An Introduction into Pollen Analysis Used in Archaeological Work with Some Examples from Interdisciplinary Projects

Pollen is the male part and the smallest organic unit in the pollination process of flowers that is necessary to make the next generation of plants. Palynology is the study of pollen, together with the study of spores from, for example, ferns, mosses, etc. We also include the study of some other selected microelements like charcoaldust.

The method of pollen analysis, using all these different types of fossils, is today the main technique in the reconstruction and study of vegetation history and vegetation changes through time. To date, the method has been used with great success on both Quaternary and Pre-Quaternary deposits. The main idea in the analysis is to determine the different fossils to the lowest taxonomic level possible, and then look for changes in the microfossil composition from one level to another.

Sometimes botanists still feel that some people believe in a permanent, never-changing vegetation. This despite the present-day heavy airpollution in most of Europe with its decrease in the coniferous forests, or the great reforestation, mainly by deciduous trees, caused by reduced grazing, both in coastal areas and at higher altitudes for instance in Scandinavia today.

Different aspects of human impact have changed the vegetation in Europe to a great extent during thousands of years. However, the main factors over the millions of years of plant life have been climatic changes and geological phenomena like glaciations, sealevel changes, continental drift, etc. In addition, plant succession and competition have been of importance at shorter timescales.

The pollen analytical method is simple to learn. At many different universities and colleges courses are given at different levels in their educational programmes.

The level of taxonomic determination depends on the required precision of the work, and to reach a sufficient level may be difficult in some cases. The vegetable or plant kingdom is based on the *species*. Related species make a *genus*, and related genera make a *family*, and then *orders* and *classes*. Some pollen of genera and families are today more or less easy to split up. Some taxa are, however, complicated. One of them, Poaceae or Gramineae or the grass family, which includes all the cereals, is more complicated. In the same pollen diagram we therefore may see different taxonomic levels represented, family, genera and species at the same time. If the determination of fossil grains and the counting is under control or has reached a sufficient level, the ensuming pollen diagram will be the result of the laboratory part of the analysis. (I will here ignore the chemical treatment used to remove the mineral and organic particles from the pollen and spores, and the statistical errors arising from counting).

How then do we use the pollen diagram? The interpretation of a pollen diagram in most cases is *much* more difficult to learn, not only for archaeologists or geologists, but also for botanists and palynologists. Still a large number of botanists and palynologists spend much time and effort trying to improve the method in order to understand more fully the pollenrecords from the past.

The pollen diagram is a result of the vegetation composition locally and regionally, flowering, pollen and spore dispersal, preservation conditions in different sediments, chemical treatment, and statistical errors and calculations. These factors are all rather complex, for example the different vegetation communities present in the pollen-source normally differ from wet to dry types, from infield to outfields, etc., in addition to long-transported pollen from other types.

Finding the way from the pollen diagram to the past environment therefore needs much experience and theoretical and practical knowledge of different fields like plant ecology, together with some knowledge of geology, climatology, and archaeology. Only a few of the palynologists cover all these fields, if anybody. Sometimes we feel we succeed, sometimes not.

Very often a pollen diagram or a group of diagrams has been made to solve a particular problem or a series of questions. A data-set like a pollen diagram therefore may contain valuable information for other scientists, for example archaeologists before an excavation within a certain area.

A large number of archaeologists today have realised the great advantages of pollen analysis, and use the method to study the environment of the past, in this case its vegetation history. The method *is* of great importance in the study of the last 5-6000 years history of the Holocene. In some projects it is the main method in addition to archaeology, whereas botanical studies of the vegetation history isolated over the same period *must* similarly consider the role of human impact. There *is* thus a reciprocal interaction between pollen analysis and archaeology. Therefore, joint projects with both pollen analysts and archaeologists have made great progress in several countries during the last 25 years, especially in Europe.

How does it work? In most cases archaeological projects involve palynologists. In some cases the archaeologists collect the samples in the field, and deliver them to a palynologist for analysis. In other cases, the palynologist collects the samples her-/himself and prepares the diagram or set of diagrams. The person makes a botanical discussion, and conclusions are the end of the palynologist's work. In other projects, a second set of discussions start together with the archaeologists, and a joint paper is made with joint conclusions based on both archaeological and botanical finds, records and evidence. I myself believe in this second strategy. It prevents misunderstanding and misinterpretation by both. Concerning the conclusions, they may improve as one goes further on, and they are more easily understood by others.

