Pollen Analysis in Archaeogeology and Geoarchaeology

Abstract

Man as an ecological factor is an object of study of equal interest to archaeologists and palaeoenvironmentalists. Archaeology and palaeoenvironmental sciences increase our knowledge of interaction between nature and man and they act complementarily to each-other both directly and indirectly. This paper tries to outline the research strategy when the geological method pollen analysis is used to study this relationship. It may be applied to the problems as « service science » to archaeology and then as one of the many natural sciences used within and together with it. It may also work for itself as a geoarchaeological method, alongside with archaeological studies. Some practical points are made as to cooperational work between archaeologists and pollen analysts.

The concept « Cultural landscape » is discussed.

The importance of the study of marginal areas both for archaeology and archaeogeology is stressed. The importance of intensified research in the palaeoenvironmental problems in Society is stressed.

Introduction

Man as an ecological factor is an object of study of equal interest to archaeologists and palaeoenvironmentalists. Archaeology as well as palaeoenvironmental natural science increase our knowledge of the interaction between nature and man, and they act complementarily to each-other both directly and indirectly.

There is a long tradition in the Nordic countries of cooperation between archaeologists and scientists working with the natural sciences, geology and Quaternary palaeoecology in particular. This tradition dates back to the second half of the 19th century, when the combined investigations of the Danish kitchen middens were carried out. Archaeologists, biologists and geologists made joint efforts to describe the finds from the middens and to interprete them in terms which would be described as palaeoecological research today (Forchhammer and Steenstrup, 1848 ; Steenstrup, 1848, 1851*a*, 1851*b*, 1853, 1854, 1855 ; Worsaae, 1852, 1860).

The possibilities for successful contributions from geologists to archaeological research increased greatly when Lennart von Post presented his pollen analysis method in 1916, but the results were somewhat doubtful in the beginning (von Post, 1916). The pollen curves, and especially the marker levels in the pollen diagrams were dated with the aid of archaeological finds, both artefacts found in precisely defined stratigraphical positions in pollen analysed sequences, and with the aid of pollen analysis of remains of adhearing deposits on isolated finds known to come once from mire or lake deposits. These datings were later used for age determinations of other archaeological artefacts, and the sample possibilities of circuit evidences were frequently pointed out by critics (but in vain).

This situation was cleared up when the radiocarbon dating method was introduced, but it is surprising to note that the established ages of zone systems and marker levels proved to be remarkably correct nonetheless (Libby, 1952).

In the meantime the palaeoenvironmental considerations attracted increasingly greater interest, from archaeologists. Archaeology had hitherto been a branch of Art History, and especially the History of Style, to a large extent. It had developed in the direction of Palaeoecology quite early, but that branch of archaeology gained lesser interest from the public than the excavations of hoards or graves where finds of precious artefacts, gold and silver in particular, could be made. There was, in fact, no noticeable acceptance of the environmental archaeology till after the Second World War.

We have to make an effort to study the dynamics in the interaction between nature and man today in the light of the approaching, or already registered, environmental catastrophes. This has changed attitudes to archaeoenvironmental research both from public and from funds. It is desirable that combined studies should be carried out, and team research with broad competence is to be encouraged.

Archaeogeology and Geoarchaeology

I have tried to define two main lines of geological investigation types in the cooperation between geologists and archaeologists within the palaeoenvironmental research.

My definition of *archaeogeology* in this paper describes it as a complementary science to archaeology in excavations, the conservation of artefacts found there, or in the mapping of exploitation in the geoenvironment, the result of the human land use in the past. The geologist may serve as the describer of the deposits underlying embedding, or covering the archaeological material under excavation. He may be acting as the adviser as to which conservation methods should be used, or as producer of maps of the distribution of phosphate contents in the soil profile generated by human activities in the past. He may also make investigations in mire- or lake-deposits nearby. With the aid of pollen analysis the geologist may be describing the changes in the amount of land use, which has been occurring in the investigated area and its surroundings, and which would add information for the interpretation of the excavated materials.

Geoarchaeology, however, here means when the geologist alone tries to depict the cultural development of an area of different size, not being collaborating directly with archaeologists or other anthropologists and using geological materials and methods exclusively.

I consider pollen analysis to be the main method in both cases, supplemented however by other palaeoenvironmental investigations, sometimes including the use of archaeological studies. There are other investigation types too, which should be applied to geoarchaeologically defined problems.

