nearest to the growth places, the distance may roughly be put at 1000 km; the most distant at some 1500 km. Because of his material Maher concludes contrary to the accepted view, that the proved long distance carrying of *Ephedra* in the air shows that the Late Pleistocene *Ephedra* finds in the Great Lakes region can not be taken as evidences for *Ephedra* growth in the region during Late Pleistocene time.

In my opinion the present finds of *Ephedra* on Öland are too few to support the theory of *Ephedra* growth there during the Preboreal and later times.

I have therefore left this pollen type outside the actual grouping.

Epilobium—V.

Equisetum—V (own curve).

Euphrasia type—T, H.

Fagopyrum—T, C.

Filipendula—V, H.

On a pollen morphological basis it does not seem to be possible to distinguish different types. On the Alvar it is most probable that the bulk of the *Filipendula* pollen emanates from *F. vulgaris*, which then would be terrestrial.

Fumana—T.

Galium—V, H.

Gentiana type—T, H, S.

Geranium type—T, H.

Globularia—T.

Gramineae (spont.)—V (own curve).

Hedera—T (own curve).

Helianthemum—T.

For a long time pollen of *Helianthemum oelandicum* has been mentioned from Late Pleistocene sediments in northern Europe. Its pollen has been considered as safely distinguishable from *H. nummularium*, and for instance in Erdtman, Berglund and Praglowsky (1961, p. 24) it is stated that *H. nummularium* has a "reticuloid" pattern in a surface view, which is not present in *H. oelandicum*.

On Öland three species belonging to the *Helianthemum italicum* group are found: *H. oelandicum*, flowers in early June, endemic on the island, *H. canum* and *H. italicum* ssp. *rupifragum* both flowering in the autumn. The pollen of these three species seems to be undistinguishable from each other. However, also pollen with the reticuloid pattern can be found in all the species' reference samples, and pollen without this pattern has been observed in slides with *H. nummularium* reference. The reference material at the Department of Science, Danish National Museum also shows the same picture, and there is obviously need for a statistical investigation of the *Helianthemum* species' pollen. In waiting for the publishing of such an investigation I have chosen to show my material as *Helianthemum* sp. However, it may be added that most of my *Helianthemum* finds belong to the *Helianthemum italicum* (= *oelandicum*) type.

Hippophaë—AP.

Hippophaë has been found remarkably high in the stratigraphy. The youngest finds on the Great Alvar are from Subatlantic time. This indicates that *Hip-*

Hippuris—A.
Hordeum—T, C.
Humulus type—T, H.
Hydrocotyle—F.
Hypericum—T, H.
Iris—F.
Jasione type—T, H.
Juniperus—AP.
Labiatae—V, H, S.
Lastraea dryopteris—V, H.
Leguminosae—V, H, S.
Linum catharticum—T, H.
Linum usitatissimum—T, C.
Littorella—A.
Lycopodium annotinum—T.
Lycopodium clavatum—T.
Lycopodium alpinum/complanatum type—T.
Lycopodium selago—V.
Lysimachia vulgaris—F.
Lythrum—F.
Melampyrum—T, H.
Menyanthes—F.
Myriophyllum alterniflorum—A.
Myriophyllum spicatum—A.
Myriophyllum verticillatum—A.
Mercurialis—T.
Nymphaea—A.

Nymphaea seems to have been a very common plant on Öland in past times. It is mentioned by Sterner (1938) as rarely seen.

Ophioglossum—T.
Parnassia—V.
Picea—AP.
Pinus—AP.
Plantago lanceolata—T, H.
Plantago major/media—T, S.
Plantago maritima—T, H.
Plantago tenuiflora—T.
Polygala—V, H.
Polygonum aviculare type—T, H.
Polygonum persicaria type—V, H.
Polypodium—T.
Polypodiaceae—V (own curve).
Populus—AP.
Potamogeton, sect. *Coleogeton*—A.
Potamogeton, sect. *Eu-Potamogeton*—A.
Potentilla/Fragaria type—V, H.

Attempts have been made to study the pollen of *Potentilla fruticosa*, which seem to be slightly smaller than other species' pollen within the type. I have, however, considered this difference to be of minor value when working with fossil material, and I do not

think that it is possible to distinguish distinct subtypes within the Swedish species of *Potentilla* and *Fragaria*.

Pteridium—T.
Ranunculus—V, H, S.
Rhamnus frangula—AP.
Rhamnus cathartica—AP.
Rhinanthus type—T, H.
Rosaceae—V, H.
Eu-Rumex—V, H, S.
Rumex acetocella type—T, H.
Salix—AP.
Saxifraga oppositifolia type—T.
Scleranthus type—T, H.
Scrophulariaceae—T, H.
Secale—T, C.
Sedum—T.
Selaginella—T.
Solanum dulcamara—V, H.
Sorbus—AP.
Succisa—V, H.
Taxus—AP.
Thalictrum—V.
Tilia—AP.
Trifolium—T, H, S.
Triticum—T, C.
Typha latifolia—F.
Typha/Sparganium type—F, H.
Ulmus—AP.