A successful project involves ethics, characteristics and qualities of the people involved, and it involves that each of the participants knows each other's scientific « language » or terminology used. By this the participants also learn how to ask the right questions. Perhaps this is the most important factor in an interdisciplinary project. However, back to pollen analysis again. Most of the archaeologists are in some way familiar with the genus *Urtica* (nettle), *Plantago* (plantain) or *Artemisia* (mugwort), and the different cereals mentioned in discussions and interpretation work. They are all very important. In addition changes in the forest composition play an important role. The vertical vegetation zonation, for example in the Alps, both on south-facing and north-facing slopes is important, as is the south-north latitudinal zonation in Europe. The occurrence and spread of weeds may differ from one area to another. Therefore well-defined human impact in one area will not necessarily have the same effect on the vegetation at different latitudes or altitudes. We also know that some species, for example pine or spruce disperse their pollen by wind over many kilometres, while pollen of other trees and shrubs which are insectpollinated can hardly be found at all. Pollen from *Hordeum* (barley), may be found some 100 metres away from the infield, while *Triticum*-pollen, (wheat), is rather poorly spread, only a meter or so.

Generally therefore pollen from crops or weeds may only tell us about the presence of humans or their domestic animals somewhere in the catchment. A closer study of the different taxa present in a set of diagrams will give more details (Fig. 1).

Except for the different cereals, the *Plantago lanceolata* (ribwort) has among archaeologists most likely been the most popular plant taxon in the European flora. As a weed, the species follows domestic animals and has been used quite frequently in the interpretation work, and several missunderstandings have developed in the recent years in the literature. The plant was a native plant in the Late-Glacial flora in most of Europe. After the trees arrived, it survived mostly on seashores from South Europe to the coast of North-Norway. This complicates interpretation of pollen diagrams from sites close to the actual seashore. Such a plant, an apophyte, which is favoured by human activity, may be used successfully, with care in interpretation. On the other hand, far away from suitable natural habitats, the same species may occur as an anthropocore, a plant which is introduced by man. In such cases the interpretation is easier. The third possibility is the occurrence of pollen from, for example the same species, above or outside the climatic potential growing-area. Wind, humans, or domestic animals can be involved in pollen transport.

The interpretation of one single pollen diagram from a limited area normally gives rise to alternative conclusions. Another diagram from another site close by, may give another picture, and so on. Sometimes synchronous dated stages in different diagrams close to each other are similar, sometimes not. The reasons for this can differ. The most obvious one can be explained in an archaeological way. Some archaeological sites are small, only 1 m^2, for example a resting site with some charcoal. If you move some meters away, perhaps there are no finds. In such a case also the local vegetation will differ.

In a large area with a more or less uniform land-use, synchronous sections in the diagrams may conform inside the site, but differ between, for example, infields, outfields, hay meadows or grazing areas. The pollen diagram is a kind of window into the past with a foreground with some local information, and a background with more regional or general contributions.