Practically all environmental problems have historical aspects. These ought to be studied geoarchaeologically or palaeoecologically. Only then the consequences of immissions to the environment and the sometimes harmful influence of man to nature should be possible to forecast in planning processes.

Pollen analysis

Pollen analysis emerged quite logically as a further development of the methods of the palaeophysiognomic school, which (similarly to the palaeofloristic school) studied the history of plants and vegetation of northern Europe largely during the Holocene the last 10,000 years. Fruits, seeds, and other macro-remains, recovered from lake deposits or mire sequences, had proved to yield information merely on the internal development of the sampled site rather than of the surrounding areas. Pollen analysis uses a material which reflects the development of the vegetation of the surroundings instead. By introducing his pollen analysis method, Lennart von Post (Figs 1 and 2) finally demonstrated the insufficiency of the palaeofloristic method and pollen analysis became famous over night.

Pollen and spores

Pollen and spores resemble each other morphologically to a certain extent. They may both be recovered from peat-, gyttja- or soil-samples prepared for pollen analysis.


Fig. 1. Lennart von Post, the father of pollen analysis photographed during field work and at coffee table with his students (among them Gunnel Linnman).

Pollen grains form part of the « Male » reproduction apparatus of the phanerogams, the common plants. They represent a rather antiquated part of the plant, phylogenetically speaking, preserving many conservative details which may suggest relationship between plants or groups of plants. Evolution may have made these relationships less obvious in the plants' modern appearence.

Spores play quite another role in the reproduction system of the cryptogams, and they may be said to have a similar function as the phanerogam seeds have.

The pollen analysis method

Plants produce pollen for their reproduction. An eventual surplus is distributed to the surrounding environment and may become fossilized and preserved in soils, peats, lake sediments or other deposits. The wall of the pollen grain of most plant types is built of chemically very resistant compounds. Therefore the soil sample, peat or gyttja can be treated in the laboratory with very strong bases and acids to dissolve or facilitate the removal of all other parts of the sample. This procedure will leave the pollen grains concentrated as a residual available for pollen analysis.

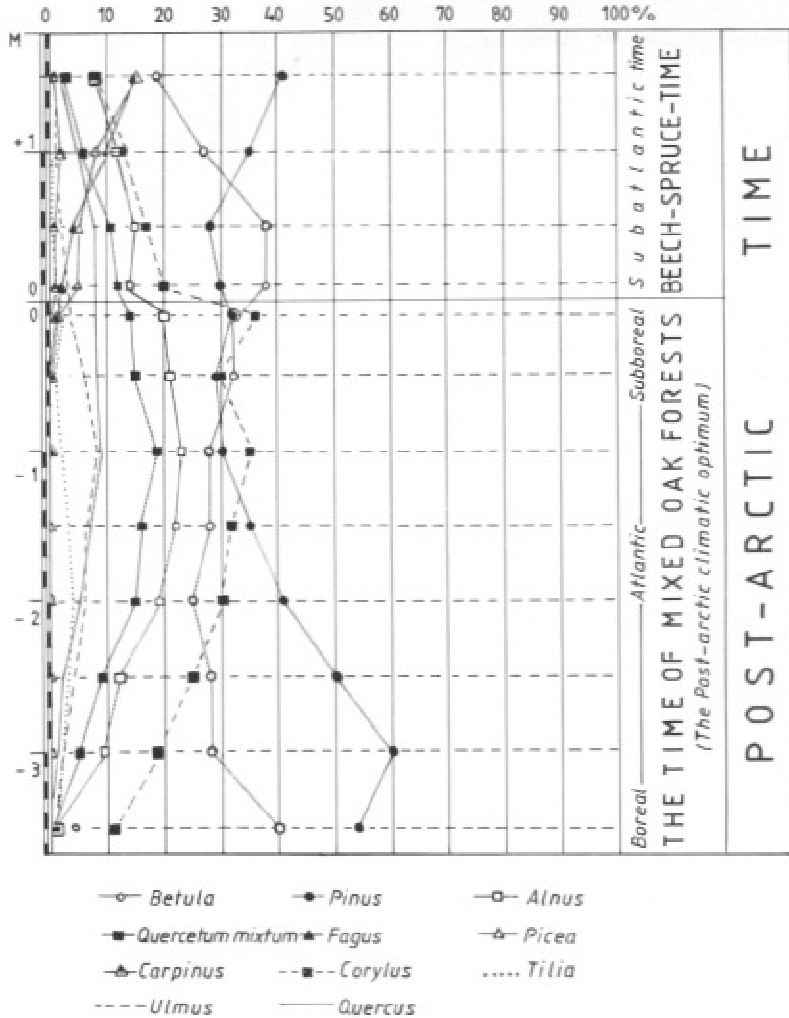

Fig. 2. The concluding pollen diagram from von Post's original paper. It describes the principles of the forest history for southern and central Sweden. It is redrawn for this publication, and von Post's sub-division terms have been translated (von Post, 1916).

