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Ivy, Mistletoe and Elm
Climate Indicators - Fodder Plants

A Contribution to
The Interpretation of the Pollen Zone Border VII-VIII

By
J. Troels-Smith

With 6 Plates

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C. A. REITZELS FORLAG (JØRGEN SANDAL)
KØBENHAVN 1960

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ANDELSBOGTRYKKERIET I ODENSE

CONTENTS

Introduction

KNUD JESSEN (1935) fixed the border between his pollen zones VII–VIII which, broadly speaking, separates the Atlantic period from the Sub-Boreal period in Danish pollen diagrams, at the level "where the curve for the Oak Mixed Forest bends inwards, often because the frequency of the linden especially drops quickly".

In 1941 IVERSEN in his paper "Land Occupation in Denmark's Stone Age. A Pollen-Analytical Study of the Influence of Farmer Culture on the Vegetational Development" pointed out, that this characteristic fall in the curve for the oak-forest indicates a human interference – a land occupation – where forest was cleared in order to make room for fields and pastures. In the paper mentioned, IVERSEN suggested fixing the zone border VII–VIII at an earlier level, i. e. at the point where the curves for elm *(Ulmus)* and ivy *(Hedera)* begin to decline. IVERSEN thought that the decline of ivy, especially, indicates a change from an Atlantic climate with mild winters to a more continental one with cold winters. Later on (1944), after an investigation of the temperature demands of ivy, IVERSEN defined his interpretation more explicitly. According to him the decline of the elm curve may be explained if one assumes that the rather thermophilous *Ulmus campestris* was common in the Atlantic period, as well as *Ulmus scabra*. In that case, a decrease of the winter temperature at the beginning of the Sub-Boreal period may have caused a disappearance of *Ulmus campestris*, and, consequently, a reduction of the elm pollen frequencies.

As a result of investigations which SVEND JØRGENSEN, deputy keeper of the National Museum, and I have carried out in the West-Zealand bog Aamosen and in Switzerland through a number of years, I have reached the opinion that the decline of the elm curve may not have been due to a change in climate. In counts of large numbers of pollen (about 2000 forest-tree pollen grains in each analysis), at levels above and beneath the elm decline in both areas, a few certain traces of agriculture appear immediately above the decline but no such traces occur beneath it (TROELS-SMITH 1954, 1955).

Hence, we may ask whether the zone border VII–VIII as defined by IVERSEN was due to a climatic change, as he thought, or whether the vegetational changes resulted from human interference. A third alternative is the possibility that a climatic change was accompanied by the introduction af agriculture in Denmark (cfr. O. PARET, 1948).

During the past 10 to 15 years I have had the great pleasure of discussing these problems with Dr. IVERSEN. These – often dialectical – discussions have been very profitable, not only because I have shared IVERSEN's vast knowledge in the forest-botanical field, but also because the discussions caused a more explicit formulation of our attitudes to the various problems. Last, but not least, I want to thank Dr. IVERSEN for the stimulation which, in my opinion, is the greatest profit of a discussion carried on with the sole object of reaching the naked truth.

For several years I have planned the publication of the full results achieved by many years' excavations in Aamosen and to use that opportunity for stating my points of view with regard to the most ancient Farmer Cultures in Denmark and to the climatic changes that probably took place immediately before and after the time when agriculture caused significant alterations in the history of the forest.

Circumstances have continuously delayed such a publication. My points of view were stated at two lectures at The Geological Society of Denmark (21/2 1955 & 12/1 1959) and I think it right to give a brief outline in the present paper.

The pollen-analytical material, on which my reflections are based, was counted mainly by SVEND JØRGENSEN. I want to express my heartfelt thanks to him for the solid foundation he has laid for my rather lofty meditations. I also want to thank BENT FREDSKILD, deputy keeper of the National Museum, who has contributed by analyzing the material from Dyrholmen and Aamosen, and E. TELLERUP, police inspector, who identified samples of fossil elm wood. The diagrams have been drawn by HELGE JENSEN and O. HAEUSLER, cartographers at the Danish Geodetical Institute.

THE CARLSBERG FOUNDATION has contributed most generously to the pollen-analytical investigations of the material both from Aamosen and from Switzerland. This support was of vital importance for the research and, consequently, for the present paper. Accordingly I want to express my gratitude to the board of directors of the CARLSBERG FOUNDATION.

NATIONAL MUSEUM, DEPARTMENT OF NATURAL SCIENCES, Copenhagen, January, 1960.

J. Troels-Smith.

Ivy

In the article "Viscum, Hedera and Ilex as Climate Indicators. A Contribution to the Study of the Post-Glacial Temperature Climate" (1944), Dr. IVERSEN mentions his investigation of the relationship of those plants to the summer and winter temperatures. Most plants are rather dependent on the summer temperature, and the winter temperature is usually of little importance. The three species mentioned above are, however, evergreen and depend on the winter temperature too.

IVERSEN plotted decreasing mean temperatures for the coldest month againts decreasing summer temperatures in a co-ordinate system. A meteorological station can therefore be placed in the co-ordinate system according to its mean temperatures for the warmest and the coldest month. Occurrences of the plant species concerned may be indicated with the summer and winter temperatures at their growing places as co-ordinates. In this way it is possible to determine the temperature requirements of the species mentioned, or their "thermosphere" (i. e. "the sum of the temperature conditions under which a plant occurs and thrives in nature", vide JOAKIM FREDERIK SCHOUW 1822, cf. IVERSEN 1944, pag. 467, note 1). Of special interest is the line which delimits the area in which ivy can neither flower nor produce fruits, "the limit curve for *Hedera helix*" (vide fig. 1). It may be noticed that the ability of ivy to tolerate low winter temperatures decreases with the summer temperature or vice versa: at higher summer temperatures it tolerates lower winter temperatures, but only down to certain minimum for the winter temperature. A mean temperature for the coldest month at less than 1½° C below zero will be unfavourable for ivy, however high the temperature of the warmest month.

IVERSEN determined the average frequency of ivy pollen for the various Postglacial pollen zones in relation to the total of forest-tree pollen (exclusive of hazel). It may be preferable to reduce the pollen contributed by pine *(Pinus)*, birch *(Betula)*, alder *(Alnus)*, and hazel *(Corylus)*, the largest pollen producers, by division by four, but IVERSEN's calculation nevertheless illustrates the ocurrence of flowering ivy within the area at a certain time interval quite well. If the frequencies of the various trees vary only slightly within the areas and time intervals compared, it may be assumed that changes in frequency of ivy indicates temperature changes.

If the composition of the forest within the areas compared varies great-

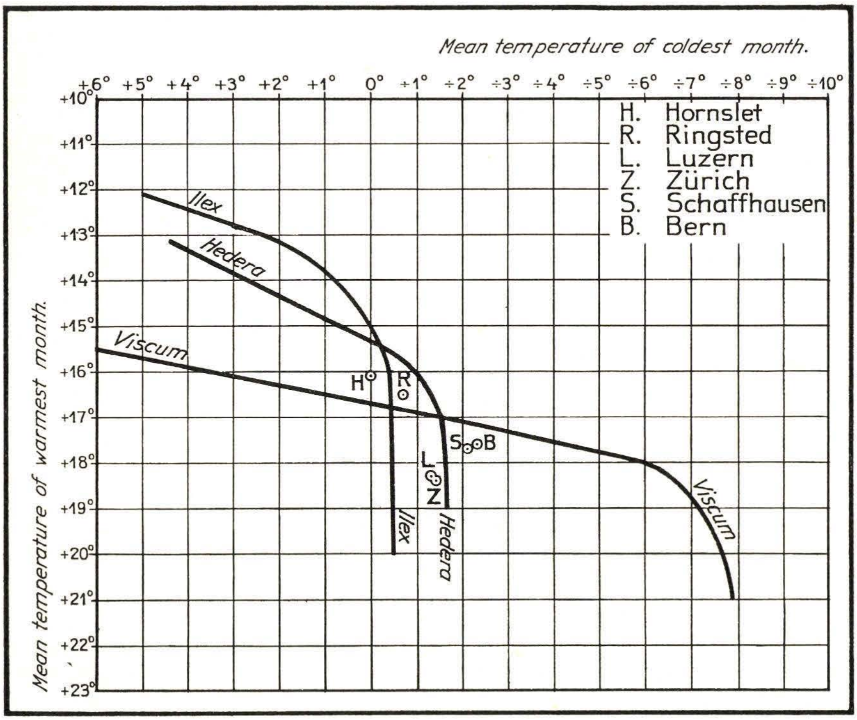

Fig. 1

ly, changes in the frequency of ivy pollen can hardly be interpreted directly as changes in temperature. Conditions other than temperature may limit the occurrence of ivy, in casu its pollen production, e. g. its relation to light and shade. I have been unable to find much literature on the subject, but I think that RYTZ (1944) states the main facts saying: "In Wäldern gemein, aber meist steril, Seltener an offenen Orten, Mauern, Bäumen, daselbst stärkere Stämme bildend und blühend"[1]). As ivy flowers in October and November, its flowering is favoured by the defoliation of the trees; nevertheless, ivy will flower most luxuriantly when it has had sufficient light to gain strength during the time of assimilation. I have failed to find any report of ivy flowering in dense forests of e. g. beech *(Fagus)* and spruce *(Picea)*. This suggests that ivy is unable to flower in a beech forest, even in favourable climatic conditions. Considering ivy's supposed demand for light in order to flower, I have used a calculation basis excluding the most shady trees: spruce *(Picea)*, beech *(Fagus)*, yew *(Taxus)*, elm *(Ulmus)* and lime *(Tilia)*. Alder *(Alnus)* has been excluded for other reasons. A large part of the present pollen diagrams are likely to be influenced by pollen produced from large, and

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[1]) I am grateful to professor MAX WELTEN, Berne, for this reference as well as for other important information.

often local, alder swamps to such a degree that a calculation basis which includes alder pollen is inapplicable.

The calculations are based on the sum of the pollen of

oak *(Quercus)* + ash *(Fraxinus)* + Poplar *(Popolus)* + pine *(Pinus)* /4 + birch *(Betula)* /4;

that is a total of the trees which demand rather much light and which give little shade (cf. CHR. VAUPEL 1863, P. BOYSEN JENSEN 1910). Accordingly, this total, is assumed to approximately indicate ivy's relation to changes in temperature. The more light, the more richly will ivy flower, even if the climate did not improve. It is very difficult to work out a basis of calculation which compensates for this completely. Possibly all shrubs, dwarf shrubs, and herbs that did not grow in swampy or damp soil ought to be included in the sum.

Switzerland.