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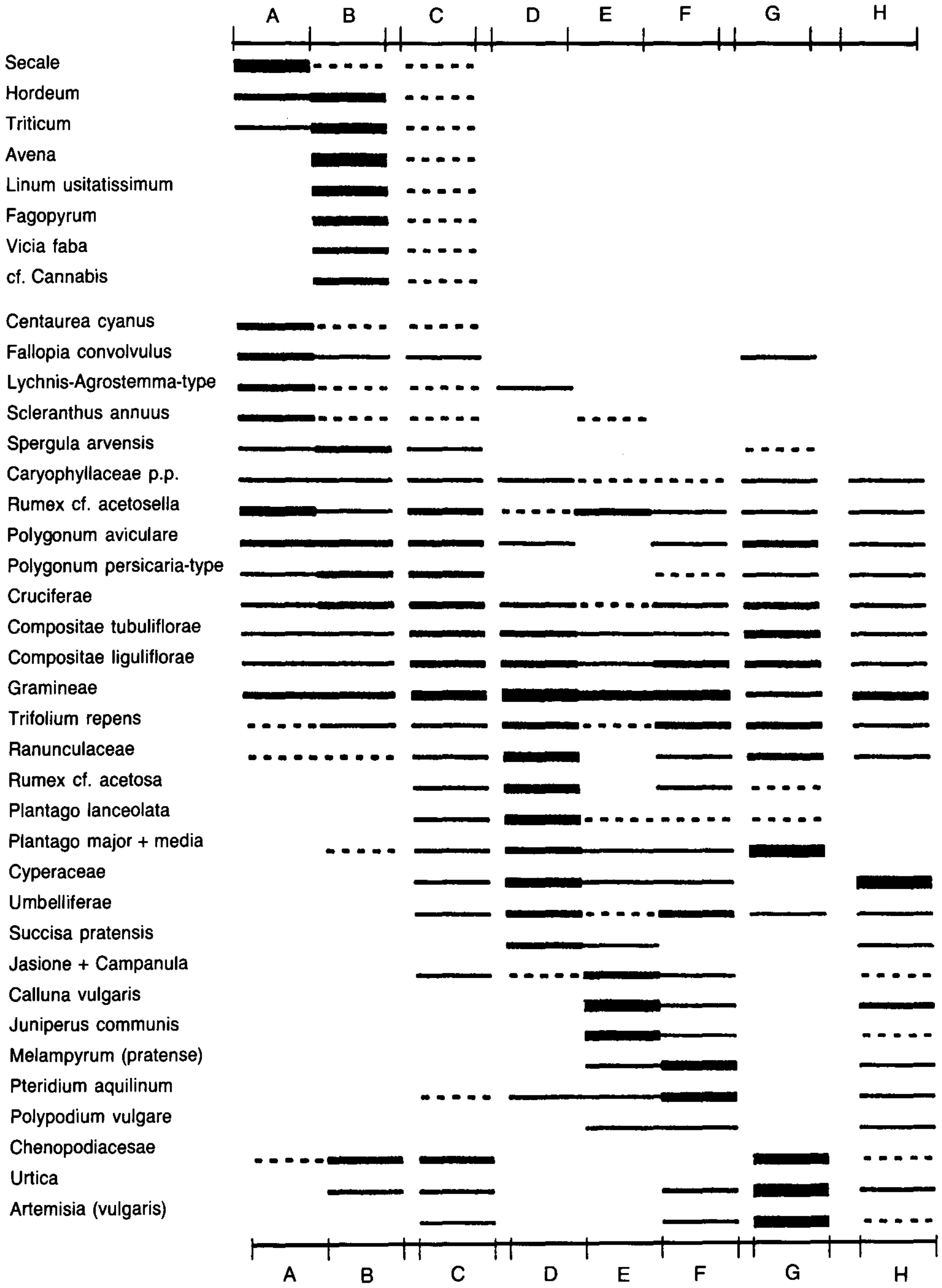
Fig. 1. The principal anthropogenic indicators in pollen diagrams and their occurrence in various farming contexts within the central lower part of Europe north of the Alps. The frequency of occurrence is considered without reference to variation in pollen production and dispersal. The graph shows in a generalized form the occurrence of the anthropogenic indicators in the area under consideration. In smaller regions with uniform climate and soil the evaluation of some of these indicators may be different.

A : Winter cereals.
B : Summer cereals and root crops.
C : Fallow land.
D : Wet meadows and pastures (more or less nitrogen-rich).
E : Dry pastures (particularly poor heaths).
F : Pastures within non-regenerating woodland (Hudewald).
G : Footpath and ruderal communities (more or less nitrogen-rich).
H : Species frequent in natural communities especially those of peaty soils, (from Behre, 1981).


A B C D E F G H
Secale
Hordeum
Triticum
Avena
Linum usitatissimum
Fagopyrum
Vicia faba
cf. Cannabis
Centaurea cyanus
Fallopia convolvulus
Lychnis-Agrostemma-type
Scleranthus annuus
Spergula arvensis
Caryophyllaceae p.p.
Rumex cf. acetosella
Polygonum aviculare
Polygonum persicaria-type
Cruciferae
Compositae tubuliflorae
Compositae liguliflorae
Gramineae
Trifolium repens
Ranunculaceae
Rumex cf. acetosa
Plantago lanceolata
Plantago major + media
Cyperaceae
Umbelliferae
Succisa pratensis
Jasione + Campanula
Calluna vulgaris
Juniperus communis
Melampyrum (pratense)
Pteridium aquilinum
Polypodium vulgare
Chenopodiacesae
Urtica
Artemisia (vulgaris)
A B C D E F G H

