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Pollen Spectra from the Double Passage-Grave, Klekkendehøj, on Møn

Evidence of Swidden Cultivation in the Neolithic of Denmark

by SVEND TH. ANDERSEN

INTRODUCTION

August 1987, the southern chamber of the double passage-grave, Klekkendehøj, on western Møn (Fig. 1), was restored by the National Forest and Nature Agency, The Ministry of Environment. In that connection a radial section of the mound was excavated by the National Museum. The author visited the excavation in order possibly to collect soil samples for pollen analysis. The excavators had noticed that the original subsoil beneath the mound had been removed before its construction; however, they were able to point out thin stripes of dark material in clay layers forming part of the building material. Hence, although a distinctive turf structure could not be seen, suspicion arose, that the clay consisted of surface soil that had been dug up in the surroundings of the mound. This suspicion was confirmed by analysis of samples secured from the dark soil horizons and the clay itself showing them to contain ample charcoal dust and some pollen grains.

Waterbolk (1954, 1958), van Zeist (1955), Groenman-van Waateringe (1974, 1988) and Casparie and Groenman-van Waateringe (1980, in Denmark Jørgensen 1965) showed that pollen spectra from the soil surface beneath prehistoric barrows may be useful for elucidation of the contemporaneous vegetation around the site. Dimbleby (1962, 1985) developed this method further by analyzing pollen throughout the soil horizons preserved beneath barrows and in soil used for construction of the mounds. The pollen diagrams from the soil sections made it possible to reconstruct not only the vegetation contemporary with the barrow, but also to detect vegetational changes induced by man prior to its construction. In Denmark, soil sections beneath Single-Grave barrows in Western Jutland have been analyzed successfully by Odgaard (1985, Odgaard and Rostholm 1988). At Klekkendehøj, only soil from the building material was available for pollen analysis. As will be discussed below, these pollen analyses give unique and unexpected new insight into the way of life of the people who constructed the passage grave.

Material

The age of the passage grave at Klekkendehøj is around 3200 BC (Flemming Kaul, personal communication). The sections from the mound will be described later by the excavators. The clay used for construction of parts of the mound is grey, calcareous, clayey till. The dark stripes were a few centimeters thick and inclined radi-

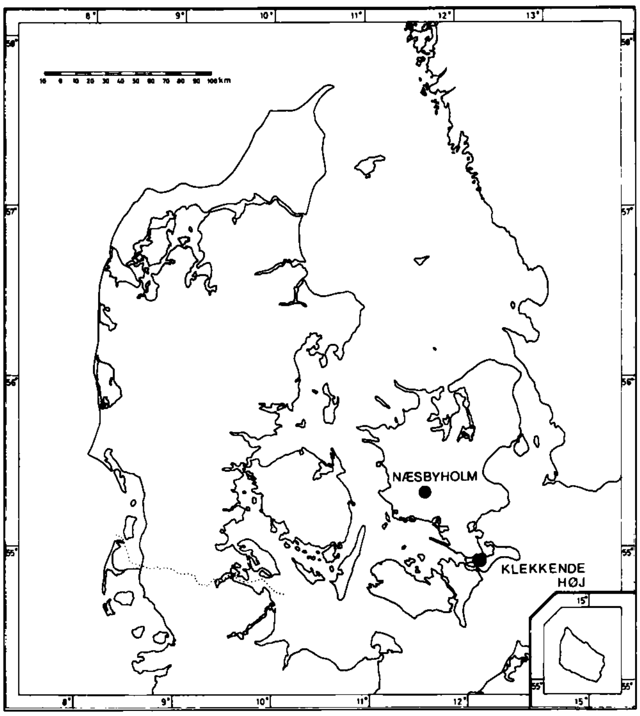

Fig. 1. The location of Klekkendehøj and Næsbyholm Forest.

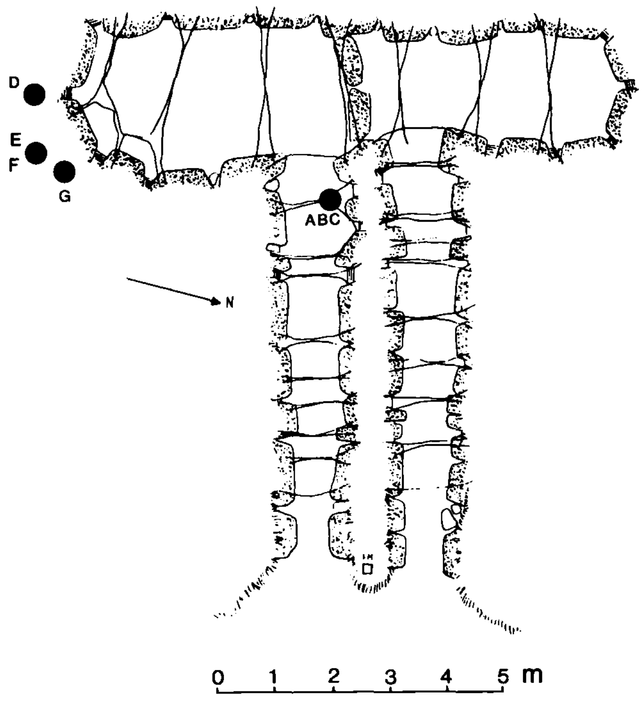

Fig. 2. Plan of the double passage-grave in Klekkendehøj with indication of the samples used for pollen analysis. The plan was measured by Svend Hansen.

ally from the centre of the mound. They contained slight amounts of alkali-soluble humus, which masks the mineral grains and produces the dark colour together with charcoal dust. The humous stripes were clearly delimited from the lighter clay. Such rendzinas used for building material of prehistoric earthworks have also been noticed by Dimbleby (1985). The residue after removal of the mineral matter was a solid mass of charcoal dust with scattered pollen grains. The samples also contained slight amounts of fragments of plant tissue, which may derive from young plant roots.

The location of the samples secured for pollen analysis in relation to the passage grave is shown on Fig. 2. Three samples (A, B and C) derived from dark stripes in a vertical section above the innermost part of the southern passage. Their depth was 0.8–1.0 m below the surface of the mound. Samples D, E and F were secured in sections immediately south of the southern chamber. Samples D and E were from dark stripes, and sample F from light clay 10 cm above sample E. Their depth was 1.5 and 2.1 m below the surface. Sample G, finally, was secured by the excavators from a 50 cm wide spot of dark material continuous with the dark stripe where sample E was taken.

Radiocarbon dating was not performed, because the soil samples contained fragments of plant tissue, which may be modern, and because a part of the charcoal may be older than the mound.

Methods

The samples were prepared for pollen analysis with hydrochloric acid, potassium hydroxide, hydrofluoric acid and acetolysis mixture and were mounted in silicone oil. The residue from sample F (clay) was much smaller than in the other samples but otherwize similar to them.

Annulus diameter (anl-D) was measured for all grass pollen grains (size class 1.2 μm). In addition, the largest and the smallest diameters (M+ and M−) were measured in all grains with annulus diameters larger than 7 μm and sculpture (scabrate or verrucate) was determined with phase contrast equipment. All the grass pollen grains were more or less crumpled.

Species names for plants in latin follow *Flora Europaea.* English names are from Clapham *et al.* 1952. Species without English names are indicated in latin alone.

Pollen preservation

Pollen grains with corrosion scars occurred occasionally, but corrosion did not hamper identification of the grains. In sample D, 43% of the alder pollen showed corrosion scars. Many of the grains were somewhat crumpled as often seen in soil pollen samples.