Three localities have been examined (based on material published in 1955 by TROELS-SMITH): 1) Weier at Thayngen near Schaffhausen, 2) Wauwilermoos north-west of Luzern, and 3) Burgäschisee north of Berne. A total of 171 ivy pollen grains was found here. Fig. 1 shows the meteorological stations of Schaffhausen, Luzern, Berne, and Zürich indicated by the letters S, L, B, Z. It may be noticed that all 4 stations are located close to "the limit curve for Hedera"; Luzern and Zürich just within the area in which ivy occurs; Schaffhausen and Berne just outside it. The summer temperature at these stations is 1–2° C. higher than that of Denmark and the winter temperature 1–2° C. lower. On the other hand, the mean extremes are comparatively smaller in Switzerland than in Denmark (vide ALT, 1932: Klimakunde). This means that ivy at the same mean temperature in the coldest month of the year will find more favourable conditions in Switzerland than in Denmark. On the whole it is to be expected that a slight fall in the January temperature in Switzerland will be unfavourable for ivy, whilst a decrease in summer temperature has to be rather large to reduce its flowering.

a) It may be seen from the three pollen diagrams from Switzerland (Plate I, II, III) that ivy flowered luxuriantly, with an average frequency of 1,34 %, at the time when the oak forest dominated (in the bottom sections of the diagrams). As soon as beech began to get the upper hand, the ivy curve falls more or less rapidly, to an average of 0,45 % in all the diagrams, a very significant decline, indeed. Ivy is unable to flower in the shade of beech trees, but this has been taken into consideration by the exclusion of beech and others (see above) from the calculation sum. Hence, the decrease of ivy points to a change in climate, which probably consisted of a lowering of the winter temperature (see above).

b) At a higher level in the pollen diagrams a characteristic decline in the beech curve may be observed. Earlier (1955) I interpreted this change as the result of a forest clearance by neolithic farmers. The main argument was that the beech decline began exactly where the first traces of culture conditioned plants *(Cerealea, Plantago major,* etc.), appear.

In the pollen diagram from Weier ivy vanishes completely in the analyses 9–10, immediately after a sudden decline in the curves for beech *(Fagus)* and elm *(Ulmus)*. At the level where ivy disappears about 2 % cereal *(Cerealea)* pollen occurs along with a single pollen grain of knotgrass *(Polygonum aviculare)* and a small maximum for pollen of apophytes (TROELS-SMITH 1955). In a following part of the pollen diagram no cereal pollen is found and a decided minimum of apophytes occurs. In this section ivy re-appears with frequencies at about 0,5 %. The uppermost section of the diagram belongs to the culture layer itself and will be dealt with later on. In other words, the Weier diagram seems to indicate that the occurrence of ivy after the beech decline is inversely proportional to the intensity of the influence of culture.

The diagram from Egolzwil shows a considerably more prolonged decline in the curves for beech *(Fagus)* and elm *(Ulmus)* than at Weier. Again ivy appears at the decline of beech, and the species attains frequencies of no less than 1,0 %. Subsequently, the curves for both beech and elm decline rapidly, and ivy disappears in the sample immediately below the lower culture layer (analysis no. 8). Between the lower and the upper culture layers the elm curve shows a pronounced maximum simultaneously with the occurrence of a single ivy pollen grain.

The Burgmoos diagram shows a rather similar development. Immediately after the decline in beech the ivy rises to about 0,5 %; at the same time the curve for elm decreases gradually, but as that curve gets below about 15 %, ivy disappears.

The above observations suggest that ivy flowered richly when human interference was weak (it is assumed that the decreases of beech as well as for elm were caused by neolithic farmers), but the species disappeared when that interference became more vigorous.

Before conclusions are reached it may be useful to return to the occurrence of ivy in the culture layers themselves at Weier and Egolzwil.

At Weier (culture layer from the Michelberger Culture) the frequencies for ivy rise to about 1,5 % in the culture layer itself. A separate sample (taken inside a hut just above the floor, at an investigation in 1956) showed no less than 39 % ivy pollen. The sample, distinctly manure-like, contained large quantities of fly's pupae, small pieces of stems of ivy *(Hedera)* and *Clematis*, and numerous twigs of ash *(Fraxinus)* (Huber & v. Jazewitsch 1958). At Burgäschisee Süd, a settlement from the late Cortaillod Culture, MAX WELTEN (1955) found, correspondingly, an average of 46 % ivy pollen – in a single analysis even 81 % – in the culture layer itself. In the most distant part of the lower culture layer at Egolzwil (E_3, Early Cortaillod Culture) 0,4 % ivy pollen occurred, in 2 goat or sheep excrements 1,1 % ivy pollen occured on the average, and in the latest culture horizon near Egolzwil (late Cortaillod Culture) 2,6 % was found.

It might be assumed that the expansion of ivy at the decline of beech was due to a climatic change in favour of ivy, e. g. a change to milder winters, a hypothesis which is supported by several finds of wood of holly *(Ilex)* in neolithic layers[1]), or to particularly favourable light conditions caused by considerable forest clearances – disregarding the fact that such an effect is assumed to have been eliminated in part by the calculation basis chosen (vide p. 8).

The fact that ivy disappears from the pollen diagrams at a level where intense human interference or farmer settlements in the immediate vicinity of the basins are indicated may be explained in a reasonable way if it is assumed that the farmers reduced the ivy populations by using the plants for fodder. The outstanding abundance of ivy pollen in the culture layers can hardly be explained unless it is assumed that the cattle was fed with flowering ivy at that time, and that the cattle was kept within the area of the dwelling place – at least for part of the year.

Denmark.

Since 1944 when Iversen published the results of his investigation of the occurrence of *Hedera, Viscum,* and *Ilex* in Denmark in Postglacial time, similar investigations from the Præstø area in Denmark (Mikkelsen 1949) and from Southern Norway (Hafsten 1956 & 1957) have appeared. Like Iversen, Mikkelsen based the percentages on the forest-tree pollen total (excl. of hazel *(Corylus)*). Hafsten used the total of the oak mixed forest trees. Hence the results of the authors mentioned cannot be compared with the present calculations directly. Some hints may be obtained, however. The frequency of ivy in Denmark in Sub-Boreal time (zone VIII) is only 19 % of its frequency in Atlantic time (zone VII) (cf. Iversen 1944, pag. 466). All of Denmark should be represented fairly well in the material mentioned, but Djursland may be overrepresented. In the Præstø area ivy attains in the Sub-Boreal 15 % of its frequency in Atlantic time. The percentages for the areas of Oslo and Kristianssand, respectively, are about 35 % and 40 % according to the figures and curves published by Hafsten. It seems clear that ivy decreased considerably in the areas mentioned in Sub-Boreal time.

At the National Museum, Department of Natural Sciences an extensive pollen analytical material is on file in which the frequencies for ivy pollen have been calculated, based on the pollen sum suggested here. Unfortunately, this material cannot be published in the present paper. Two pollen diagrams are shown in plates IV–V. They have been selected because they represent an inland area (Aamosen) and a fjord area (Dyrholmen).

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[1]) Horgen (Neuweiler 1925, p. 232); Steckborn, Robenhausen and Moosseedorf (Neuweiler 1905, p. 94). Less than about 0,5°C. below zero in the coldest month of the year will be fatal to *Ilex* (see Iversen, 1944).

1. Aamosen.

In the part of the Aamose diagram (plate IV) which covers the period immediately below the elm decline (analysis no. 6–9) the ivy curve is found at 1,2 %, and it shows a minimum at a slightly lower level (cf. page 29). At the elm decrease (analysis 10 and upwards) the ivy curve decreases too and the frequency for ivy is about 0,35 % in the period between the elm-decline and the characteristic maximum for ribwort *(Plantago lanceolata)* or, more exactly, at the point in the diagram where the curve for ribwort rises strongly (analysis 26). Indicators of agriculture occur in that period too, such as pollen of cereals, pollen of great plantain *(Plantago major)* and ribwort *(Plantago lanceolata)*, ramson *(Allium ursinum)*, elder *(Sambucus)*, and St. John's wort *(Hypericum)*, etc. Also dated to this period are thin-walled funnel-necked beakers of A-type with impressions of naked barley, emmer, club wheat or common wheat – and domesticated ox and sheep (Troels-Smith 1954). Ivy has another set-back, this time to 0,04 %, simultaneously with the land occupation demonstrated by Iversen, which is characterized above all by extensive pastures (analysis no. 26–29). After the ribwort maximum and regeneration of the forest ivy prospered again.

2. Dyrholmen.

The diagram from Dyrholmen (plate V) displays the same characteristic occurrence of ivy. In late Atlantic time, before the elm-decline and before the first traces of agriculture, the ivy frequency is 0,72 % (analysis no. 1–5). At the time of the earliest farmer culture, i. e. after the elm-decline and before the land occupation demonstrated by Iversen (analysis no. 6–13), it is 0,24 %, at the time of the land occupation 0,13 % (analysis no. 14–22), and after the land occupation it rises to 0,35 %.

The inverse relationship between the frequency of ivy and the appearance of the two forms of farmer culture is striking. Ivy decreases strongly at the appearance of the farmer culture, and, as a rule, still more at the land occupation by the shepherd people. This may be explained if it is assumed that ivy suffered greatly from the forest clearance and the subsequent land occupation fires (cf. Iversen 1949. p. 16, note 1), and also that the cattle moving freely about would discover and do away with the ivy with more zeal than the farmers when they collected the leaves for fodder. When the shepherds migrated to another place and the forest regenerated, ivy had an opportunity to revive and flower anew. This has been pointed out very clearly by Iversen in his pollen diagram from Sækkedammen (Iversen 1949, plate II, cf. below pag. 21).

The use of ivy as a fodder plant.

As we have seen, the pollen analytical investigations mentioned, especially those from Switzerland, have made it possible to interpret the course of the ivy curve in Sub-Boreal time as an indication that the farmers gathered its leaves and flowers for fodder, and the loose cattle of the shepherd people decimated it still more by eating it. There is reason, therefore, to call attention to the fact that ivy has been known and valued as a fodder plant in historic time.

In classical literature ivy is mentioned already by THEOPHRASTOS († 286 B. C.). In Greece it was connected with the Dionysos-Cult, and in Egypt ivy was consecrated to Osiris. Ivy has also been a favourite in any kind of ornamentation up to the present time (cf. TOBLER 1912).