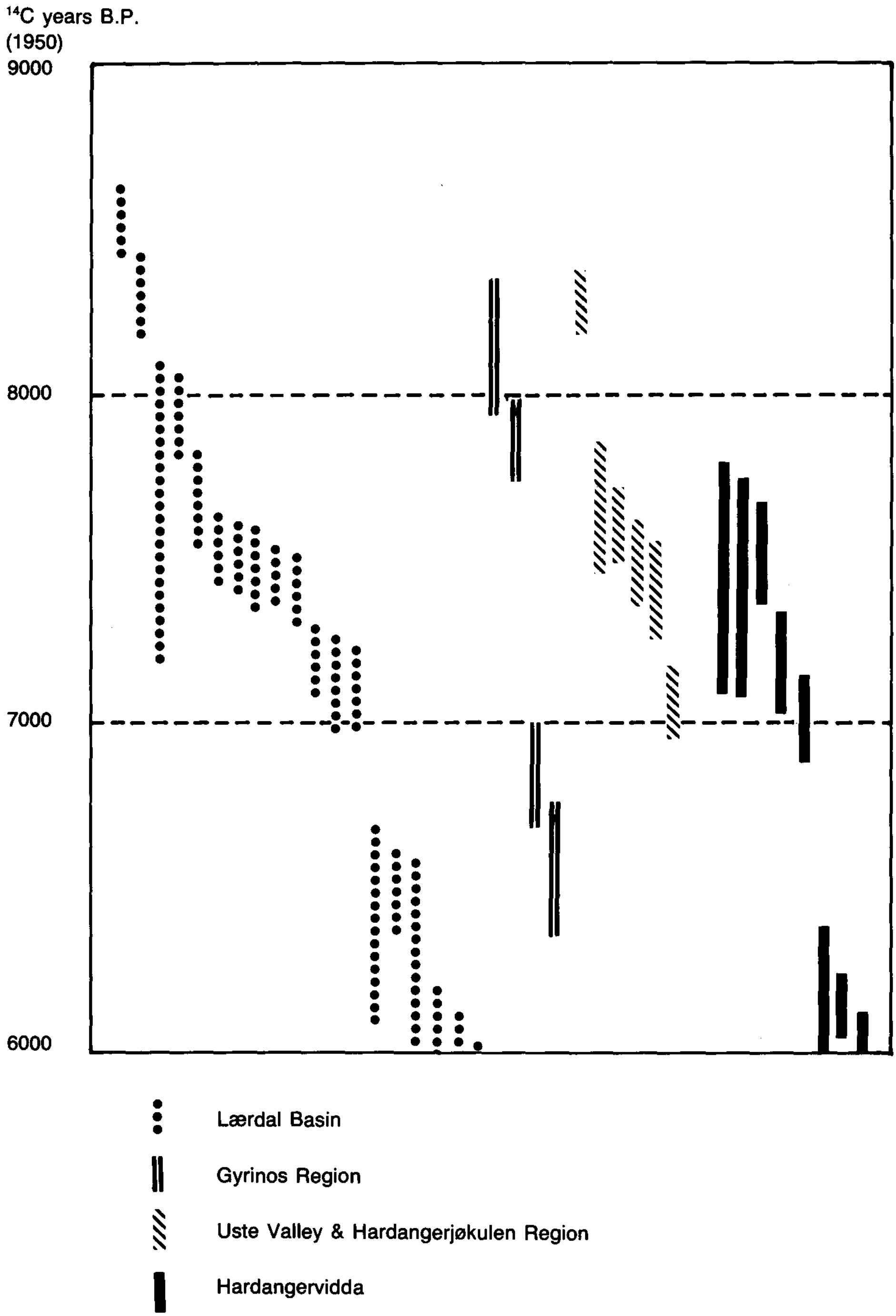


Fig. 2. Radiocarbon dates of charcoal from the 37 oldest settlements sites older than 6000 years B.P. from the southern Norwegian mountainous areas. All dates are uncalibrated, represented with one standard deviation, and calculated on the basis of a halflife of 5570 years, (from Moe et al.*, 1978).*

It will never give a complete picture of both fine-scale and broad-scale patterns of human impact, and it is not a magic method. This paper may, so far, have seemed like a long list of disadvantages or limitations in using the method, despite the fact that the method has been in use by archaeologists since 1919 in a work by von Post in a Bronze Age Swedish study.