Pollen grains show a great variation in shape, such as the form of the whole grain, the structure of the wall, or the sculpture of the surface (Fig. 3). These criteria have been used for describing them and for drawing up their systematics. This includes the construction of determination aids, so called pollen « keys » or pollen « tables », which enables the pollen analyst to relate specimens found to plant species, genus, family or other taxon (Table 1).

Table I. Example of a determination « key »

This concerns the plantain family and is of particular interest for the study of human impact (Faegri Iversen, 1975).

A. Pores with distinct annulus	
B. Pores operculate	
C. More than 8 pores ; grain distincly micro-echinate	*Plantago lanceolata*
CC. Less than 8 pores ; not distincly micro-echinate, though minute punctae may be seen in Ph	*P. coronopus*
BB. Pores rarely operculate, but with isolated granules. 5-9 pores. Distincly micro-echinate	*P. maritima* s.l. p.p. *P. alpina*
AA. Pores without distinct annulus, with granules, no operculum	
B. Grain normally more 30 µm. Pores numerous (> 8), sharply delimited	*Littorella uniflora*
BB. Grain less than 30 µm	
C. Pores sharply delimited, 5-9. Distincly micro-echinate	*Plantago maritima* s. str
CC. Pores not sharply delimited	
D. Punctae indistinct or invisible	*P. major*
DD. Punctae distinct (Ph)	
E. Verrucae rather indistinct or very small. Pores numerous (> 9)	*P. tenuiflora*
EE. Verrucae distinct	
F. Verrucae very coarse	*P. media*
FF. Verrucae less coarse	*P. montana* s.l. p.p.

A pollen analysis is the registration of all pollen grains present in a hazardously selected portion of a collected sample. It represents the *sedimentation* of pollen to the sampling spot during a certain time span. Once complete, such pollen analysis is often called a *pollen spectrum*.

The pollen in a spectrum is composed of several pollen assemblages of different provenance. One spectrum may derive from the immediate surroundings, one may represent some wider vicinity of the sampling spot, and one has been transported over longer distances to sediment. In an open landscape a larger portion of the tree pollen sedimentation comes from source assemblages further away. Locally produced pollen grains from weed communities in the surrounding landscape play a greater role proportionally compared to the tree pollen. In a forested area, then, the locally produced tree pollen dominates both within the tree pollen sum and over the weed pollen. Furthermore, the size of the sedimentation basin (lake, pond, bog, fen) is of interest as to the representativity of a sample. Pollen spectra, which are almost exclusively representative for the immediate surroundings, characterize samples from very small basins, while samples from wider basins represent wider areas (Fig. 4).