In literature one may find many scattered references as to the usefulness of ivy as a fodder plant. HEGI, for instance, mentions that goats eating ivy leaves produce more milk, and SHIRLEY HIBBERD (1893) writes, "In seasons of drought and scarsity of provender the plant has proved of great value as cattle food; for horses, cattle, deer, and sheep are partial to it; the latter especially so". ORWIN (1938) discusses the great difference between fodder in former times and now and draws attention to the fact that "even so late as the latter part of the seventeenth century the diarist Evelyn was at pains to discuss the comparative fodder values of the leaves of the common forest trees – articles of the diet which no farmer to-day would dream of including in his cattle rations". In a footnote he adds, furthermore, "Evelyn, John, Sylvia. See, for example, his remarks on the superiority of the leaves of the ash. A hundred years earlier, Master Fitzherbert advised farmers to do any topping and lopping of trees in winter, "that they beastes maye eate the brouse, and the mosse of the bowes, and also the yues (ivies)" ("The Book of Husbandry" (1523 A. D)).

As a curiosity it may be added that SHAKESPEARE in his "The Winter's Tale" lets the old shepherd, indignant with his two youthful helpers who have gone hunting instead of minding the sheep, say: "Would any but these boiled-brains of nineteen and two-and-twenty hunt this weather, they have scared away two of my best sheep, which I fear the wolf will sooner find than the master: if any where I have them, 'his by the sea-side, browsing of ivy . . ." (vide Shakespeare "The Winter's Tale" by Sir Arthur Quiller-Couch and John Dover Wilson 1931).

In the vicinity of San Cataldo in Italy Dr. IVERSEN has seen a farmer gathering a large basket of ivy leaves for use as fodder for his cattle as late as in March 1953.

It seems understandable that the winter-green foliage has been tempting as a means of fodder, particularly when food was running short and when spring-time was near. On the other hand, the ripe berries have unfavourable qualities; they act as a laxative and cause sweating and vomiting (HEGI 1926). These qualities were probably already known in the Stone Age. At any rate, it is indicated from the above mentioned observations from the manure-layer in Weier that at least a part of the ivies had been collected during October-November, its flowering months.

Mistletoe

The thermal-limit curve for mistletoe published by IVERSEN (1944) deviates conspiciously from the curve for ivy. Whilst an average temperature at less than 1,5° C. below zero in the coldest month of the year will be unfavourable for ivy, mistletoe proves to be much more hardly. At a summer temperature of about 18° C. it may tolerate temperatures down to about 6° C. below zero in the coldest month. In other words, mistletoe demands rather warm summers (generally more than 16°–18° C.), and it tolerates rather cold winters.

IVERSEN calculated the frequencies for mistletoe pollen in post-glacial time on a basis of total tree pollen (excl. of hazel) too. The remarks about the applicability of this sum for ivy (vide pag. 6) also apply to mistletoe. The fact that mistletoe cannot thrive on every kind of tree must be taken into consideration. The species occurs never on beech *(Fagus)* and elm *(Ulmus)*, hardly ever on ash *(Fraxinus)* and oak *(Quercus)*, and rarely on hornbeam *(Carpinus)*, alder *(Alnus)*, and wild cherry *(Cerasus)*. It may sometimes be found on hazel *(Corylus)*: "Zerstreut und vereinzelt wohl im grössten Teile des Mistelgebietes als Wirtspflanze beobachtet; nach H. wächst die Mistel auf der Hasel gut an, wird aber durch Lichtentzug infolge der starken Verzweigung an dauerndem Gedeihen verhindert" (WANGERIN 1937, pag. 1002, vide also TUBEUF 1923, f. inst. pag. 755). Mistletoe has three sub-species or varieties, one growing on pine *(Pinus)*, one on silver fir *(Abies)*, and one on deciduous trees.

In order to express the occurrence and flowering of mistletoe and its relation to changes in temperature in a better way, I suggest a calculation based on the sum of the pollen of the following plants:

Pine *(Pinus)* /4 + silver fir *(Abies)* + willow *(Salix)* + poplar *(Populus)* + birch *(Betula)* /4 + lime *(Tilia)* × 2 + maple *(Acer sp.)* × 2 + apple *(Malus)* × 2 + hawthorn (Crataegus) × 2 + (Prunus sp.) × 2 + mountain ash (rowan) *(Sorbus)* × 2.

As in the sum for ivy, pine and birch are divided by 4 on account of their large pollen production. Correspondingly I have multiplied by 2 the poor pollen dispersers, such as lime *(Tilia)*, maple *(Acer sp.)*, apple *(Malus)*, hawthorn *(Crataegus)*, plum and sloe *(Prunus sp.)* and mountain ash (rowan) *(Sorbus)*. Information from Wangerin and Tubeuf has been decisive in the choice of components in this pollen total.

It may be assumed that the flowering of mistletoe – in casu its production of pollen – depend on its possibility of assimilation. In other words, a larger production of pollen would result from more copious light available in the places of growth irrespective of nourishment from the tree of hospitality. Unfortunately, I have not succeeded in confirming this assumption from the literature, and I have not been able to investigate the matter myself. It is worth noticing that mistletoe normally flowers in March or even earlier in mild winters. The flowering takes place long before the leaves of the tree of hospitality come out (except for individuals growing on pine and silver-fir) and this is favourable for a dispersal of its pollen, which is probably produced in small quantities, as the species is insect-pollinated.

Switzerland.

The occurrence of mistletoe in Switzerland in post-glacial time was also investigated at Weier, Wauwilermoos, and Burgäschisee (Troels-Smith 1955). A total of 35 pollen grains of mistletoe was found. The meteorological stations, which are supposed to be representative of the localities examined, are located fairly near to the part of the thermal limit curve for mistletoe which indicates the minimum summer temperature required by the species. Thus Schaffhausen and Berne are situated 0,5°, inside of the curve, Luzern and Zürich are slightly more favourably, that is nearly 1,5° inside the curve. This means that slightly cooler summers would be unfavourable for mistletoe at the localities mentioned, but considerably colder winters would do it no harm.

During the period with dominance of the oak forest and before beech was of any importance, mistletoe occured with an average of 0,36 % for the three localities examined. During the beech maximum, mistletoe *(Viscum)* was reduced to half the amount, i. e. 0,20 %. After the great decrease in beech *(Fagus)* and elm *(Ulmus)*, which presumably was due to interference from neolithic farmers, the frequency of mistletoe was reduced by one half again, to 0,09 %.

It must be emphasized that this interpretation is very tentative as it is based on only 35 pollen grains, and it is not possible to examine the occurrence of mistletoe in the parts of the pollen diagrams which post date the beech decrease and are influenced by agriculture. Still, it is evident that the species decreases with the activity of the farmers. These farmers certainly knew mistletoe, as stems and leaves from the species have been found in the "Pile-dwellings" near Moosseedorf, Berner Mittelland, belonging to the middle Neolithic (vide Heer 1865; Neuweiler 1905, p. 62). A theory that the decrease of mistletoe was due to a lower summer temperature is contradicted by contemporaneous finds of pollen and seeds of *Vitis sp.* (possibly *Vitis silvestris)*. (Pollen: vide the diagram, plate I, analysis no. 10, 17–18 and plate II, analysis no. 15; seed: St. Blaise, Neolithic period, vide Neuweiler 1905).

The decrease of mistletoe at the time when beech began to increase in Switzerland suggests that the summer temperature decreased.

Denmark.

Iversen (1944) draws attention to the fact that mistletoe decreased considerably less than ivy at the elm decline. In Sub-Boreal time the ivy reached only 19 % of its value in Atlantic time, whilst the corresponding figure for mistletoe was 30 %. Furthermore, mistletoe was more common in the first half of Sub-Boreal time than in the second. Iversen's material is rather representative of the whole of this country, but the former fjordareas on Djursland are somewhat over represented.

For the Præstø area Mikkelsen (1949) states that mistletoe in Sub-Boreal time reached only 13 % of its value in Atlantic time – i. e. a much greater fall. Iversen and Mikkelsen based their percentages on the total of forest-tree pollen (excl. of hazel).

In the Oslo area the decrease is about 40 %, and in the area of Kristianssand-Mandal about 25 %. Hafsten's calculation (1956) is based on the sum of components of the Oak Mixed Forest (oak *(Quercus)*, elm *(Ulmus)*, lime *(Tilia)*, and ash *(Fraxinus)*).

The general impression is that the frequency for mistletoe was reduced by more than one half in Sub-Boreal time.

In the diagram from Aamosen (plate IV) mistletoe attains 0,65 % at the end of Atlantic time (analysis no. 6–9), calculated on the basis of the sum employed here. It falls to 0,12 % in the period between the decline of elm and the land occupation by the shepherd people (analysis no. 10–25). It disappears completely at the last mentioned level (analysis no. 26–29), but at the regeneration of the forest it reappears at 0,25 %. This means that mistletoe reached only about 20 % of its value at the end of Atlantic time at the time of the earliest agriculture.

In the diagram from Dyrholmen the frequency of mistletoe in late Atlantic time is 0,14 % (analysis no. 1–5). At the earliest agriculture it rises to 0,24 % (analysis no. 6–13), and then disappears simultaneously with the land occupation by the shepherd people. Besides the diagram from Dyrholmen, published in this paper, several others from the locality are available in which the occurrence of mistletoe has been calculated, based on the sum employed here. But even that extensive material does not change the fact that mistletoe increased definitely at the time of the earliest agriculture.

An abrupt decrease or almost complete disappearance of mistletoe at the time of the land occupation by the shepherd people is common to the investigations in Aamosen and Dyrholmen. This is peculiar as one would not expect that untethered cattle would do any harm to mistletoe, which usually grows beyond of the reach of the cattle. For the time being, two explanations may be suggested. It may be conceived that the rather large clearances for pastures were made at places where the forest was less dense and that mistletoe was more abundant in such places and that for that reason was reduced more significantly. Secondly, and this seems to me more plausible, it may be that the shepherds had cut down trees covered with mistletoe to alleviate food scarcity in late winter, when it was difficult for the untethered grazing cattle to find feed.

The increase for mistletoe at Dyrholmen simultaneously with the earliest agriculture is still less comprehensible as it is contrary to experiences from Aamosen. It may be explained either by a considerable rise in the summer temperature – a possibility to be taken into account – or it may be that the more copious light, resulting from the (perhaps selective) forest clearances by the first farmers, afforded more favourable conditions for mistletoe with the result that its pollen production increased.

Either explanation leaves open the possibility that the farmers may have used mistletoe for fodder to a greater or less extent. A safely dated macroscopic find of mistletoe from Denmark belongs to this very period. A charred berry[1]) was confined within a thick-walled potsherd belonging to the Ertebølle settlement Storelyng X (H 12141) in Aamosen which is contemporaneous with, or postdates, the elm decline, but is earlier than the Muldbjerg settlement[2]). The first farmers must therefore have known mistletoe. The fact that mistletoe not always decreased simultaneously with the earliest farmer culture may indicate that a decisive climatic change was n o t the cause of its decrease, but rather its use for fodder. The opposite possibility would be that the earliest farmer culture set in before a fall in the summer temperature took place at Dyrholmen and after a similar change in Aamosen.