Numerous examples can be given on the use of pollen analysis in connection with archaeology such as : the beginning of crops or cereal growth ; changes in forest composition including discussions on the elm-decline or on the opening of the dense forest ; or on the change in landscape from, for instance, forest to heath-area. References to such work are many. A few are mentioned in the literature list. Work in marginal areas are fewer, and three examples of joint projects from such an area will be given.

Pollen diagrams normally indicate no sign of disputable Mesolithic impact on the environment. This may be a result of several factors. Early impact could have frequently been of minor nature, pollen sampling sites may be located too far from the areas of impact to detect signs of anthropogenic activity, there may have been few or no foreign crops, few apophytes, or the pollen diagrams themselves may be of insufficient detail to reflect clearly shortterm ecological changes. However, the Mesolithic problem may be solved be vegetation historians by considering the nature of the regional environment.

The first example is taken from the mountain areas in South-Norway. Chronological differences in archaeological sites are apparent between the southern and the northern parts ; almost 1000 years later in the south, at Hardangervidda, than in the northern districts, *e.g.* Laerdal (Figs 2 and 3). Topographically there is a marked difference from the south to the north. Most of the plateau in the south lies between 1100 and 1300 meters above sealevel (treeless today), while the northern part lies between 1200 and 1600 meters. Great effort was made to find older sites than *ca.* 7500 years in the south, with the same archaeological technics, methods and people. The general vegetation history showed a very rapid colonisation of birch and pine just after deglaciation (*ca.* 9000 B.P.). A maximum treeline was reached up to *ca.* 1250 m. The area in the south was more or less covered by forest (Fig. 3). The Mesolithic people were linked to reindeer-hunting, and the reindeer preferred the open areas in the north. After the decrease in tree-line, the southermost areas were also suitable. This is, so far, the most likely answer for this archaeological problem.

The next example is a study of stock-keeping on the Hardangervidda plateau, an area already presented. At an early stage of the work, it became clear that the archaeological as well as the pollen material held information that was indicative of the presence of grazing animals somewhere in the area during an early phase of the Neolithic. The archaeological material in question consisted of flakes chipped of polished flint axes from southern Scandinavia, Neolithic types, and of pottery (Fig. 4). Anthropogenic indications in pollen diagrams consisted largely of the presence of more or less isolated grains of *Urtica*, Chenopodiaceae, *Artemisia* and *Plantago lanceolata*. The earliest occurrences are dated to *ca.* 5200 B.P. (Fig. 5). These types of pollen continued for most of the Neolithic ; the amounts, although small, did not differ essentially from those from the last two centuries, when we know that a large number of domestic animals grazed the same area every summer from the end of June to the beginning of September.

The archaeological and palynological methods both show the same pattern dated to the same time. Based mainly on this, the conclusion is that the area was frequently visited by groups of people with cultural affinities with the earliest south-east Norwegian Neolithic agricultural population ; moreover they indicated that these groups took domestic animals with them to the mountain plateau during the summer.

The last example is a very close interdisciplinary case study from the centre of Hardangervidda, the Halne area. A large number of archaeological sites was found, some were excavated, some not, some dated and some not. On the other hand, two pollen diagrams were made within the same area and interpreted carefully.

The main idea behind the experiment was to try to make progress in the interpretation of the total data available from the area. In a synthetic diagram on the same timescale all information and interpretations were presented for the reader (Fig. 6). This kind of synthesis is a typical end-product including different aspects on human activity. The main results show an almost continuous use (summer-use) of the area from at least 4800 B.P. to 2800-2500 B.P., and from 2200 B.P. to the present. There is evidence that the area was used in 3 different ways : (1) hunting and fishing as indicated by osteological finds, different kinds of arrows and other hunting equipments ; (2) movement of domestic animals from lower altitudes as indicated by pollen of selected anthropochores ; and (3) semi-permanent occupation with grazing by domestic animals as suggested by changes in local vegetation, finds of pits and fire-cracked rocks.