The two *Ulmus* types mentioned by Faegri & Iversen (1964, p. 190, and the literature which is referred there) have been investigated in the diagrams from Stormaren and Gladvattnet. They have not been drawn into the diagrams as the occurrence of the two types within the different Scandinavian *Ulmus* species does not seem to be quite clear. I have started investigations in this respect on recent material, but these studies have not yet been completed.

Umbelliferae—V, H, S.
Urtica—V, H.
Utricularia—A.
Valeriana—V, H.
Viburnum—AP.
Viscum—T (own curve).

The grouping of the plants according to Sterner's information (1938) of moisture demand and culture dependence was first made as an experiment on the Stormaren material. As the result was very encouraging, I used the grouping on the entire material from the Great Alvar and from Middle Öland.

The result suffers from the detailed determinations of pollen and spores, which have not been possible

to carry out as distinct as has been desired. Thus pollen types have been put to more than one group in many cases. This, of course, restricts the value of the grouping somewhat. However the curves on the whole react in the way one would expect them to if the grouping was correctly or almost correctly done.

This is especially well demonstrated in the Stormaren diagram.

In the future, pollen analysis will have to work with big amounts of registered pollen and spores for the establishment of vegetational development and cultural influence in the landscape history. Grouping of the material in a similar way as has been carried out in this paper may serve as a good help in the interpretation stages and make the pollen diagrams

easier readable. In my opinion the future pollen analysis will have to work with computer made diagrams and diagram calculations as manual calculations take too much time to be carried out safely. Preparations of making a program for computer made pollen diagrams according to various ecological groupings of the analysis material has already been made and will be reported on later.

The accompanying diagram (Fig. 116) includes a compilation of the paleofloristic material in this study. It only shows the extent of the analysis material and this will be treated again in a common paper from the team work reported on in the final chapter above.

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Abbreviations

- Acta Arch.* — *Acta Archaeologica*.
- APhS* — *Acta Phytogeographica Suecica*.
- BGIU* — Bulletin of the Geological Institutions, Uppsala.
- Bot. Not.* — *Botaniska notiser*.
- DGU* — Danmarks Geologiske Undersøgelse.
- FV* — Fornvännen.
- Geo. An.* — *Geografiska Annaler*.
- GFF* — *Geologiska Föreningens i Stockholm Förhandlingar*.
- R.C.* — *Radiocarbon*
- SBT* — *Svensk botanisk tidskrift*.
- SGÅ* — *Svensk Geografisk Årsbok*.
- SGU* — *Sveriges Geologiska Undersökning*.
- STF* — *Svenska Turistföreningens årsskrift*.
- Sv. Nat.* — *Sveriges Natur*.
- Vallhagar* — *Vallhagar. A migration period settlement on Gotland/Sweden*.

FYSIOGNOMISK KARTA
I TVÅ BLAD ÖVER
ÖLANDS STORA ALVAR

UPPRÄTTAD 1962, 1963 och 1966
AV LARS-KÖNIG KÖNIGSSON

PHYSIOGNOMIC MAP OF THE
GREAT ALVAR OF ÖLAND
SURVEYED IN 1962, 1963, AND 1966

Teckenförklaring
Legend

- Svallade grusiga och sandiga avlagringar
Gravel and sand
- Häll, delvis täckt med vittringsjordar
Bedrock partly exposed, partly covered with weathering soils
- Alvarsjö
Alvar lake
- Större våt
Temporary pool
- Våtängar
Swampy meadows
- Områden utanför det egentliga Stora alvaret
Areas outside the Great Alvar
- Karstområden
Karst areas
- Doliner
Dolines
- Alvarets gräns
The Alvar limit
- Byar
Village
- Stenbrott
Quarry
- Väg
Road

Skala 1:25 000

0 1 2 3 km

(A) Appendix 1. Geological sections

Cross section 515. The limnic and thelmatic parts of the sequence are shown under one heading. The dashed line represents a pre-Ancylus carr peat. Between them a sandy layer

Cross section 500, detail (305/500-350/500). Legend, see profile D

Cross section 375, detail. Legend: 1 Cultivated layer (plough soil). 2 Gravel lenses. 3 Organic lenses in sandy material. 4 Sand with high organic content. 5 Moraine. 6 Carr peat. 7 Carex-peat.

Longitudinal section 300, detail (300/520-300/530). Legend for profiles B and D. 1 Moraine. 2 Carr peat. 3 Reddish yellow sand. 4 Grey sand. 5 White sand. 6 Calcareous gyttja. 7 Calcareous gyttja with sand lenses. 8 Calcareous gyttja with higher detritus content. 9 Fine detritus gyttja. 10 Shell horizon. 11 Shell horizon with humus. 12 Coarse detritus gyttja. 13 Peat. 14 Cultivated layer (plough soil). 15 Bones. 16 Wood. 17 Old crack with detritus content.

... och den bladbekrönta näcken
gigan rör i silverbäcken (Erik Johan Stagnelius 1821/1823)

Analyses by Thirolf Candolin

Analyses by Lars-König Königsson

Analyses by Ingrid Sørensen

C₁₄

St 1299

Analyses by Thorolf Candolin

Analyses by Thorolf Candolin

Analyses by Thorolf Candolin

Analyses by Thorolf Candolin

Analyses by Lars-Konig Konigsson

Liträsk, Parish of Vickelby, Öland LT 1

Pris 54: — kronor