The use of mistletoe as a fodder plant.

Like ivy, mistletoe has also been known and mentioned since Greek antiquity. Its usefulness as bird-lime is mentioned by THEOPHRAST (371–286 B. C.), PLINY (23–79 A. D.), and others. The Danish name of "Fuglelim" (i. e. bird-lime) for mistletoe speaks for itself (TUBEUF 1923, p. 49 ff.). HIPPOKRATES († 377 B. C.) recommends it as an efficacious remedy against epilepsy and up to fairly modern times it has been used as a remedy for all sorts of complaints. PLINY mentions how the cutting off of mistletoe growing on oaktrees formed part of the sacrificial celebraions of the druids (Celtic priests) (vide TUBEUF 1923). Mistletoe was known in Scandinavia too, and most people have heard about the part it played in the death of Balder (Voluspá i Sæmundar Edda from about 950 A. D., verse 31, quoted from JOHS. HANSEN 1933):

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[1]) I take this opportunity to thank Professor KNUD JESSEN for his determination of this fruit.

[2]) A leaf of mistletoe was found and determined by HARTZ (vide JESSEN 1920, pag. 238) at Taarbæk, north of Copenhagen. The leaf was found in calcareous mud which may be dated to the "time immediately preceding the deepest lowering of this country in the Litorina period (V. MILTHERS 1935, pag. 151). That is to say, the time just before the Sub-Boreal transgression reached its maximum value there. The finds from Storelyng and Taarbæk are the only macroscopic finds of mistletoe from post-glacial time in Denmark.

Ek sá Baldri	I saw for Balder
Blóðgum tívur	The glorious god
Óðins barni	The child of Woden
ørlog folgin	The fate was hid
stód um vaxinn	Stood there grown
vollum hæri	Taller than mound
mjór ok mjok fagr	Tender and fair
mistilteinn.	Mistletoe.

TUBEUF (1923, pp. 53–61) collected much information about the use of mistletoe as cattle fodder, chiefly in Central Europe. A few extracts may be given here:

THEOPHRASTUS informs his readers that people in Greece: "die Rinder und das Zugvieh mit Misteln fütterte und es nach der Ernte damit aufzog". – Even in these days do Greek peasants in the country round Parnasus use mistletoe for feeding their sheep and oxen. – Pliny mentions that the Galls were feeding their cattle with mistletoe "um es fruchtbar zu machen und gegen Krankheiten zu schützen". In France and Belgium at the present time (1923 and earlier) mistletoe is likewise used as fodder for cattle. TUBEUF also names quite a number of districts in Germany and Austria where mistletoe is used as a fodder plant, especially in winter. It is stated that feeding with mistletoe increases the milk yield and makes the butter a nice yellow colour. It is being exploited to such a degree that people will climb tall and almost inaccessible trees with special climbing fittings in order to get hold of the mistletoe, if they do not simply cut down the trees to get it in an easier way. – Lastly (TUBEUF, p. 61) mistletoe is known to have been used for bread-making in East Prussia in times of famine.

A great many other examples might have been added, but the ones mentioned presumeably give sufficient proof for the great demand of mistletoe as a fodder plant through the ages up to the present time.

Elm

The elm decline.

Most pollen diagrams from Northern and Central Europe show an abrupt fall in the elm curve which is often used as a border-line between Atlantic and Sub-Boreal time.

Before beginning a detailed discussion of the elm decline, it may be worthwhile to formulate more explicity which kind of elm decline we are going to investigate. It is evident that when an area with pure elm forest (Morrison 1959) or an oak mixed forest with elm occurring more or less scatteredly, is cleared in order to make room for fields or pastures, elm will decrease abruptly, either on its own or together with other components of the oak mixed forest, in comparison with areas covered with a different kind of forest. The "land occupation-phase" described by Iversen (1941) from Danish diagrams, in which elm decreases greatly together with the other components of the oak mixed forest, is not connected with the problems to be discussed here. The thing concerned is the incomprehensible selective decline in elm, which cannot be explained by clearances of larger area of elm forest to make room for fields or pastures; i. e. the elm decline which according to Iversen marks the border-line between zone VII and zone VIII.

I shall not attempt a general explanation of the elm decline. It must be interpreted individually for each locality based on pollen diagrams and in relation to all local circumstances, such as prehistoric settlements, early forms of agriculture, local climatic oscillations, local soil conditions, etc. Here I intend to interpret the elm decline in the investigated localities in Denmark and Switzerland only.

In the Danish as well as in Swiss pollen diagrams the curves often show influence from spreading or decimation of local alder forest. This makes the elm curve less distinct, and I have therefore employed a sum based on:

elm *(Ulmus)* + ash *(Fraxinus)* + lime *(Tilia)* + oak *(Quercus)* + hazel *(Corylus)* /4.

This sum allows a close study of the relative shifts within the oak mixed forest in Denmark as well as in Switzerland. Beech was of no importance in Denmark in this period, whilst in Switzerland it was a dangerous rival to the oak forest. For that reason the beech pollen has been included in the calculation sum for the beech curve.

Four possible explanations will be investigated: 1) disease, 2) deterioration of the soil, 3) changes in climate, and 4) human interference.

1. Disease.

In recent years first America, then Europe have suffered from an elm disease, and naturally one may think that such a thing or attacks from insects may have caused the elm decline. On the other hand it would be very difficult to prove such causes. Unless another cause is found the effect of which may account for the course of the elm curve, however, disease or insect attacks will have to remain a possible explanation (cf. IVERSEN, 1955).

2. Deterioration of the soil.

Elm demands a rather rich soil, and leaching would slowly impede its ability to grow in areas with poor soil. A gradual decrease in frequency might be expected, beginning in the poor areas and continued in the more fertile ones. As the elm decline is fairly abrupt in both poor and fertile areas, however, this interpretation may be rejected (cf. IVERSEN, 1955).

3. Changes in climate.

When IVERSEN (1941) fixed the zone boundary VII–VIII at the point in the diagrams where the curves for ivy and elm fall, his argument for a climatic change was as follows: The course of both curves could be explained without difficulty by a climate with colder winters having replaced one with less cold winters. This would agree well with the abrupt decrease of ivy, especially in fjord-areas (lake Korup!). Such localities, tempered by the near-by sea, would be very favourable to ivy in winters free from ice; if, however, the cold increased and the fjords became covered with ice, the ivy unprotected by snow would freeze to death (cf. IVERSEN 1944). If it were supposed that the elm stock in Denmark consisted not only of *Ulmus scabra* but also of the more thermophilous *Ulmus carpinifolia,* the northern boundary of which is immediately south of Denmark at present, then increasingly cold winters might involve an extinction of the latter species resulting in reduction of the total production of elm pollen.

Against this interpretation the following may be offered:

a) Elm decreases in Norway too, although it must be assumed that *Ulmus carpinifolia* never grew so far north. It decreases in Switzerland too, where *Ulmus carpinifolia* presumably found extremely favourable conditions since late Boeral time. At least, *Ulmus carpinifolia* occurred in Switzerland in Neolithic time (vide NEUWEILER 1910, p. 197 & 1925, p. 231). It would considerably support IVERSEN's theory if it could be proved that *Ulmus carpinifolia* was relatively common in Denmark in Atlantic time, but decreased or vanished in Sub-Boreal time. Unfortunately, the pollen of the elm species cannot be separately identified, and during our research-work in Denmark and Switzerland neither SVEND JØRGENSEN nor I have succeeded in detecting any difference in the appearance of elm-pollen in Atlantic or Sub-Boreal time in identical sediment conditions above and beneath the elm decline (cf. IVERSEN 1955). On the other hand large pieces of wood or charcoal of elm may be determined to one or other of the two species (vide NEUWEILER 1910, p. 188). A rather large collection of elm wood and charcoal has been determined in Denmark (vide JESSEN 1920 & 1935a, and unpublished determinations by E. TELLERUP). Even so it has not yet been possible to find any traces of *Ulmus carpinifolia* either in Boreal, Atlantic, or Sub-Boreal time, although the species may presumably have found favourable habitats e. g. in the area around Aamosen. Considering the climatic conditions at that time (vide below) it is remarkable that the species has not yet been found neither in Atlantic nor Sub-Boreal time. As long as the species has not been identified there is no real basis for the theory that its extinction caused the fall in the elm curve.

b) It has been shown above that ivy and sometimes also mistletoe decrease vigorously in areas where farmer cultures expand. In Switzerland it was shown that flowering ivy had been gathered and used as fodder for cattle. In Denmark, therefore, one cannot a priori exclude the possibility that the decrease of ivy was due to an exploitation for cattle fodder. Of course, this does not leave out the possibility that the winters became colder at the same time, and both factors may have worked together. A find at Dyrholmen of no less than three pollen grains of holly *(Ilex)* from the time immediately after the abrupt fall in the curve for ivy and elm, and before the immigration of the shepherd people is therefore of great importance.[1]) Dyrholmen is situated in a fjord-area which on the one hand would benefit from the influence of the sea in mild winters and on the other hand would be strongly exposed in winters when the sea was covered with ice.

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[1]) Pollen finds of *Ilex Aquifolium* L. from Denmark: Atlantic time (Zone VII) a total of 8 finds: Dyrholmen 4 finds (1 in HP 23671; 1 in HP 23664 = analysis no. 1, plate V; 1 in HP 23663 = analysis no. 2, plate V; 1 in Dr. 88). Aamosen 3 finds (1 in HP 14419; 1 in HP 395; 1 in H 2394 – for the two last mentioned vide SVEND JØRGENSEN 1960). Præstø-area 1 find (vide MIKKELSEN 1949, Orup Mose, plate XIVb, analysis 3). – Sub-Boreal time (zone VIII) a total of 11 finds: Simultaneously with the earliest farmer culture 3 finds. Dyrholmen 3 finds (1 in HP 23657 = analysis no. 8; 1 in HP 23654 = analysis no. 11, plate V; 1 in Dr. 78). At the same time and later than the landoccupation of the shepherd people 8 finds. Dyrholmen 4 finds (1 in HP 23650 = analysis no. 15, plate V; 1 in Dr. 125; 1 in Dr. 127; 1 in Dr. 137). Aamosen 2 finds (1 in H 12341; 1 in R 694). Præstø-area 2 finds (vide MIKKELSEN 1949, Even, Dalinge Gaard, plate IX, analysis no. 3; Borre, Møn, plate XVII, analysis no. 21, this last found was made by B. BRORSON CHRISTENSEN when counting the sample in question in the DEPARTMENT OF NATURAL SCIENCES, NATIONAL MUSEUM after the publication of the diagram. I want to thank professor MIKKELSEN for allowing me to publish it in the present paper). In a raw-humus deposit in Draved forest IVERSEN (1958) detected rather large quantities of *Ilex* pollen from both Sub-Boreal and Sub-Atlantic times. – HP 23671 etc. refer to the store-numbers of the samples in the DEPARTMENT OF NATURAL SCIENCES, NATIONAL MUSEUM.