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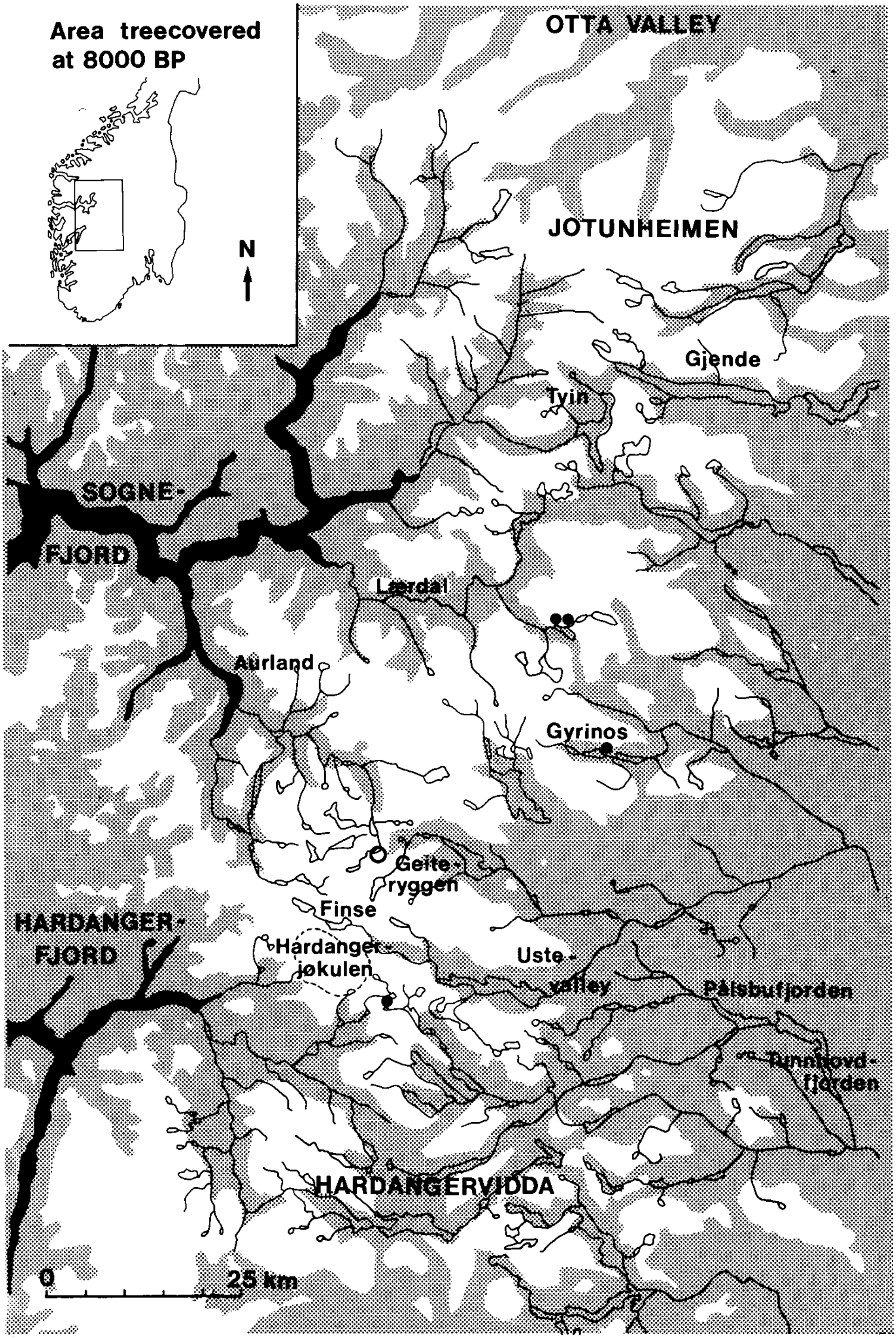
Fig. 3. A reconstruction of the treeline and forested areas in the western parts of the southern Norwegian highlands, shows large unforested areas (white) north of Hardangervidda. Tree covered areas are shaded. Treeline in the eastern parts is put at 1200 meters above sea level and at 1000 to 1100 meters in the western parts, gradually increasing eastwards. The treeline in the Uste valley, up to Finse, is based on pine stumps at 1150 meters, but it is possible that the treeline was about 1200 meters, or close to the lake Finsevatn (1210 meters). Late 9th millenium settlement sites are represented with black dots. (From Moe et al.*, 1978).*