Identification of grass and cereal pollen

Cereals have larger pollen grains with larger annulus diameters than most wild grasses, and various cereals can be distinguished by size, annulus diameter and sculpturing (see discussion in Andersen 1979, Kühler and Lange 1979). The average size of each grain (largest and smallest diameter divided by 2) is more or less modified in crumpled grains, whereas the original diameter of the annulus can be measured in nearly all grains. Due to overlap in the size ranges of the species, individual grains can rarely be identified, and size frequency distributions are necessary for distinction of the various taxa. Pollen size is likely to be nearly the same as the figures stated in Andersen 1979.

Fig. 3. shows annulus diameter distribution for 237 grass pollen grains (topmost curve). Grains with annulus diameters smaller than 7 μm predominate. These grains are likely to derive from various wild grasses. The peaks for scabrate grains with annulus diameters at 8.4 and 9.6 μm, indicate presence of pollen of the barley group, which includes barley (*Hordeum vulgare*), einkorn (*Triticum monococcum*) and some wild grasses.

Fig. 4 shows the average size of the scabrate pollen grains with annulus diameters 7.2 and 8.4–10.8 μm (topmost curves). Of the grains with annulus 7.2 μm, two grains are distinctively of barley-type size, whereas the smaller grains are likely to derive from wild grasses. The size of the pollen grains with larger annulus (8.4–10.8 μm) is widely scattered, presumably because of crumpling, but are near the size-range of the brome species and barley and einkorn, except for one small grain, presumably a wild-grass pollen grain.

The annulus diameters of all grains referred to barley-type are very similar to barley and einkorn and are somewhat larger than those found in rye-brome (*Bromus secalinus*) and *Bromus hordeaceus* (Fig. 3). Rye-brome is very frequent in Neolithic seed material in Denmark (Jensen 1985), and was probably cultivated (Knörzer 1967), and *Bromus hordeaceus* occurred as a weed (Jensen 1985). These two species can only have been scarce, if present at all, in this material. Wild grasses of barley-type are couch-grass (*Agropyron*), which was identified only with uncertainty in Neolithic seed material, the sea-shore species lyme-grass (*Leymus arenarius*) and marram grass (*Ammophila arenaria*), and float grass (*Glyceria*), which occurs in swamps. It is therefore most likely that the barley-type pollen from Klekkendehøj belongs to barley or einkorn, both of which were cultivated in the Middle Neolithic (Jørgensen 1982).

The verrucate grass pollen grains with annulus diameters larger than 7 μm are mostly smaller than or fall within the size range of meadow oat (*Avenula pratensis*, Fig. 4), which has the largest grains within the wild grasses with verrucate pollen. These grains probably belong to that species and other wild grasses. Two grains with very large annulus fall within the size range of bread wheat (*Triticum aestivum*) and emmer wheat (*T. dicoccon*) and must derive from one of these species.

The wheat species release practically no pollen grains before threshing (Willerding 1986). The barley-type pollen from Klekkendehøj, therefore, presumably belongs mainly to barley. However, at least emmer or bread wheat were certainly also present. Emmer was the commonest crop in Middle Neolithic time (Jørgensen 1982).

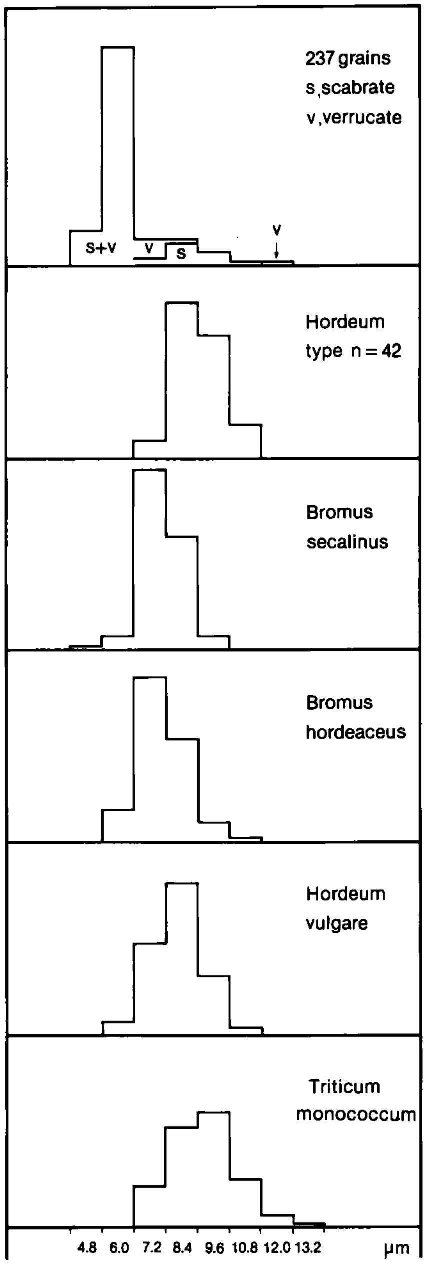

Fig. 3. Annulus diameter (anl-D) in 237 grass pollen grains and pollen grains referred to barley-type (*Hordeum*-type) from Klekkendehøj, and in modern pollen of rye-brome (*Bromus secalinus*), *Bromus hordeaceus*, barley (*Hordeum vulgare*), and einkorn (*Triticum monococcum*, from Andersen 1979).

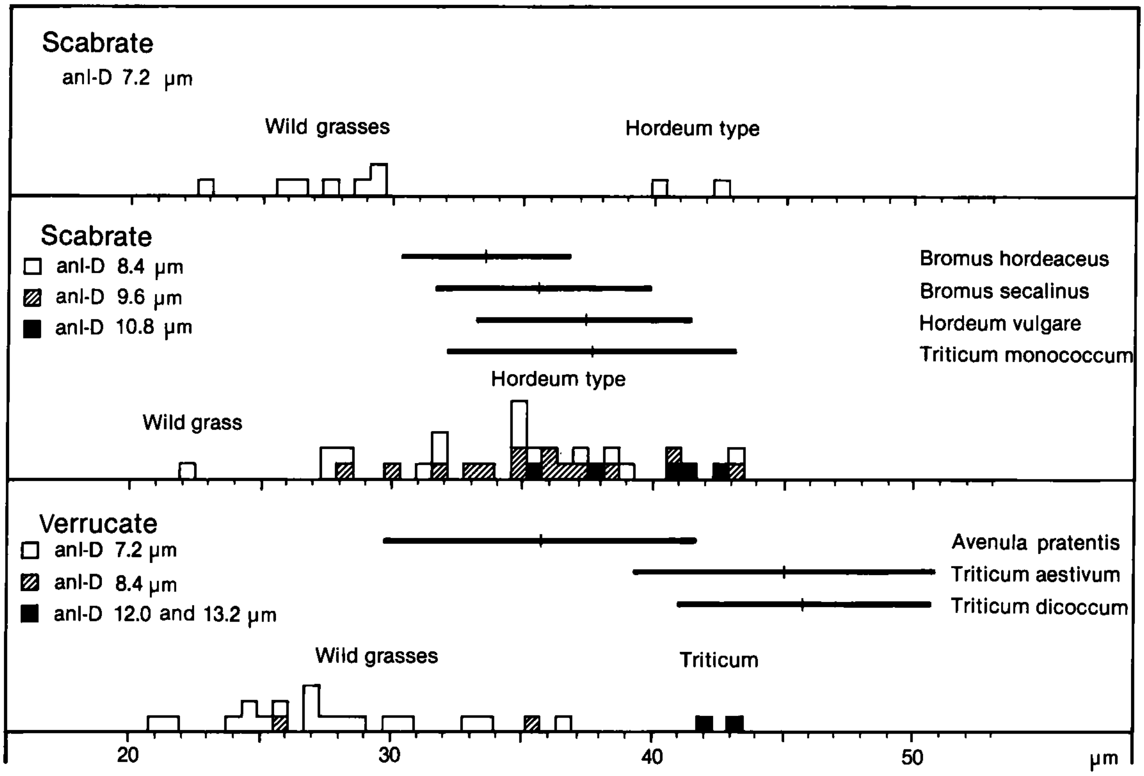

Fig. 4. Average size (M+ + M−/2) of individual grass pollen grains from Klekkendehøj and size range ($\bar{x} \pm 2s$) for modern pollen of *Bromus hordeaceus*, rye-brome (*Bromus secalinus*), barley (*Hordeum vulgare*), einkorn (*Triticum monococcum*), meadow-oat (*Avenula pratensis*), bread wheat (*Triticum aestivum*) and emmer wheat (*Triticum dicoccon*, from Andersen 1979).