It may be assumed that the pollen production of holly in Atlantic time was essentially greater than indicated by the number of pollen grains found, as the density of the foliage in the virgin forest would have prevented dispersal of its pollen, and the dispersal of its pollen may have improved when farmers had given the forest a more open character by their clearances. Still, holly thrived in the area at a time when ivy was reduced to ⅓ of its frequency in Atlantic time. It appears from IVERSEN's thermal limit curve for holly that this is even more sensitive to cold winters than ivy. Holly hardly endures temperatures less than 0,5° C. below zero in the coldest month of the year, whilst ivy can stand as much as 1,5° C. below zero. *Lonicera* has a similar demand for mild winters. This plant has also been found at Dyrholmen (one pollen grain contemporaneous with the land occupation of the shepherd people). No less than 5 pollen grains of *Lonicera* were found by BENT FREDSKILD in a bog on Hjortholm, Stavnsfjord, on the island of Samsø. They are contemporaneous with, or immediately following, the land occupation of the shepherd people in early Sub-Boreal time.[1]) At the same time the occurrence of no less than 7 pollen grains of *Vitis* in Sub-Boreal time shows[2]) that the summer temperature can not have decreased so substantially as one might have expected on account of the decimation of mistletoe which often occurred simultaneously with and after the elm decline, the warmth-demands of *Vitis* being more or less the same as those of mistletoe.

In this connection reference may be made to the frequent occurrence of the marsh-totoise in Sub-Boreal time (32 finds; and from Atlantic time 49) which indicates that the summer temperature at that time must have been about 20° C. in the warmest month of the year (vide DEGERBØL & KROG 1951).

c) If the elm decline was due to a general climatic change this change must have been simultaneous within large areas. In this connection it may be reasonable to mention the circumstances at Sækkedammen. IVERSEN interpreted the pollen diagram from this place as showing that the land occupation by the shepherd people took place in the last part of Atlantic time, in other words the zone border VII–VIII occurs distinctly after the forest regenerated (IVERSEN 1949, plate II). According to the pollen-analytic examinations now available (TROELS-SMITH 1954, and also the material on file in the DEPARTMENT OF NATURAL SCIENCES, NATIONAL

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[1]) Pollen finds of *Lonicera Periclymenum* L. from Denmark: Atlantic time (Zone VII) no finds. Sub-Boreal time (Zone VIII) simultaneously with the earliest farmer culture, no finds. At the same time and later than the immigration of the shepherd people, Hjortholm, Samsø, 5 finds (1 in H 19993; 4 in H 19989). Dyrholmen 1 find (1 in Dr. 128). In a raw-humus deposit in Draved forest IVERSEN (1958) detected rather large quantities of pollen of *Lonicera Periclymenum* from both Sub-Boreal and Sub-Atlantic time. – H 19993, Dr. 128, etc. refer to the store numbers of the samples in the DEPARTMENT OF NATURAL SCIENCES, NATIONAL MUSEUM.

[2]) Pollen finds of *Vitis sp.* from Denmark: Atlantic time (Zone VII) no finds. Sub-Boreal time (Zone VIII) simultaneously with the earliest farmer culture 5 finds: Dyrholmen (1 in HP 23653 = analysis no. 12, plate V; 1 in Dr. 81; 1 in Dr. 82), Aamosen (1 in H 830; 1 in H 3543). At the same time and later than the immigration of the shepherd people 2 finds: Dyrholmen (1 in HP 23635: analysis no. 23, plate V). Borre, Møen (vide MIKKELSEN 1949, plate XVII, analysis 21). – HP 23653, etc. refer to the store numbers of the samples in the DEPARTMENT OF NATURAL SCIENCES, NATIONAL MUSEUM.

MUSEUM) it seems certain that the first land occupation by the shepherd people took place simultaneously with the occurrence of funnel-necked beakers of B-type (BECKER 1948). Beakers of this type have been found in Aamosen in connection with the earliest land occupation phase. The Muldbjerg settlement is dated to 2820 B.C. (TROELS-SMITH 1956 a, TAUBER 1956 and 1960) and precedes the earliest land occupation there. The elm decline is earlier than the Muldbjerg settlement. As there is no reason to suppose that the shepherd culture (funnel-necked beakers of B-type) was essentially earlier at Sækkedammen than at Aamosen, the conclusion must be that the elm declined considerably later at Sækkedammen than at Aamosen, by 2–300 years on a rough estimate.

Summing up, it seems that nothing points to a change in climate simultaneously with the elm decline. Consequently, this explanation appears considerably weaker.

4. *Human interference.*

When, in 1941, IVERSEN suggested the ivy-elm decline as a boundary between Zone VII and Zone VIII there was no hint of the occurrence of agriculture in Denmark at an earlier date than the land occupation described by himself (indicating the introduction of a shepherd culture, cf. TROELS-SMITH 1954). In all the diagrams published by IVERSEN (1941 and 1949 – excl. of Sækkedammen, vide above p. 21) the land occupation is plainly separated from the boundary suggested by him; he had therefore no reason to suppose that interference with the vegetation from farmers caused the decrease for elm and ivy. Since then very considerable pollen analytic data have appeared (FÆGRI 1944, INGE MÜLLER 1947, WATERBOLK 1954 & 1956, TROELS-SMITH 1954 & 1955) which show that one must consider the existence of forms of agriculture in Europe which manifest themselves in a way differing from the land occupation demonstrated by IVERSEN (which apparently was a shepherd culture with or without knowledge of grain cultivation). In Switzerland, especially, the first traces of agriculture had obviously no connection with extensive pastures and they occurred just after elm began to decrease. So far no areas have been found in Denmark with a cultural influence nearly so strong as that found in Switzerland; nevertheless a similar agriculture must have existed in Denmark at some time between the ivy-elm decline and the arrival of the shepherd people. Indicators of such an agriculture are finds of pollen of grain *(Hordeum* and *Triticum,* vide plate IV–V), weeds such as great plantain *(Plantago major),* few and scattered finds of pollen of ribwort *(Plantago lanceolata),* knotgrass *(Polygonum aviculare),* etc. Furthermore, pollen analytical examinations have dated thin-walled funnel-necked beakers of A-type (BECKER 1948, TROELS-SMITH 1954) with impressions of naked barley, emmer, common wheat or club wheat (determined by Dr. HANS HELBÆK) to the same period. Also domestic animals, ox as well as sheep, have been dated to this period (Øgaarde-Komplexet, domesticated ox I; Mul. I, domesticated ox and sheep.)[1] The activity of the farmers may, therefore, have caused the decline not only in the ivy curve but also in the elm curve.

The land occupation-phase described by IVERSEN has the characteristic that all the components of the oak mixed forest decrease at the same time as the clearance itself took place contrasting with a corresponding increase for all other trees, shrubs and herbs. This definitely indicates that an oak mixed forest was cleared; a forest type, the components of which do not form uniform stands, but grow scattered amongst each other. The decrease of elm in Denmark only a few hundreds years earlier cannot have been due to clearance of pure elm stands. Then, the elm was cut down selectively or it was exposed to an interference which prevented or reduced its production of pollen.

It has been suggested that the elm decline may have been due to utilization of its leaves for fodder, a procedure which may have prevented it from flowering (NORDHAGEN, vide FÆGRI 1940, p. 122; FÆGRI 1944, p. 457; TROELS-SMITH 1954 & 1955). Of all the trees known, in Switzerland as well as in Denmark, the leaves of which may be used as fodder, elm and ash are considered the best. Elm takes the longest time to be able to flower again after polling (7–8 years, cf. SØREN VE 1930). This means that an extensive harvesting of leaves for use as fodder would be fatal to the pollen production of elm.

The Neolithic farmer pioneers in Denmark and Switzerland have had to face a continuous primeval forest with hardly any grass vegetation. Still, finds from both countries indicate the presence of oxen and sheep although no pastures existed in such dimensions that they can be traced in the pollen diagrams. It will undoubtedly be correct to assume that the people used leaves for feeding their cattle, in the first place from elm but also from ash, lime, hazel, etc. Rather extensive pastures indicating a shepherd culture with freely grazing cattle may be demonstrated in Denmark at a slightly later date, and this justifies an assumption that the earlier farmer culture had no real pastures.

A lucky find on a house-floor at Weier (Michelberger Culture) of heaps of leaves of elm *(Ulmus)*, birch *(Betula)*, oak *(Quercus)*, lime *(Tilia)*, maple *(Acer)*, and ash *(Fraxinus)* (vide Guyan 1955, p. 262 & fig. 34) has proved the theory that leaves were used as fodder. Not far from this house-floor the above mentioned pieces of ivy-stems (vide p. 9) were found on the floor of another house, probably a stable. It may be appropriate here to quote HUBER & v. JAZEWITSCH (1958, p. 451 & fig. 2): "In Häcksel der Stallstreu fanden sich neben einigen Stückchen Waldrebe *(Clematis)* und Efeu *(Hedera)*, der noch heute in den Wäldern am Hochrhein fast jeden Stamm erklimmt [Note: In diesen Wäldern schlingt auch die subfossil noch nicht nachgewiesene mediterran-atlantischen *Dioscoreacee Tamus communis* (Schmerwurz). *Clematis* und *Hedera* sind auch pollen-analytisch nachgewiesen (Troels-Smith)], und zwei von TROELS-SMITH entdeckten Buchenholzplittern *(Fagus silvatica)* vorwiegend

[1]) When the text says 'sheep' and not 'sheep and/or goat' as previously (TROELS-SMITH 1954) the reason is, that the truth has now been determined with certainty by ULRIK MØHL.

1–4 jährige Eschenzweige *(Fraxinus excelsior)*. Das beweist, dass die Bauern damals wie heute Esche schneilten, um ihr nährstoffreiches Laub zu verfüttern. Gestützt wird diese Ansicht durch den Fund einer Holzschale, welche aus einer Eschenmaserknolle geschnitzt war; diese Maserknollen entstehen nämlich reichlich im Gefolge der Schneitelung (Abb. 2)." A wooden bowl made from typical Bird's Eye elm (Burr Wood) is known from a find in Christiansholms Mose in Denmark, which presumably is contemporaneous with the Muldbjerg settlement in Aamosen, dated to the period between the elm decline and the beginning of the land occupation of the shepherd people.