Area treecovered
at 8000 BP
N
OTTA VALLEY
JOTUNHEIMEN
Gjende
Tyin
SOGNE-
FJORD
Lærdal
Aurland
Gyrinos
Geite-
ryggen
Finse
HARDANGER-
FJORD
Hardanger-
jøkulen
Uste-
valley
Pålsbufjorden
Tunnhovd-
fjorden
HARDANGERVIDDA
0
25 km

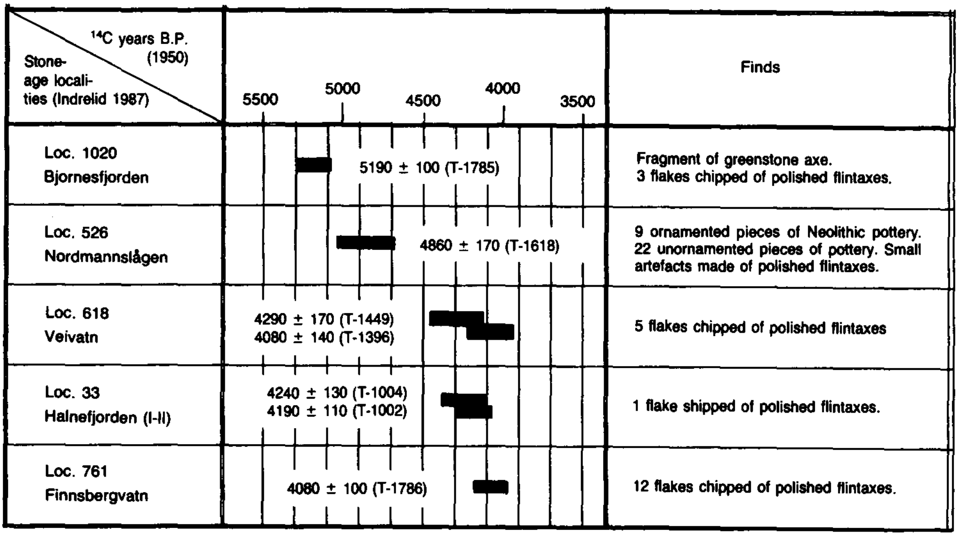


Fig. 4. Radiocarbon-datings and selected archaeological sites finds 5 different sites at Hardangervidda. (See text). (From Indrelid and Moe, 1982).

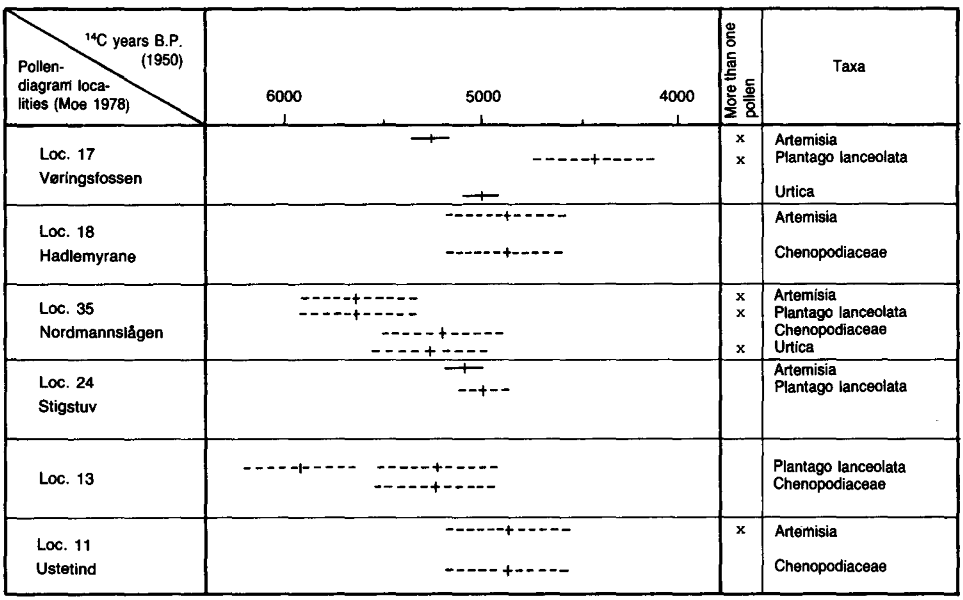


Fig. 5. Oldest pollen of Plantago lanceolata, Urtica, Artemisia, *and Chenopodiaceae from Hardangervidda dated direct by ^{14}C-datings with one standard deviation or by interpolation (300 years) (after Indrelid and Moe, 1982).*