Pollen counts from the humic-soil and clay samples. Origin of the pollen floras (Table 1).

Pollen counts from the samples from Klekkendehøj are shown in Table 1. Due to the low concentration of pollen grains, many slides were scanned for each sample. The figures for numbers of tree pollen and non-tree pollen grains and spores per slide give an impression of the pollen concentration in relation to the masses of charcoal dust. These figures are distinctively higher in sample D than in the other samples.

The taxa identified were divided into the groups trees, bare-soil plants, dry-meadow plants, other herbs, shrubs, and forest plants. These groups will be discussed further below. The numbers of pollen grains and spores in the samples A-F are too low for percentage calculation. Table 1 shows, however, that the pollen and spore floras of the samples A, B, C, E and G, from humic horizons, and sample F, from clay, are alike, whereas the tree pollen in sample D differs distinctively from the other samples. It may be concluded that the pollen flora of the samples A, B, C, E and G came from areas with similar vegetation, and that the pollen flora of the clay sample (F) was derived from a humic horizon with a similar pollen flora by down-mixing. The humic horizon, where sample D was obtained, must come from a place with a vegetation, which differed from the other samples.

One taxon, ligulate composites (Compositae, Liguliflorae), forms an exception, as these pollen grains occurred in highly varying numbers and were particularly frequent in the clay sample (F). The ligulate composites comprise a large number of genera and species, whose pollen is difficult to differentiate. The pollen grains found were rather uniform and not unlike those of dandelion (*Taraxacum*), however, several other genera could also be represented.

Pollen grains captured on a land surface can be transported into the soil by the soil fauna and by percolating water. Dimbleby (1985) found that a cover of 40 cm of soil is sufficient to give adequate protection of the pollen flora of buried soils against contamination with pollen from an exposed surface above. Hence, it is unlikely that the pollen floras of the samples from Klekkendehøj, at 0.8–2.1 m below the surface of the mound, were contaminated with younger pollen. They must consist of pollen and spores present in the soils at the time when the mound was constructed.

The pollen grains and the charcoal dust found in the shallow humic horizons from Klekkendehøj had presumably been mixed into the soil by soil fauna before the soils were dug up to be used for building the mound. Lesser amounts of pollen grains and charcoal dust were mixed into the clay. Dimbleby (1985) has shown that spores deposited on a chalk soil were transported downwards to maximally 20 cm depth in 4 years. After 9 years, the concentration of spores was highest in the topmost 2.5 cm of the soil, and the concentration of spores was 75% less at 2.5–5 cm depth. Pollen grains deposited on the surface of a calcareous soil are therefore buried to a shallow depth in a short span of years.

Pollen grains buried in calcareous soils vanish within a few years due to biological breakdown (Havinga 1971, Dimbleby 1985). The pollen grains from the soil horizons at Klekkendehøj must therefore have been derived and buried within a short span of time. Their preservation up til today must be due to low oxygen pressure in the dense clays and hence, absence of biological activity.

Much of the charcoal dust present in the soils was probably more or less contemporaneous with the pollen flora. Charcoal from former times may also be present, however, as charcoal is extremely resistant to decay.

The ligulate-composite pollen mentioned above, which occurred in varying amounts and was particularly abundant in the clay sample, must have been buried in a different way. High concentrations of pollen from insect-pollinated plants in soils have often been observed (Havinga 1963, Bottema 1975). These have been ascribed to burial by burrowing bees, and Havinga and Bottema both mention the preference of the digger bee (*Halictus*) to collect pollen from ligulate composites, in particular those with yellow flowers such as dandelion. The high concentrations of ligulate-composite pollen in the clay sample (F), where other pollen was particularly scarce, indicates that this pollen was transported into the soil by burrowing bees. As the depth of the burrows of European bees averages 25–50 cm (Bottema 1975), it is unlikely that the bee-derived pollen was buried after the construction of the mound, and it must be assumed that the pollen was present in the soil when the mound was built and was probably buried shortly before that time. As sample F does not contain particularly high numbers of other insect-pollinated plants, it is not likely that pollen other than the ligulate-composite pollen was buried by bees. The ligulate-composite pollen found in other samples was presumably buried in the same way.

Reconstruction of the vegetation around Klekkendehøj. Land-use

The pollen spectra from the soil horizons in the mound of Klekkendehøj offer a unique possibility for reconstruction of the vegetation and land use around the mound at the time of its construction. Ordinary pollen spectra from lakes or bogs include pollen derived from large areas, probably around 300 square kilometers, which may comprise a variety of vegetation types and a mosaic of human activities, and the time span of each pollen spectrum may include several tens of years (cp. Groenman-van Waateringe 1988). Even in small hollows, where the pollen spectra may include pollen derived from less than 1 ha, difficulties occur because the transport of pollen from the terrestrial vegetation to the hollow by wind may cause underrepresentation of badly transported pollen, and because some pollen taxa may include plants from the hollow itself (cp. Andersen 1985). The pollen spectra from Klekkendehøj are narrowly focussed in time and in space; badly transported pollen may be registered because the samples derive from the spots, where the plants grew, and the pollen analyses include solely terrestrial pollen. Moreover, the pollen spectra from lakes and bogs, and small hollows in some cases, may not point to a definite archaeological context (cp. Madsen 1985). At Klekkendehøj, we know for certain, that the land around the mound was occupied by the passage-grave people.

The pollen and spore flora from Klekkendehøj was divided into groups of plants of common ecological significance (Tables 2–5). Comparison with present-day plant associations was avoided, because these may have differed from the past communities, especially cultural plant associations, which are strongly influenced by the