There are, therefore, good reasons to believe that the first farmers in Switzerland as well as in Denmark fed their cattle with leaves, i. e. of elm and kept them tethered, as no signs of contemporary large pastures have been found.

As a kind of summary I shall here offer an interpretation of a pollen diagram from Falbygden in Central Sweden (3a Kroppsjön), recently published by MAGNUS FRIES (1958). Due to the kindness of MAGNUS FRIES in placing his pollen counts at my disposal, I have been able to recalculate the pollen diagrams according to the other diagrams published in this paper.

A large Megalithic settlement existed at the beginning of the late Stone Age in Falbygden, but later the Swedish boat-axe Culture spread all over the area. Grain-growing and gathering of leaves for use as fodder, probably began at the immigration of the Megalithic people (Megalithic Culture is not a shepherd Culture as presumed by IVERSEN 1941, vide TROELS-SMITH 1954 & WATERBOLK 1954). This event is pictured in the pollen diagram by the first appearance of cereal pollen *(Cerealea)*, pollen of great plantain *(Plantago major)*, and a characteristic fall in the elm curve (analysis no. 13). Simultaneously with the Megalithic settlement, pollen of both cereal *(Cerealea)* and Great plantain *(Plantago major)* occur whilst the elm curve is very low. The first appearance of ribwort *(Plantago lanceolata)* is accompanied by a rise in the elm curve from 1,1 % to 75 % and immediately afterwards also a sharp rise in the curves for wild grasses and ribwort (analysis no. 22). It may be assumed that a shepherd culture (the Swedish boat-axe people?) arrived in the area and brought great numbers of cattle with them. The cattle were not fed on leaves but grazed at large. This event (I assume) gave the many polled elm and ash trees renewed possibilities for flowering. The overwhelming and sudden flowering is evidence in support of this supposition. If the elm had been totally extinct and had then returned, one would have expected its curve to rise slowly at first and then more and more rapidly – but the rise takes place between two analyses!

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Summing up, the only plausible explanation of the otherwise incomprehensible fall in the elm curve seems to be that the elm was used for leaf-feeding or was exploited by the farmers in some other selective way. Deterioration of the soil or changes in climate may be disregarded as unlikely explanations; and the inverse relationship of the elm curve to the occurrence of such indicators of culture as cultivated plants and weeds makes it appear unlikely that elm disease caused the elm decline. The wooden vessels of elm and ash, shaped from Bird's Eye wood (found in Christiansholms Mose and in Weier, respectively) and the occurrence at Weier of many 1–4 year old shoots of ash, suggest that polling of trees was known. Lastly, the heaps of twigs and leaves found in the settlement at Weier directly indicate the practise of collecting leaves for fodder.

The use of elm as a fodder plant.

Nowadays farmers in remote parts of Europe may still be found feeding their cattle on leaves, and only a few generations back this was quite a common thing. A quotation from Orwin has already been given above (p. 12). There is no doubt that the special tools and rather particular terminology connected with the collection of bark, twigs, and leaves for fodder indicates a wide-spread use and a very ancient origin for that method. Unfortunately, this important subject has not been thoroughly investigated, and only a very few attempts at outlines are available (above all others Brockmann-Jerosch's paper from 1918). – Through several years I have collected notes on the use of leaves for fodder, and I have arrived at the conclusion that this procedure must have been of enormous importance in former times. In Denmark, at the present day, only the polled willows and poplars remind one of an ancient and much used operation.

Columella (born at the time of Christ) tells about the popularity of ash and elm amongst the Italian peasants because of the great value of their leaves and young shoots as fodder. Both trees were planted especially for this use. He particularly recommends the planting of ash in the more raw mountainous parts as it would do better there than elm (Brockmann-Jerosch 1918).

In Norway many valuable papers are available: Ve (1930), Stoltenberg (1933), Visted & Stigum (1951), and Nordhagen (1954). In that country the trees were used in three different ways. In winter or spring, before leafing, the domestic animals might be given "beit", i. e. branches or whole trees of birch and pine, etc. were dragged along to the farm for the domestic animals to nibble off the barks and buds. "Skav" could also be used as a supplement to other kinds of fodder; thin shoots of inter alia elm, mountain ash, and aspen were collected and the bark peeled off for use as fodder. Most important was "lauving"; this meant collecting 2–3 years old leafy twigs, which might be used directly but mostly were made up in bundles ("kærver"), dried and stored, and used for winter feeding. Where no other way of feeding was used, very large quantities had to be collected. In this connection a large farm in Gausdal in Norway may be mentioned where, in 1870, no less than 1700 "kærver" were collected (Visted & Stigum 1951). A fairly large "kærve" would approximately cover the daily requirements of one cow. Extremely large quantities, therefore, had to be collected if only a fair sized cattle stock was to be fed on leaves for perhaps the greater part of the year.

Much poetry is known from Norway pointing to the value of the different trees as use for fodder. One specimen may be given here (from STOLTENBERG 1933):

Alm fødar, Ask gjødar.	Elm feeds, ash manures,
Or sveltar, Vier veltar.	Alder starves, willow tumbles over (from malnutrition)

It is a well known fact that elm and ash are always mentioned as the most valuable, next hazel, lime, and oak, then birch and aspen, and lastly, mountain ash, alder, and willow which are considered the least valuable. The esteem in which these trees are held depends on the species growing on the spot; when in some particular place birch and aspen are emphasized as the most valuable trees, the reason will probably be that elm and ash do not exist in that area.

In Switzerland BROCKMANN-JEROSCH has collected an extensive material about feeding with leaves. His investigations, on the whole, agree with the Norwegian ones. He also emphasizes elm and ash as the most valuable trees, then maple, oak, hazel, beech (the young leaves), and lime, and lastly mountain ash, willow, alder, and birch.

SØREN VE (1930) gives detailed information about the inability of trees to flower after the cutting off of their young shoots. Elm, especially, suffers as its shoots must be 7–8 years old before flowering. Lime and ash are less sensitive and need only 4 and 2–3 years respectively, whilst birch is affected very little. As a rule the trees are polled on a rotation of 2–4 years, and this means that elm is prevented from flowering in an area thoroughly exploited, whilst lime and ash may have a better chance, and birch, alder, and willow will hardly be affected.

In conclusion I shall mention that almost everywhere in Europe traditions of feeding with leaves may be met with. Looking through literature shows how widely its use has been. Any kind of exploitation of trees for use as fodder, be it branches or shoots, bark or leaves, will reduce the ability of those trees to flower. Elm will suffer most severely, lime and ash less, and alder, poplar, and birch least of all.

Summary

Ivy, mistletoe and elm as fodder plants.

Ivy, mistletoe, and elm have been examined with the intention of investigating the possibility that they were used as fodder plants in the Stone Age. The results are as follows:

1. Ivy (Hedera).

The very high percentage of ivy pollen in Swiss settlement-layers as well as in layers reminiscent of stable manure indicates decidedly the fact that the cattle ate flowering ivy. Likewise, it is difficult to explain away its peculiar occurrence in the pollen diagrams following the first appearance of the earliest agriculture, unless one presupposes a local but intensive exploitation of ivy for use as fodder. In Denmark its occurrence is distinctly inversely proportional to the presence of agriculture in an area. Simultaneously with the earliest agriculture ivy decreases greatly and it becomes almost totally extinct at the time of the land occupation by the shepherd people. Vice versa, its percentage will rise again when the farmers or shepherds leave the area. The simultaneous occurrence of Ilex in Switzerland and both Ilex and *Lonicera* in Denmark makes it difficult to explain the decline in ivy by assuming a lowering of the winter temperature. Lastly, ivy has been used and valued as a fodder plant in historical times.

2. Mistletoe (Viscum).

Apart from a slight rise in one single locality (Dyrholmen) mistletoe usually decreases in Switzerland as well as in Denmark simultaneously with the introduction of agriculture. The contemporaneous occurrence of *Vitis* at both places makes the theory of a lower summer temperature an unlikely explanation of the decrease. Traditions handed down from historical time show mistletoe to have been a valuable and much used fodder plant.

3. Elm (Ulmus).

The decline in elm simultaneously with the occurrence of farmer cultures, points strongly to interference by farmers as the cause. Finds

in Denmark and Switzerland of wooden bowls made of Burr Wood of elm and ash, respectively, indicate further that the earliest farmers in both areas knew of the polling of trees, whilst the heaps of collected leaves of, inter alia elm and ash found at the settlement at Weier Switzerland proves this. These facts give strong evidence in support on the theory that collection of leaves and shoots for fodder caused the elm decline. Other explanations may be excluded as unlikely, i. e. change in climate, deterioration of the soil through leaching, or elm disease. Reports from nearly all parts of Europe testify to the fact that feeding on leaves was in common use, elm – and secondly ash – producing the best fodder.

Ivy and mistletoe as indicators of climate.

1. Switzerland.

a) Before the increase of beech in Switzerland, the oak forest was predominant. Ivy and mistletoe were very frequent at the same time suggesting a relatively high annual temperature with mild winters and warm summers.

b) Simultaneously with the increase of beech ivy as well as mistletoe decreased heavily, giving the impression of a lower annual temperature with colder summers and winters. There may be reason to assume that this change in climate favoured the increase in beech.

c) Simultaneously with the decrease in beech the earliest agriculture has been traced. But the strange circumstance that ivy increased and attains a higher frequency where the influence of culture was slight or non-existant together with the occurrence of *Ilex* and *Vitis* point to another rise in the annual temperature. It is not unlikely that a change in climate involving a higher annual temperature simultaneously with interference from farmers may be the twofold cause of the decrease in beech.

2. Denmark.

In zone V ivy and mistletoe occurred sporadically in Denmark; both species attain rather high frequencies in the zone VI and VII, whilst both decrease more or less rapidly in zone VIII. Above, it was pointed out that in spite of the decrease of ivy and mistletoe in Sub-Boreal time, there is no reason to think that the climate in Sub-Boreal time as a whole differed much from that of the Atlantic time.

In this connection it may be appropriate to mention the transgressions, followed by regressions, detected in the Littorina deposits from Atlantic and Sub-Boreal time in Denmark (Iversen 1937, Troels-Smith 1937, Knud Jessen 1937, Troels Smith 1939 & 1942). Ultimately, these transgressions and regressions must be conditioned by climate, i. e. the eustatic rise of the sea-level was due to a supply of melted ice as water to the oceans. In other words, a rise in the sea-level of the oceans reflects a rise in temperature. The simultaneous isostatic motions of the earths crust veil these eustatically conditioned sea-level oscillations. Undoubtedly, the late Atlantic and the Sub-Boreal transgressions were approximately of the same dimensions; at any rate, the mollusca-fauna, known from early Sub-Boreal time, indicates no lowering of the summer temperature of the sea.