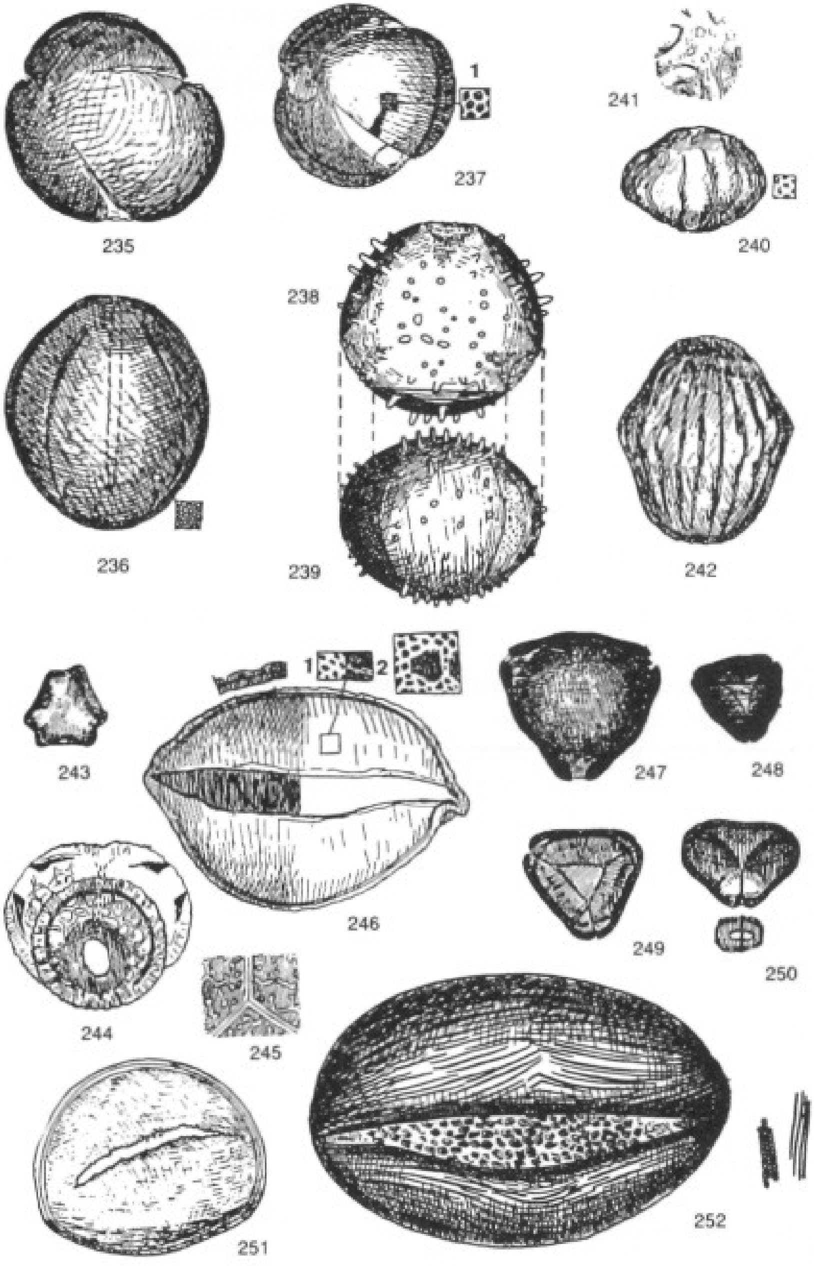

Fig. 3. One plate from Erdtman's « An introduction to pollen analysis *», which was printed in 1943 in the US. This rather early text book has played an important role for the distribution of the method. Even if von Post developed the method, Erdtman was one of the first to publish extensive pollen studies in a congress language (Erdtman, 1921). This gave him a prominent position in this science very early. This plate exemplifies the form variation and differences in surface patterns among pollen, which may be used as distinguishing criteria in the analysis work (Erdtman, 1943).*

The pollen productivity of a plant varies very much depending on the mode of transfer of pollen from anther to pistil. Some plant types transfer their pollen with the wind, and it is then necessary to produce an enormous amount of pollen if the desired number of pistils should intact be really reached by them. Most of the wind transfered pollen is never used in reproduction and gets lost to sediment on land or lake surfaces. Some plants have specialized their transfer of pollen, using for instance insects, birds, snails, water currents or gravity as transmitters. This means that fewer pollen need to be produced for the reproduction purposes and that, consequently, less surplus is released to the surroundings. The variation in pollen production causes problems for the pollen analyst when interpreting the source communities from pollen spectra. He will always have to take into the account the overrepresentation of the heavy producers within the plant communities.

Pollen of various sizes, different shapes and different surface sculptures may have differentiated possibilities in the air born transfer. The size varies from more than 1 mm (*i.e.* pollen from corn) to a few thousandths of 1 mm (*i.e.* the pollen from most orchid species). The dispersal of the larger and heavier grains in the air is normally only a question of some hundreds or some tens of metres or, in extreme cases, a couple of metres.