Soil	Humic					Clay	Humic
Sample	A	B	C	E	G	F	D
Number of slides	13	14	8	12	8	19	9
Tree pollen per slide	7	14	10	7	7	3	26
Non-tree pollen and spores per slide	4	2	2	1	1	2	66
Trees	92	202	82	82	56	55	232
Hazel, *Corylus avellana*	51	108	54	55	42	26	41
Alder, *Alnus glutinosa*	15	38	11	7	4	5	175
Birch, *Betula*	14	39	9	8	7	15	5
Lime, *Tilia cordata*	2	7	1	1	–	–	1
Oak, *Quercus*	1	–	–	–	–	3	3
Elm, *Ulmus*	–	2	2	–	–	3	–
Ash, *Fraxinus excelsior*	1	–	–	–	–	–	+
Maple, *Acer*	–	1	–	–	–	–	–
Pine, *Pinus sylvestris*	8	7	5	11	3	3	7
Bare-soil plants	7	8	1	–	1	6	76
Barley-type, *Hordeum*-type	2	1	–	+	1	1	37
Wheat, *Triticum*	–	1	–	–	–	–	+
Wormwood, *Artemisia*	3	3	–	–	–	2	1
Sheep's Sorrel, *Rumex acetosella*	–	2	–	–	–	1	23
Cornflower, *Centaurea cyanus*	–	1	–	–	–	–	3
Goosefoot Family, Chenopodiaceae	2	–	–	–	–	–	+
Great Plantain, *Plantago major*	–	–	–	–	–	2	+
Stonecrop, *Sedum*	–	–	1	–	–	–	–
Sheep's Bit, *Jasione montana*	–	–	–	–	–	–	1
Perennial Knawel, *Scleranthus perennis*	–	–	–	–	–	–	4
Knotgrass, *Polygonum aviculare*	–	–	–	–	–	–	3
Persicaria, *Polygonum persicaria*-type	–	–	–	–	–	–	1
Corn Spurrey, *Spergula arvensis*	–	–	–	–	–	–	1
Field Madder, *Sherardia arvensis*	–	–	–	–	–	–	1
Dry-meadow plants	9	2	3	4	2	6	48
Ribwort, *Plantago lanceolata*	6	–	–	4	–	5	39
Adder's Tongue, *Ophioglossum vulgatum*	1	2	2	1	2	–	+
Greater Knapweed, *Centaurea scabiosa*	–	–	–	–	–	–	2
Red Clover, *Trifolium pratense*	–	–	–	–	–	–	2
St. John's Wort, *Hypericum*	–	–	–	–	–	–	2
Field Scabious, *Knautia arvensis*	–	–	–	–	–	–	1
Bellflower, *Campanula*	–	–	–	–	–	–	+
Bracken, *Pteridium aquilinum*	2	–	1	2	–	1	2
Wild grasses, Poaceae undiff.	14	8	4	–	3	1	377
Other herbs	13	3	3	–	1	6	79
Umbellate Family, Umbelliferae undiff.	7	2	3	–	–	1	–
Tubulate Composites, Tubuliflorae	1	–	–	–	1	4	5
Crucifer Family, Cruciferae	4	1	–	–	–	–	4
Pink Family, Caryophyllaceae	1	–	–	–	–	–	1
Buttercup, *Ranunculus*	–	–	–	–	–	1	39
Thistle, *Cirsium*	–	–	–	–	–	–	16
Bedstraw, *Galium*-type	–	–	–	–	–	–	12
Peaflower Family, Fabaceae undiff.	–	–	–	–	–	–	2

Shrubs	5	4	1	2	–	5	–
Willow, *Salix*	–	–	1	1	–	2	–
Black Elder, *Sambucus nigra*	1	3	–	–	–	–	–
Sambucus racemosa	2	1	–	1	–	–	–
Spindle-tree, *Euonymus europaeus*	1	–	–	–	–	1	–
Hawthorn, *Crataegus*	–	–	–	–	–	1	–
Rose, *Rosa*	1	–	–	–	–	–	–
Forest plants	2	5	3	3	–	6	14
Ferns, *Dryopteris*-type	2	3	3	3	–	6	10
Stinging Nettle, *Urtica dioica*	–	1	–	–	–	–	–
Sanicle, *Sanicula europaea*	–	–	–	–	–	–	1
Sphagnum	–	1	–	–	–	–	3
Heather, *Calluna vulgaris*	2	–	–	–	–	1	3
Pollen and spores	144	232	97	91	63	86	826
Ligulate Composites, Liguliflorae	43	17	17	1	–	489	57
Ligulate Composites, numbers per side	3	1	2	0.1	–	26	6

Table 1. Pollen counts from 7 soil samples from Klekkendehøj.

method of agriculture (cp. Willerding 1986). The percentages of trees were calculated separately, with corrections as suggested by Andersen (1970, 1980, note 1), and other plants were calculated in percentage of the non-tree pollen and spores. The ligulate composites were excluded from this pollen sum. Sample D was calculated separately, and the other samples were joined, because of their uniformity. Tables 2–5 also indicate presence or absence in the contemporaneous pollen flora from two small hollows in Næsbyholm Storskov 3400–2700 BC.

Trees (Table 2). Evidence of burning

Tree pollen constituted a major part of the pollen flora in samples A–F (80%) and a minor part in sample D (28%). The tree assemblage in A–F is dominated by hazel (50%) with lesser amounts of alder, birch and lime (12–14%), whereas the other deciduous trees noticed were very rare. The pine pollen was presumably derived by long-distance transport. Alder dominates entirely in sample D (73%), hazel was present (17%), and other trees were scarce.

The tree assemblage in samples A–F differs essentially from the virgin forest known from Atlantic time by the scarceness of lime, oak and elm, whereas hazel and birch were more common than registered for the Atlantic forest (see Andersen 1985). The hazel-dominated woodland at Klekkendehøj was clearly secondary forest, produced by intervention of man. The alder-dominated woodland from sample D may have been more or less natural.

The tree pollen spectra indicate that the clays used

Samples	A-F	D	N
Number of pollen and spores	713	829	
Trees, % of pollen and spores	79.8	28.0	
Number of taxa		9	12
*Hazel, *Corylus avellana*	50.4	17.2	+
*Alder, *Alnus glutinosa*	12.0	73.2	+
*Birch, *Betula*	13.8	2.1	+
*Lime, *Tilia cordata*	13.2	3.3	+
Oak, *Quercus*	0.6	1.3	+
*Elm, *Ulmus*	2.1		+
Ash, *Fraxinus excelsior*	1.2		+
Maple, *Acer*	1.2		+
Pine, *Pinus sylvestris*	5.5	2.9	+
Beech, *Fagus sylvatica*			+
Hornbeam, *Carpinus betulus*			+
Spruce, *Picea abies*			+

* Deformed grains occur.

Table 2. Pollen spectra for trees from soil samples from Klekkendehøj (A-F without D, and D). Tree genera and species, corrected, in percentage of the tree pollen sum. N = sites in Næsbyholm Forest.

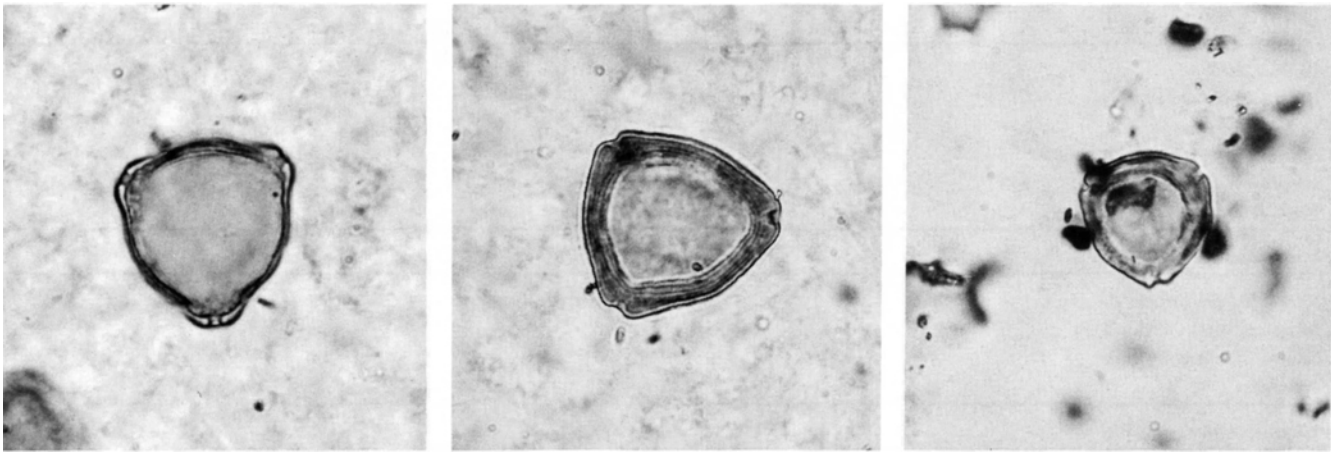

Fig. 5. Hazel pollen grains. Left: A normal modern pollen grain. Middle: A modern pollen grain heated to 300° C for 15 minutes. Right: A deformed hazel pollen grain from Klekkendehøj (the grain is smaller than the modern grain due to treatment with hydrofluoric acid).

for construction of the mound derived from distinctly differing habitats. Klekkendehøj is situated on a small hill, and wet areas occur within 100–200 m distance. The hazel-dominated samples may derive from the immediate vicinity, whereas the alder-dominated soil must have been transported from a wetter area, at least 100 m away. Dimbleby (1985) mentions similar examples of building material fetched at some distance from the barrows themselves.