Whatever the interpretations of the climatic causes of the transgressions, either by changes between oceanic periods (mild winters, cool summers) and continental periods (cold winters, warm summers) or by shifting of the mean temperature of the year (from mild winters and warm summers to cold winters and cool summers) the oscillations are likely to cause changes in the water-level of lake-basins and in the growth of the raised bogs. Such changes can actually be detected. The recurrence surfaces (Ry) detected by GRANLUND (1932) in the raised bogs express periods with greater precipitation or less evaporation which succeeded periods with less precipitation or greater evaporation. In large basins with shallow water, as for instance Aamosen, it has been possible to indicate periods of drying-up and periods of rising water-level, which have caused the formation of floating peat-islands (TROELS-SMITH 1951, 1954 & 1956). Such periods of rising and falling of the water-level have been detected in late Atlantic time before the earliest agriculture and at the beginning of Sub-Boreal time after the arrival of the farmers. Here, too, it must be assumed that climatic changes which caused the falling and the rising of the water-level, were of much the same dimensions in both Atlantic and Sub-Boreal time.

This means that neither the transgressions or regressions of the sea, nor the water-level oscillations in the lake-basins, show any sign of a general large-scale climatic change at the boundary between the two periods. By extensive pollen countings the correlation between the occurrence of ivy and mistletoe and the transgressions detected at the coast and the water-level oscillations of the lake-basins in Atlantic time will be a task for the years to come. Dating by help of radiocarbon may be a great help here. If, however, one works with too large time-intervals, for instance the whole of Atlantic time or the whole of Sub-Boreal time, such small climatic oscillations will be veiled. Furthermore, it has to be taken into consideration that Neolithic farmers have probably used mistletoe or ivy for fodder so that the amount of pollen of these plants in synchronous deposits may not be a good expression of their possibility of flowering and thereby of climatic conditions.

Pollen zone border VII-VIII.

As a result of the present investigation it may be stated that the zone border VII–VIII as defined by IVERSEN (1941) most probably register the introduction of a special form of agriculture (TROELS-SMITH 1954 and 1955) different from the land occupation shown by IVERSEN. Consequently, zone borders VII–VIII need not be synchroneous in different diagrams. Whether a change in climate occur simultaneously cannot be decided at the moment.

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M.D.G.F. = Meddelelser fra Dansk Geologisk Forening, København.

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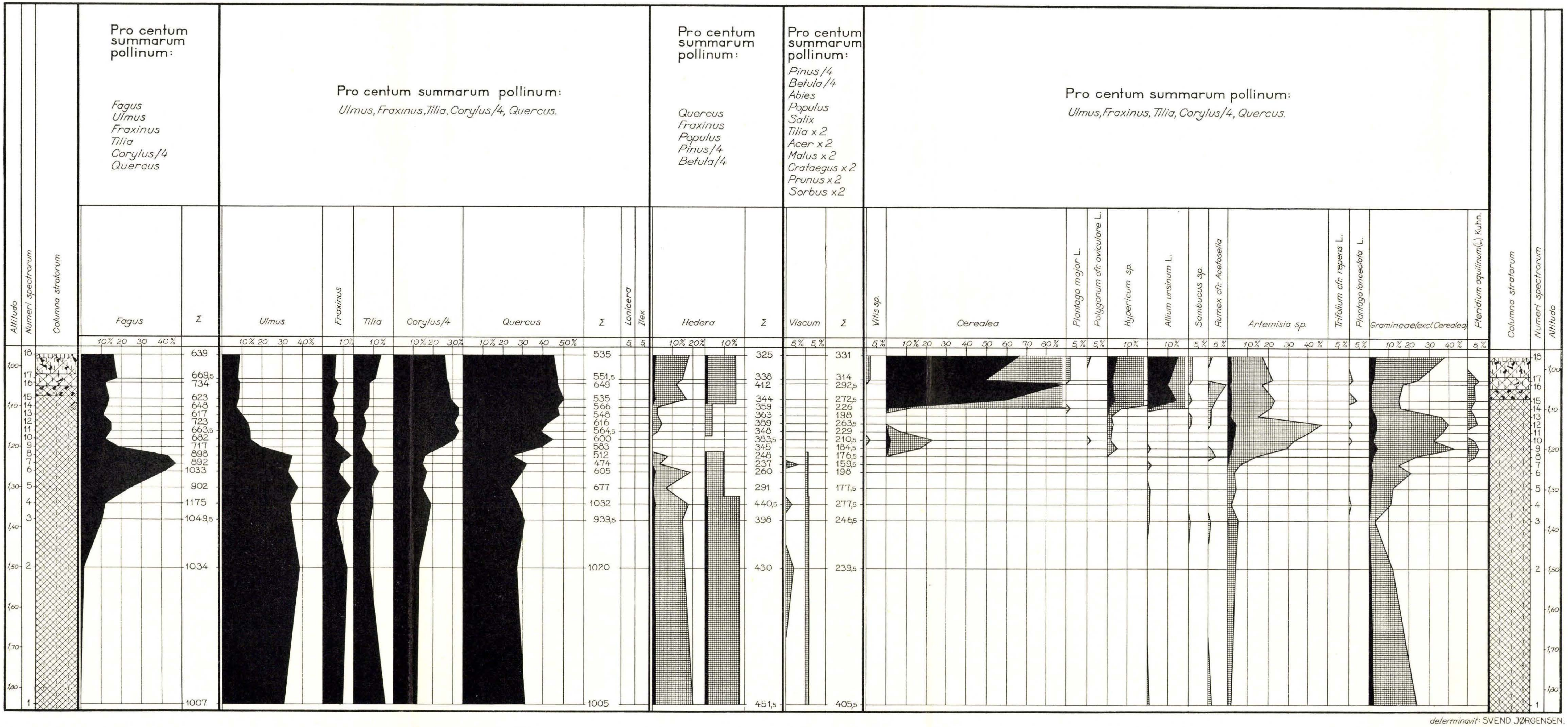
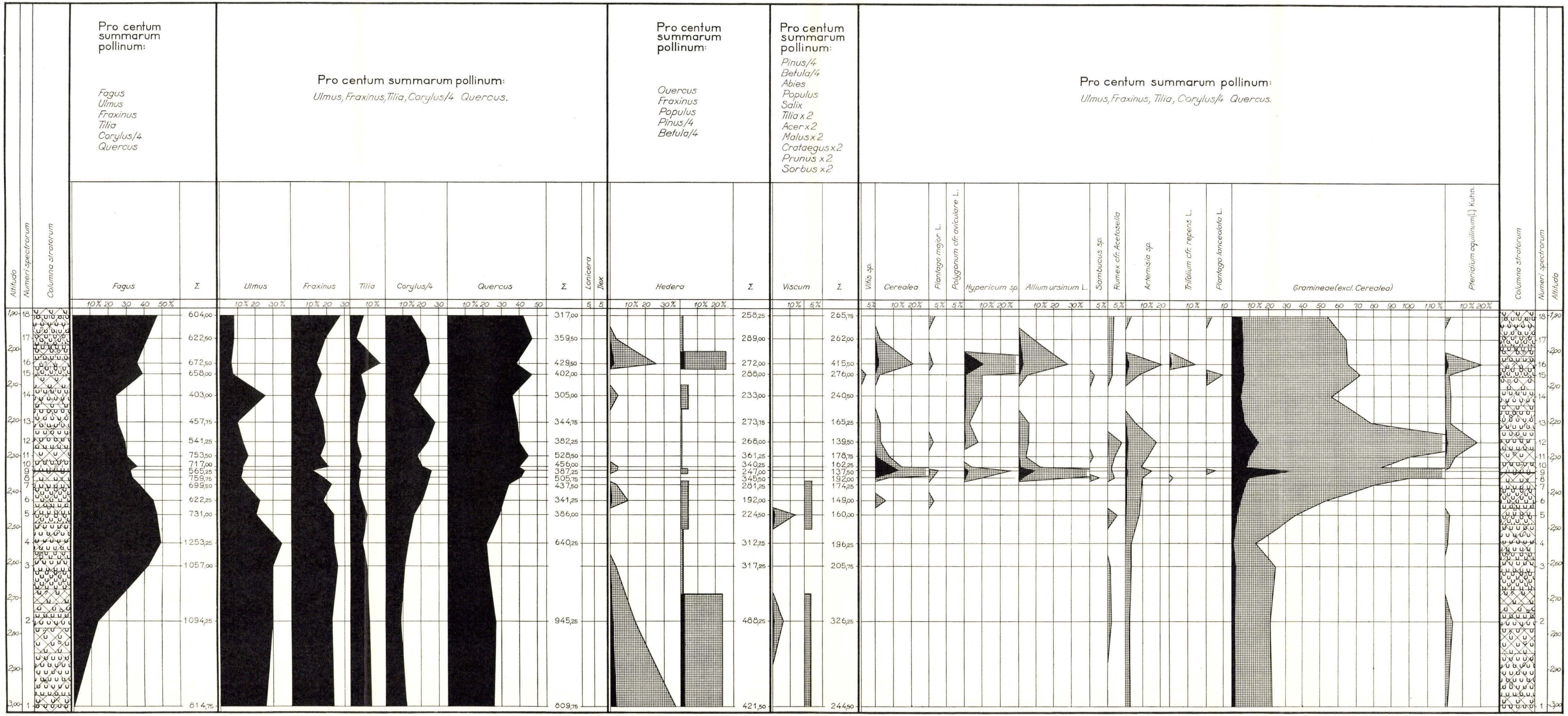