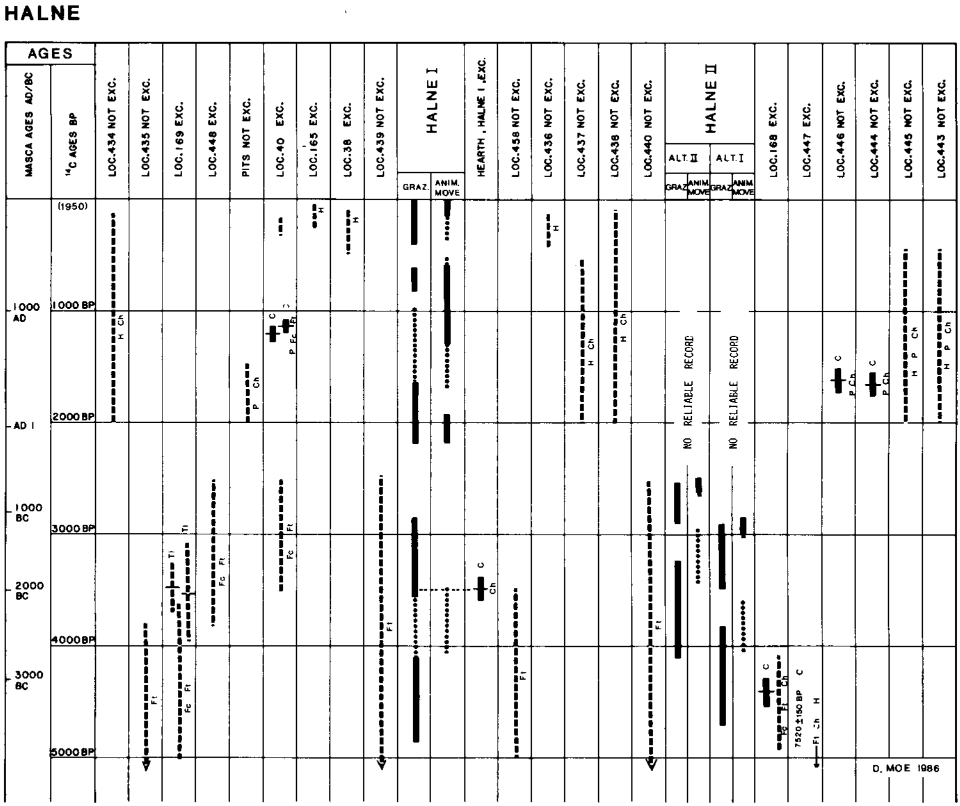


Fig. 6. Compilation diagram of known archaeological sites (with locality number) dated by typology, ^{14}C, and thermoluminescense, and estimated dated human and domestic animal influence on the vegetation in the Halne area. Archaeological sites : full line : ^{14}C-datings (C) ; broken line : typological & thermoluminescense datings (Tl). Other abbreviations : H-housegrounds, C-charcoal, p-pits, with charcoal, Ft-flakes & tools, Fc-firecracked rocks. Palynological sites (Halne I and Halne II) : Full line : local grazing : to a large extent ; animal movement : frequently, sum of pollen ⩾ 1/2 % of Artemisia, Plantago lanceolata, P. major, Centaurea cyanus *(cornflower). Dotted line : local grazing : to a small extent ; animal movement : occasionally, continuous occurrence of taxa mentioned less than 1/2 %. (From Moe* et al., *1988).*

There are still many new, exciting possibilities within pollen analysis, for example refined techniques combined in the field and laboratory for instance, accelerator ^{14}C-dating, more developed interpretation tools such as multivariate statistical methods, etc. However, the pollen analysis today already has great number of advantages alone or in joint work.

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