An important feature was the peculiar appearance in most of the tree pollen grains. The author had difficulty in identifying several of them, hazel in particular, due to exceedingly thickened exine. Communication with B. V. Odgaard revealed that he had seen similar grains in a peat layer with much charcoal. Suspicion then arose that some of the pollen grains had become deformed by heating. Acelolyzed hazel pollen was therefore mixed with powdered lime and was heated at 300° for 15 minutes. The lime was then dissolved and the pollen mounted in silicone oil. Both normal and deformed grains, where the *tectum* had increased to twice or three times its original thickness, occurred. These deformed grains did not differ from the deformed hazel pollen grains from Klekkendehøj (Fig. 5). It can be concluded that this hazel pollen had been heated while incorporated in the soil. Deformed grains with thickened exines were also observed in alder, birch, lime and elm, but deformation was somewhat difficult to observe in the alder pollen because of the exine thickenings which occur naturally in this pollen. Deformed grains were less common in sample D than in samples A–F.

It is indicated that the hazel and alder woodlands at Klekkendehøj were burned so that the pollen grains already incorporated in the soil were heated and deformed to varying degree. It can be expected that the pollen in the alder-woodland soil was less affected by heating, because of greater wetness of the soil. Most of the charcoal dust probably derives from the same burnings.

None of the non-tree pollen grains or spores were deformed. It can be concluded that they were incorporated in the soil *after* the burning.

The same tree species were recorded at the sites in Næsbyholm and, in addition, a few represented by pollen likely to have been transported from a far distance (beech, hornbeam and spruce).

Bare-soil plants (Table 3). Swidden cultivation of cereals

The bare-soil group comprises plants, which preferentially occur on bare mineral soil and avoid plant communities with a dence sward of herbs. A number of the bare-soil plants found at Klekkendehøj are annual or biennial, and a few perennial plants occur. The bare-soil plants constitute 16 and 13% of the non-tree pollen.

Pollen of barley-type is prominent (3–6% of the non-tree pollen) and a few wheat pollen grains occur. Barley itself is autogamous and is likely to be underrepresented in the pollen spectra. Vuorela (1973) found only 1–3% cereal pollen in present-day barley fields in a forested area in Finland. The wheats (einkorn, emmer, bread wheat) are even less likely to release pollen (see discussion above). It was concluded that barley was cer-

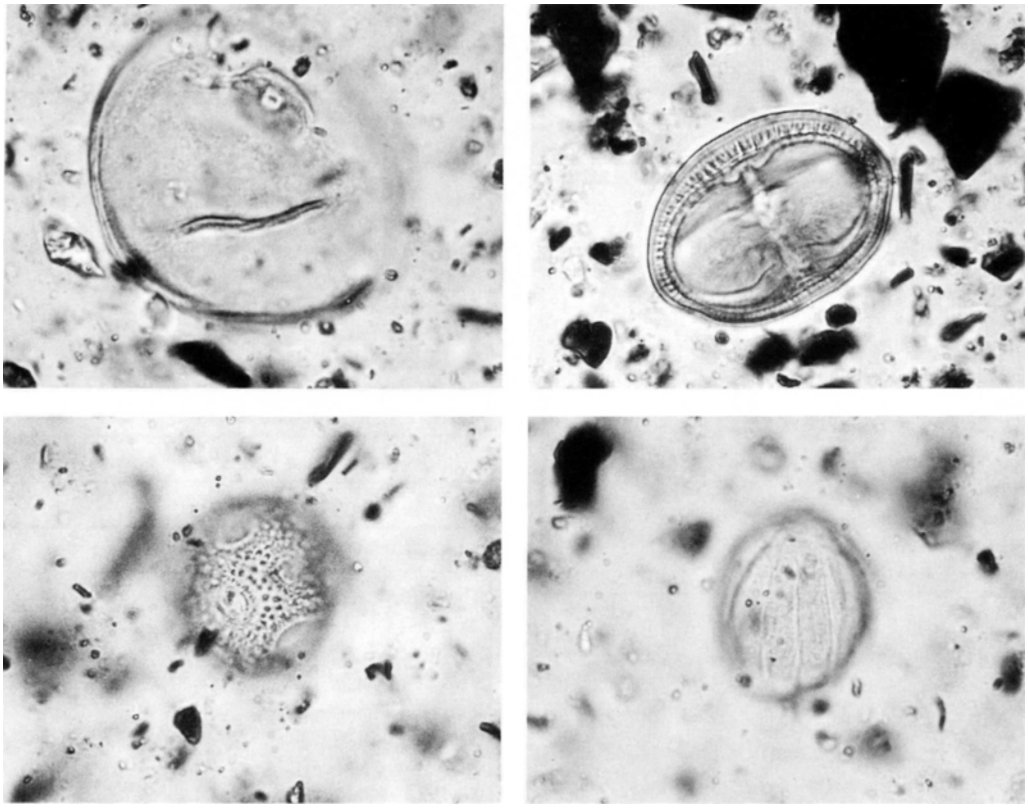

Fig. 6. Pollen grains of barley-type (*Hordeum*-type), cornflower (*Centaurea cyanus*), perennial knawel (*Scleranthus perennis*), and field madder (*Sherardia arvensis*) from Klekkendehøj.

tainly grown, possibly einkorn, and that emmer or bread wheat presumably were cultivated as well. It is a near conclusion that hazel and alder groves around Klekkendehøj were felled and burned and the bared soil then sown with cereals a short time before the passage-grave was constructed. Hence, we have evidence that swidden cultivation was in use. With swidden cultivation, the soil must not be heated excessively in order not to destroy soil organisms and humus (Steensberg 1955). This may explain why the tree pollen grains that were incorporated in the soil were not destroyed by the fire. Swidden cultivation of cereals is profitable only for a short time, even on fertile soils, as the crops then decrease (Reynolds 1977, Steensberg 1979). One advantage is, that natural weeds do not occur in the burned soil during the first crop years (Steensberg 1955). Hence we may conclude that the bare-soil plants listed in Table 3 were involuntarily introduced by man when sowing the grain. This almost certainly is true for the annual or biennial plants, cornflower, goosefoot, knotgrass, persicaria, corn spurrey and field madder. Great plantain and knawel, although perennial, also behave as annuals, as they produce abundant seeds and new plants during the first year's growth. It is less certain whether the other perennial plants in Table 3 (wormwood, sheep's sorrel, stonecrop and sheep's bit) occurred as weeds, as they are more ambiguous and may have occurred in denser vegetation. They may have invaded the fields after a few years' cultivation.

The weed flora from Neolithic time in Denmark known from macrofossils (note 2) is rather poor, comprising 14 species (cp. Groenman-van Waateringe 1979a). 9 species from Klekkendehøj are not represented there. Of these, wormwood, sheep's sorrel and great plantain occur commonly in pollen analyses.