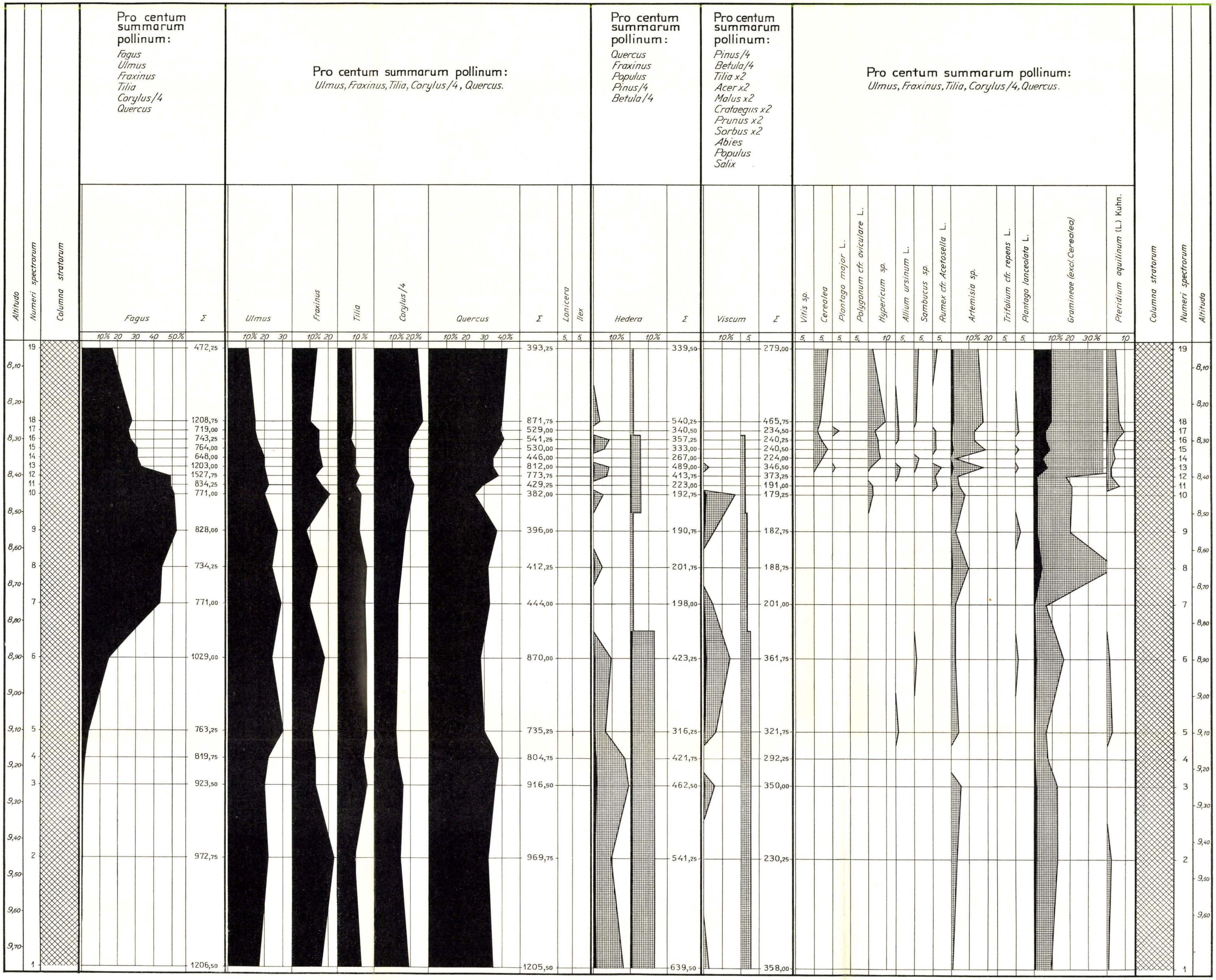
Plate I.

Egolzwil (E3-G), Kt. Luzern, Schweiz. (Troels-Smith. 1955).



determinavit: SVEND JØRGENSEN

Burgmoos, Kt. Bern, - Kt. Solothurn, Schweiz. (Troels-Smith 1955)



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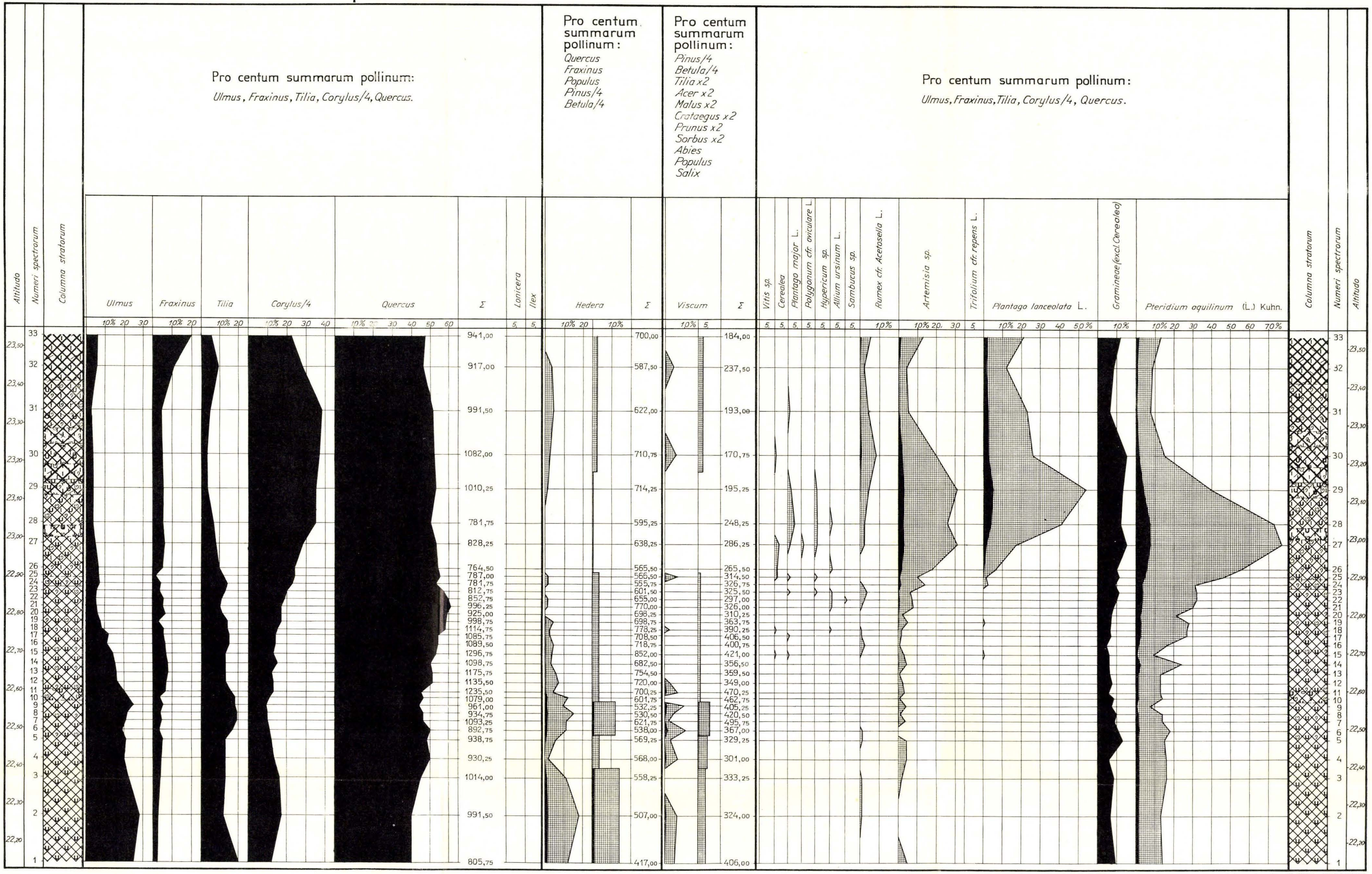
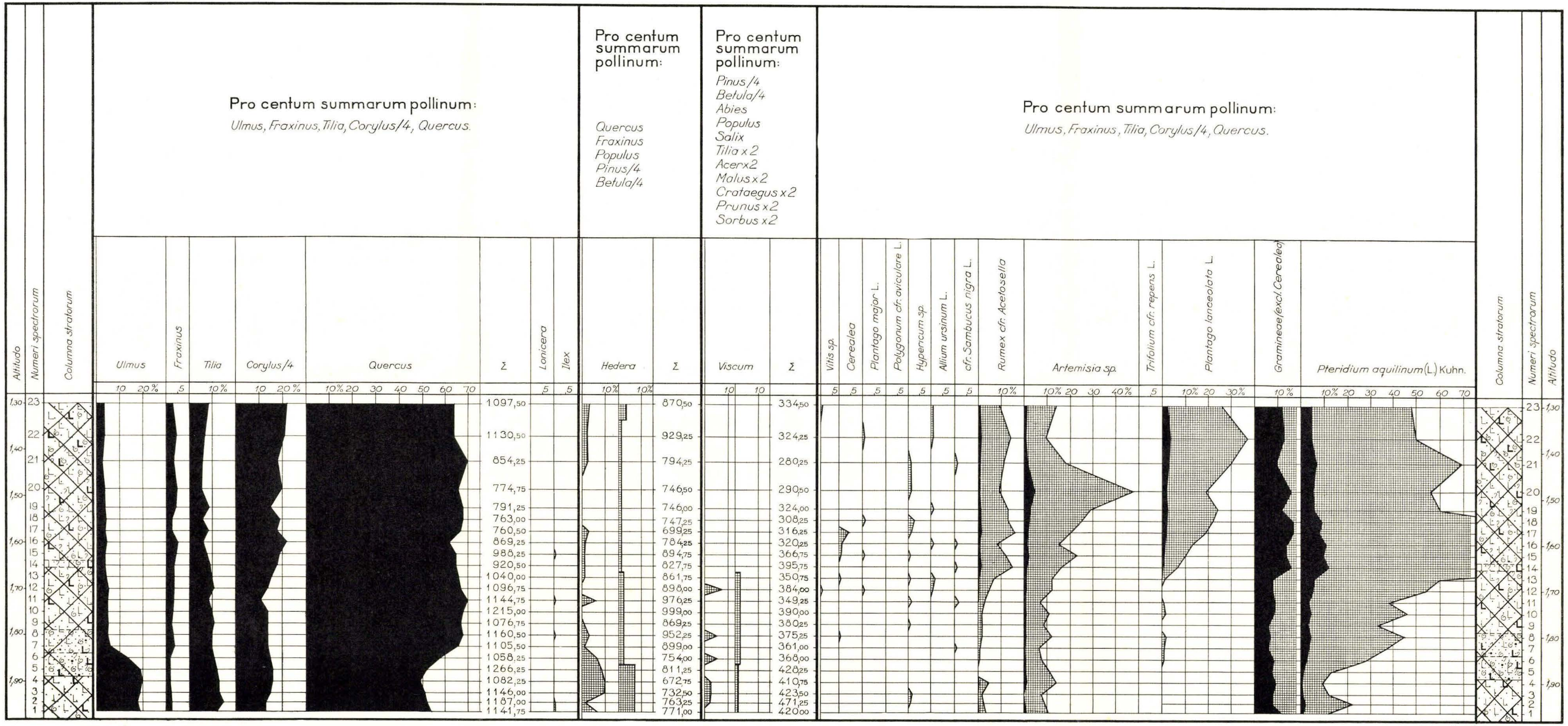
Aamosen: N. 1.000; Ø. 2.840 Pr. Ia & Bp. Ib. Danmark.



determinavit: SVEND JØRGENSEN.

Dyrholmen (240 m), Danmark. (cfr. Troels-Smith 1942)



determinavit: BENT FREDSKILD

3a Kroppsjön, Sverige. (Magnus Fries 1958)