Cornflower (*Centaurea cyanus*) occurred in Denmark in the Late-Glacial, but was extremely scarce with only three finds, of pollen grains, from the Neolithic, the Bronze Age and the Iron Age, up to the Viking Age, when it became more common (note 3, Mikkelsen

Samples	A-F	D	N
Number of non-tree pollen and spores	144	597	
Bare-soil plants	16.0	12.8	
Number of taxa		14	7
* Barley-type, *Hordeum*-type	3.4	6.4	
* Wheat, *Triticum*	0.7	+	
Wormwood, *Artemisia*	5.6	0.2	+
Sheep's Sorrel, *Rumex acetosella*	2.1	3.9	+
* Cornflower, *Centaurea cyanus*	0.7	0.5	
* Goosefoot Family, Chenopodiaceae	1.4		+
(*)Great Plantain, *Plantago major*	1.4		+
Stonecrop, *Sedum*	0.7		
Sheep's Bit, *Jasione montana*		0.2	+
(*)Perennial Knawel, *Scleranthus perennis*		0.7	
* Knotgrass, *Polygonum aviculare*		0.5	+
* Persicaria, *Polygonum persicaria*-type		0.2	
* Corn Spurrey, *Spergula arvensis*		0.2	+
* Field Madder, *Sherardia arvensis*		0.2	

* Annual or biennial.

Table 3. Bare-soil plants in percentage of non-tree pollen and spores.

1986). Macroscopic remains are known from the Neolithic in Poland and Switzerland (see Jensen 1985), and a pollen grain from Holstein (Schmitz 1957). There can be no doubt that cornflower was introduced accidentally to Denmark by Neolithic people and has grown as a weed since then, although its pollen grains were spread only accidentally to lakes and bogs. Field madder (*Sherardia arvensis*) has not been found in fossil state, neither pollen nor macrofossils. It was still a common weed in cereal fields in the early twentieth century (Ferdinandsen 1918). Macrofossils of persicaria (*Polygonum persicaria*) have been recorded from the Bronze Age onwards, and no finds of perennial knawel (*Scleranthus perennis*) are recorded from Denmark and neighbouring countries (Jensen 1985).

The number of bare-soil plants found at Næsbyholm is distinctively smaller than that found at Klekkendehøj. This may be due to difficulty in the dispersal of their pollen.

Dry-meadow plants, wild grasses and other herbs (Table 4)

The dry-meadow plants are perennial and have in common, that they are able to grow in dense swards of herbaceous vegetation. Bracken was referred to this group, because it may be common in grazed meadows. These

Samples	A-F	D	N
Dry-meadow plants	18.1	8.0	
Number of taxa		8	6
Ribwort, *Plantago lanceolata*	8.3	6.6	+
Adder's Tongue, *Ophioglossum vulgatum*	5.6		+
Greater Knapweed, *Centaurea scabiosa*		0.3	
Red Clover, *Trifolium pratense*		0.3	
St. John's Wort, *Hypericum*		0.3	+
Field Scabious, *Knautia arvensis*		0.2	
Bellflower, *Campanula*		+	
White Clover, *Trifolium repens*			+
Great Burnett, *Sanguisorba officinalis*			+
Bracken, *Pteridium aquilinum*	4.2	0.3	+
Wild grasses, Poaceae undiff.	20.8	63.4	+
Other herbs	18.1	13.3	
Number of taxa		8	8
Umbellate Family, Umbelliferae	9.0		+
Tubulate Composites, Tubuliflorae	4.2	0.8	+
Crucifer Family, Cruciferae	3.4	0.7	+
Pink Family, Caryophyllaceae	0.7	0.2	
Buttercup, *Ranunculus*	0.7	6.6	+
Thistle, *Cirsium*		2.7	
Bedstraw, *Galium*-type		2.0	+
Peaflower Family, Fabaceae		0.3	
Avens, *Geum*			+
Cinquefoil, *Potentilla*			+
Mint, *Mentha*-type			+

Table 4. Dry-meadow plants, wild grasses and other herbs, in percentage of non-tree pollen and spores.

plants constitute 18 and 8% of the non-tree pollen. The number of species is larger in sample D than in samples A–F probably because a much larger number of non-tree pollen and spores was counted in sample D (Table 3). Some of these plants, ribwort, greater knapweed, red clover and field scabious, occurred as weeds in Danish cereal fields in the early twentieth century (Ferdinandsen 1918), but if slash-and-burn cultivation was used at Klekkendehøj, it is not likely that they had sufficient time to establish themselves whilst the fields were still cultivated. The dry-meadow plants may indicate herbaceous vegetation in uncultivated places, between the fields or around large rocks that could not be removed from the fields, or, they may have spread after abandonment of the fields. Ribwort, the most frequent species, is presumably overrepresented due to its high pollen production and good pollen dispersal.

Samples	A-F	D	N
Shrubs	11.8		
Number of taxa		6	6
Willow, *Salix*	2.8		+
Black Elder, *Sambucus nigra*	2.8		
Sambucus racemosa	2.8		
Spindle-tree, *Euonymus europaeus*	1.4		
Hawthorn, *Crataegus*	0.7		+
Rose, *Rosa*	0.7		
Rowan, *Sorbus aucuparia*			+
Bird-cherry, *Prunus padus*			+
Crap Apple, *Malus sylvestris*			+
Juniper, *Juniperus communis*			+
Forest plants	13.2	2.4	
Number of taxa		4	5
Ferns, *Dryopteris*-type	11.8	1.7	+
Stinging Nettle, *Urtica dioica*	0.7		
Sanicle, *Sanicula europaea*		0.2	
Ramsons, *Allium ursinum*			+
Oak Fern, *Gymnocarpium dryopteris*			+
Polypody, *Polypodium vulgare*			+
Sphagnum	0.7	0.5	+

Table 5. Shrubs and forest plants in percentage of non-tree pollen and spores.

Berglund *et al.* (1986) found much higher percentages of ribwort pollen in grazed meadows from to-day than found at Klekkendehøj. Besides ribwort, St. John's wort and bracken survive grazing because they are not eaten by cattle. The other dry-meadow species in table 4 are less likely to flower in pastures because they flower late in the summer, and would be eaten before that time. As ribwort and bracken were not very common, it may be concluded that extensive pastures were not present near Klekkendehøj, but light grazing may have occurred.

Dry-meadow plants were recorded in nearly the same numbers in Næsbyholm as at Klekkendehøj, probably because their pollen is dispersed better than that of the bare-soil plants.

The wild grasses constitute 21 and 63% of the non-tree pollen. They are certainly overrepresented. It is somewhat difficult to decide where they grew, because the wild grasses comprise species preferring bare soil and grass swards as well. It is probably most likely that they mainly belonged to the dry-meadow vegetation.

The group listed as "other herbs" comprises pollen types that could be identified only to plant families, subfamilies or genera, which comprise a variety of species. They constitute 18 and 13% of the non-tree pollen. Pollen of the umbellate family was particularly common in samples A–F (9%), and pollen of buttercup in sample D (7%). Some of these plants may have occurred on the bare soil of the fields, but it is likely that the majority belonged to the meadow vegetation.

A similar number of taxa was recorded in Næsbyholm.

Shrubs and forest herbs (Table 5)

Shrubs are recorded exclusively in samples A–F, where they constitute 12% of the non-tree pollen. They include willow, two species of elder, spindle-tree, hawthorn and rose. Pollen of black elder has been recorded from the Early Neolithic in Denmark (Troels-Smith 1960) and seeds from the Late Iron Age and later (Jensen 1985). Pollen of *Sambucus racemosa* was recorded from recent time in Draved Forest (Aaby 1983). Fossil seeds are unknown in Denmark (Jensen 1985) and the species is considered recently introduced here but native to northern Germany. Fredskild (1978) found a wide variation in elder seeds from a Neolithic dwelling site in Switzerland, which includes black elder and *Sambucus racemosa* as well. Hence, *Sambucus racemosa* may have been introduced to Denmark by Neolithic people. The elder berries may have been favoured by the inhabitants at Klekkendehøj.

These shrubs from Klekkendehøj may have survived the burning of hazel woodland or may have spread to uncultivated places between the fields. A similar number of shrubs was recorded in Næsbyholm.

The forest plants include plants which may have grown in forest environment. They constitute 13 and 2% of the non-trees. Ferns of *Dryopteris*-type were the commonest; they may have occurred as relics from the hazel and alder woodlands or in sheltered places beneath shrubs. A similar number of taxa was recorded in Næsbyholm.

Vegetation and land-use around Klekkendehøj. Table 6

The pollen spectra from Klekkendehøj contain at least two generations of pollen, as most of the tree pollen is likely to derive from shortly before the burnings and most of the non-tree pollen and the spores from a short

					Number of taxa	
Samples		A-F	D		A-D	N
Trees	% of P	79.8	28.0		9	12
Bare-soil plants	% of NAP	16.0	12.7		14	7
Meadow (incl. grasses and others)	– – –	56.9	84.4		17	15
Shrubs	– – –	11.8			6	6
Forest plants	– – –	13.2	2.3		4	5
Heath	– – –	2.1	0.5		1	1
					51	49

P = All pollen and pores NAP = Non-tree pollen and spores.

Table 6. Summary of plant groups from Klekkendehøj.

period thereafter. Hence, tree-pollen and non-tree pollen spectra were calculated separately.

Groves of hazel, with some limes, birches and alders and alder-groves with some hazels occurred around Klekkendehøj, and were slashed and burned before the sowing of cereal crops. The difference between the percentages of tree pollen in the two sets of samples (80% in A–F and 28% in D) is somewhat difficult to explain. The tree-pollen concentration in sample D was probably smaller than in the other samples before the burning.

Iversen (1941) suggested that swidden cultivation was used widely in Denmark in Neolithic time. He assumed that virgin forest was used for this purpose (Iversen 1949). However, his own quotation of Linkola describing swidden cultivation in Finland (1916, Iversen 1941, p. 47) says: "Der junge Wald, der meistens ausschliesslich oder haputsächlich aus Laubholz besteht, wird im Alter von 20–30 Jahren gefällt; dieses findet im Juni statt. Nach einem Jahre werden im Juni bei günstiger Witterung die dürren, am Boden liegenden Bäume verbrannt". The ground is then sown with grain crops for some years. "Ist der Boden ergiebig, so kann noch eine zweite, in Ausnahmefälle eine dritte, vierte usw. Haferernte folgen. Dann lässt man die Fläche sich begrasen und benutzt sie sofort als Weideplatz oder (bei fruchtbarerem Boden) eine zeitlang als Wiese. In kurzem entsteht dort, teils aus Wurzelschösslingen, teils aus Samenkeimlingen, meistens aus beiden zusammen, ein junger Wald. Der junge Wald wird so lange als Weide benutzt, bis man ihn weider niederbrennt".

Exactly this method seems to have been employed at Klekkendehøj using secondary woodland rather than virgin forest as assumed by Iversen (1949). The swidden rotation from Finland described by Linkola was based on regeneration of birch by seedlings, and by saplings and root-suckers from alder stumps, which survived the fire. At Klekkendehøj hazel and alder groves were burned and the ground used for growing of cereals. Hazel and alder are equally well suited for producing new saplings from the old stumps and can be coppiced for centuries (Worsøe 1979). Hence, the swidden cultivation at Klekkendehøj may have been one step in a regular rotation as described from Finland by Linkola, but using mainly hazel and alder rather than birch and alder, and barley and wheat rather than rye and oats for crops. The flint axes and ard type used at that time would have been suited for this type of agriculture (Hedeager and Kristiansen 1988).

It is difficult to say whether some of the tree pollen grains date from after the burning. As most of the hazel pollen grains, at least, were deformed, and hence have been exposed to heating, trees may have been scarce in the immediate surroundings of the passage grave.

The frequencies of plants from fields (bare-soil plants), are nearly the same in the two sets of samples (16 and 13%). They are definitely underrepresented in the pollen spectra, as most of them produce low amounts of pollen. Fields therefore were extensive around Klekkendehøj. Most of the field plants were probably introduced accidentally by man, when sowing the crop grains.

Dry-meadow plants, wild grasses and other herbs from Table 4 are included in the meadow vegetation in Table 6. This vegetation constitutes 57 and 84% of the non-tree pollen. Some of these plants are strongly overrepresented (grasses, ribwort). Nevertheless, uncultivated areas with dense herbaceous vegetation must have been widespread, probably between the fields and around large rocks within the fields. As mentioned earlier, the meadow plants may also have invaded fields where crop growing had ceased. The meadow plants probably spread from open habitats in the neighbourhood. The meadows do not appear to have been exploited heavily and it was concluded that extensive pastures were not present at Klekkendehøj, whereas light grazing may have occurred. Heavy grazing might have been unwanted, because it would have had an adverse effect on the tree regeneration after swidden cultivation (see Rowley-Conwy 1981).

Various shrubs are represented in samples A–F (12%)

but not in sample D. These shrubs are insect-pollinated and therefore strongly underrepresented. Accordingly, shrubs were quite abundant around Klekkendehøj. They may have been present in the hazel groves and been preserved for various purposes (food, elder berries, sheltering of the fields?, cp. Groenman-von Waateringe 1978), whereas shrubs were apparently absent from the alder groves and did not spread after the burning there.

The forest plants, which are particularly frequent in samples A–F (13%), probably survived in the shelter of the shrubs.

The low frequency of heath plants (heather, Table 1) indicates that heath had not developed at Klekkendehøj.

The numbers of taxa recorded in the small hollows in Næsbyholm Forest are very similar to those recorded at Klekkendehøj, except for the bare-soil plants, which were considerably scarcer in the hollows probably because of ineffective pollen dispersal.

Vegetation and land-use in Denmark in passage-grave time

The hazel and alder groves recorded at Klekkendehøj together with cereals, ribwort, grasses and other herbaceous plants are very similar to the vegetation recorded during the so-called *landnam* phase of Iversen (1941). The landnam phase is reflected in East-Danish pollen diagrams by minimum for lime, low elm, maxima for hazel, alder and sometimes birch, and occurrence of cereals, ribwort and other herbaceous plants.

Iversen (1941) found a carcoal layer at the beginning of the *landnam* and he proposed that the maxima of birch, alder and hazel were due to forest regeneration after a clearance of the original woodland by the use of fire. Cattle then browsed the regenerating forest producing glades with ribwort and other herbs. Iversen also proposed that cereal crops were sown after the fire and grown for some years until the soil was exhausted in accordance with the swidden cultivation method practiced in Finland. But, as he wrote "This however is not easy to prove" (1941, p. 30, cp. Rowley-Conwy 1981, Groenman-van Waateringe 1988).

Iversen realized that the forest clearances may not have been synchronous, but connected them generally with the Dolmen Culture. Later, Iversen (1949) proposed that the land occupation phase might in some cases reflect a series of forest clearances and that the farmer people successively cleared new areas of primitive forest, because it was easier to burn than the secondary fresh vegetation. In 1967 (see Iversen 1973) Iversen realized that in some localities there was uninterrupted scrub pasture, and he suggested that hazel coppice with oak standards was maintained by suppression of the shade trees, lime and elm. These hazel groves might have been used as a food source.

Radiocarbon dating was not available at the time when Iversen proposed his *landnam* phases. Hence, it was not possible to date them and estimate their length in time. Some radiocarbon dates are now available.

Troels-Smith (1982) found that *landnam* phases with pasture may have started as early as 3200 bc (3800 BC) and could be connected with the non-megalithic funnel-beaker culture (B-type).

A pastoral phase can be recognized in a pollen diagram from a small hollow in Næsbyholm Forest on Zealand mentioned earlier (Andersen 1985). This diagram reflects vegetation on a small areal scale. Lime was suppressed in favour of hazel, alder, oak and ash, and there is a maximum for dry-land plants including ribwort and bracken. This stage is very similar to Iversen's *landnam* phase, but there is no birch maximum preceding the hazel-dominated vegetation. Field floras are weakly represented. The stage is radiocarbon-dated to 3400–2700 BC.

Landnam phases can also be recognized in pollen diagrams from Holmegård Bog on Zealand (Aaby in Andersen *et al.* 1983), and Fuglsø Bog and Elsborg Bog in eastern Jutland (Aaby 1986, Andersen 1984). There are minima for lime and in some cases oak and ash, maxima for hazel and alder, and slight maxima for land herbs including ribwort and bracken, which are preceded by more or less pronounced birch maxima. The radiocarbon dates are from about 3400 to about 3000 BC (2900 BC at Holmegård and 3200 BC at Elsborg). These hazel- and alder-dominated secondary woodlands were thus maintained for 200–700 years and were contemporaneous with the pastoral phase from Næsbyholm. In no case can they be connected directly with archaeological contexts, but they are synchronous with the Passage-Grave Culture.

Besides Iversen's pollen diagrams (1941, 1949) undated *landnam* phases can be recognized in many other east Danish pollen diagrams (Troels-Smith 1942, 1960, 1982, Mikkelsen, 1949, A. Andersen 1954). The *landnam* phase begins some time after the elm decline in most cases, and immediately above the elm decline in some, giving support to Troels-Smith's contention (1982), that *landnam* phases may have been initiated as early as 3800 BC. Many of these *landnam* phases may, however, be synchronous with the Passage-Grave Culture. The *landnam* phase nearest to Klekkendehøj is found at Borre Mose on Møn, 20 km to the east (Mikkelsen 1949).

The *landnam* phase ends in many cases with renewed increase in lime (and sometimes elm), which indicates that the human activities were discontinued and the lime-dominated forest re-established. The herb pollen frequencies rarely exceed 10% giving support to Iversen's contention (1973) that extensive hazel coppices, not open pasture, characterized the Danish landscape.

Traces of cereal fields during the *landnam* are weak in the pollen diagrams from lakes and bogs and consist mainly of scattered cereal pollen grains. Shifting swidden rotation of the type suggested for Klekkendehøj would be smoothed-out in these diagrams. The extensive hazel and alder groves from passage-grave time in Denmark may thus have been used for large-scale swidden rotation. Göransson (1986) suggested a similar procedure in Sweden; however, there was no proof of this. The coppice groves may also have been maintained for other purposes. Iversen (1973) suggested food-gathering (cp. Jørgensen 1983), and Godwin (1975), Bartholin (1978) and Malmros (1986) suggested the use of piles for building purposes (trackways and pile dwellings) and for fences.

At Klekkendehøj there is no evidence of extensive pasture, but limited grazing as described by Linkola may have occurred. At one of the hollows in Næsbyholm Forest several minima for lime and maxima for oak, alder, hazel and ash, and ample charcoal dust, dated at 3400–2700 BC, indicate repeated burning of lime-forest. There are small peaks for herb pollen. Slash and burn was probably used irregularly for promotion of browsing by cattle. At the same time, permanently grazed glades with ribwort and bracken were maintained at the other hollow mentioned above (site 1) along with groves of hazel, alder, oak and ash, which were probably used for various purposes, whereas evidence of fields is weak.

The pollen diagrams from lakes and bogs also support Iversen's surmise that grazing occurred during the *landnam* phase and that no extensive pastures were present.

The evidence of swidden cultivation at Klekkendehøj is unique and needs support from other localities. Still, it can be suggested that groves of hazel and alder mixed more or less with other trees, were maintained by the passage-grave people to be used for slash-and-burn rotation and for production of food and wood. There is also evidence that glades used for pasture occurred in limited extent.

Averdieck (1980) mentioned pollen analyses of brown earths buried under Neolithic barrows in northern Germany. The age of these barrows within the Neolithic was not mentioned and no pollen spectra were shown. Wild grasses and ribwort seem to have been common and cereals scarce. Heather was frequent in samples from sandy soils underneath barrows from the Funnel-Beaker Culture in The Netherlands and northern Germany (see Casparie and Groenmann-van Waateringe 1980, and earlier litterature quoted there, Groenmann-van Waateringe 1979b, Averdieck 1980). Hence, this vegetation differed from that found on calcareous soils in Denmark. Heather was also prominent on sandy soils in western Jutland from about 3500 BC and onwards (Odgaard, in Andersen *et al.* 1983).

Conclusion

The pollen spectra from Klekkendehøj have proved that useful information about the land-use of prehistoric cultures may be obtained by pollen analysis of soil horizons in barrows even in areas with calcareous soils. The experiences of Dimbleby (1985) have shown that prehistoric barrows were often constructed by using material from the contemporaneous land surface. Hence, such useful information can be obtained even in cases where the original soil is not preserved beneath the mound. Pollen diagrams from lakes and bogs provide a smoothed-out picture of vegetation on a large areal scale and in a datable time sequence. The pollen spectra from burial mounds are narrowly focussed in space and time and can be connected directly with prehistoric cultures. Such spectra are urgently needed for an understanding of the way of land-use employed by different prehistoric cultures. In the cooperation between the Geological Survey of Denmark and the National Forest and Nature Agency now in progress such investigations will be an important new activity.

Svend Th. Andersen, The Geological Survey of Denmark, Thoravej 8, DK-2400 Copenhagen NV.

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NOTES

1. The tree pollen counts were corrected before percentage calculation with the following factors: pine, birch, oak, hazel, alder × 0.25, elm × 0.50, lime, ash × 2.
2. Species of weeds found as macrofossils from Neolithic time in Denmark and neighbouring countries (from Jørgensen 1982, Jensen 1985): Thyme-leaved sandwort (*Arenaria serpyllifolia*), black bindweed (*Bilderdykia convolvulus*), *Bromus hordeaceus*, shepherd's purse (*Capsella bursa-pastoris*), fat hen (*Chenopodium album*), hemp nettle (*Galeopsis sp.*), cleavers, (*Galium aparine*), scentless mayweed (*Matricaria perforata*), knotgrass (*Polygonum aviculare*), self-heal (*Prunella vulgaris*), wild radish (*Raphanus raphanistrum*), annual knawel (*Scleranthus annuus*), white campion (*Silene alba*), corn spurrey (*Spergula arvensis*), chickweed (*Stellaria media*).
3. Fredskild (Degerbøl and Fredskild 1979) noticed one pollen grain in a pollen sample ascribed by him to zone VIII (with low lime and elm, and high hazel and alder percentages). This sample may be contemporaneous with Klekkendehøj. Fredskild found that the cornflower-pollen grain might be due to contamination, however, in view of the finds from Klekkendehøj, this find may be considered genuine.

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