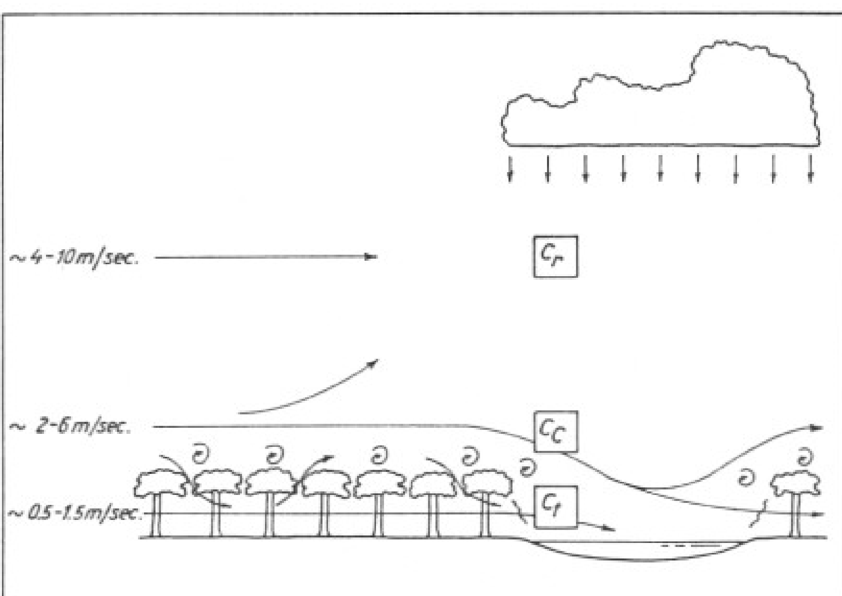

Fig. 4. Model of the pollen transfer to a basin and the sedimentation of pollen there. The role of the different assemblages, which constitute one pollen spectrum together, has to be evaluated in each case. The importance of each of them has to be judged against the others when an interpretation of a pollen diagram is carried out (from Tauber, 1969).

The reported selection of phenomena complicates the interpretation of pollen spectra into defined plant communities or landscapes. It shows that one pollen spectrum can never be translated directly into vegetational formations. For instance, the appearance of 90 % of pine pollen in a sample, does not mean that the vegetation necessarily contained 90 % of pine trees among the total number of trees in the surrounding landscape. It could just as well represent an open landscape with no pines at all and the amount of pine pollen was, then, once long distance transported to the sampling spot. The further translation of the occurrence of pine pollen into a role for the pines within the plant communities, or within the landscape, is dependent on the interpretation of the total amount of pollen in the analysis. It is also dependent on the consideration of production and dispersal potentials as well as geological and ecological coherences. It is also a matter of the skill of the palaeoecologist.

Pollen analysis may be used for many purposes. The classical one, which von Post aimed at from the beginning, was to describe the forest development for a specific area over a certain time span. Later, he became interested in its potential for palaeoclimatological studies and for studies of sea level changes. However, he mostly used tree pollen for this, and since we also know much more about herb pollen today than was known to von Post, we may also extend his goals further into the vegetational development as a whole. This also includes landscape development and one special branch of the landscape-historical studies concerns the various historical aspects of human impact upon the environment, first studied by Iversen in his classic work *Landnam i Danmarks stenalder* [The first land clearance by man during the Danish Stone Age] (Iversen, 1940).

Another classical topic is the use of pollen analysis as a dating method. The dating may concern shore line displacement, sedimentological events or cultural layers in excavations or archaeological artefacts under certain conditions.

Copropalynology is another field of interest, and it treats dung or dung pellets of animals or humans with a view to elucidating food and/or habitat selection. Latrines in medieval culture layers are suitable for such studies, supplemented by investigations of their macro-remains of fruits, seeds and the like. Investigations of stomach contents of dead animals and humans are closely related to copropalynology (e.g. Martina Sharrock, 1964 ; Markgraf, 1985 and Moe, 1983).

Pollen analysis has also been used for criminal investigation purposes (for instance the pollen contents of the clothes of assassinated victims in a search for the place of the crime). It is also used for control of honey to show the dominant plant selection which is the source of the honey, or to distinguish real honey from artificial. It is now increasingly used for in connection with allergies. Reports on pollen frequency in the atmosphere and the daily appearance of critical allergy promoting pollen types over the vegetational period are published in the daily papers or broadcast to people affected by or concerned about pollen allergies.

POLLEN ANALYSIS IN ARCHAEOGEOLOGY

Who should provide the pollen analysis ?

Lennart von Post was professor of geology at what is now the University of Stockholm. The pollen analysis method is basically a palaeontological (palaeobotanical) and palaeoecological method. It is naturally and necessarily combined with works on organic deposits, both autochtonous and allochtonous ones. A background in botany, sedimentology, palaeolimnology and soil sciences is essential to the pollen analyst.

In Sweden and in the Nordic countries the majority of the analysts work in the geological departments, but pollen analysis is carried out in many botany departments too. In the rest of Europe, pollen analysis occurs in geography and botany departments mostly, special departments of Quaternary geology (including Quaternary biology and ecology) not having developed so often as in the Nordic countries.

Botanists need to study geosciences extensively to become skilled pollen analysis workers. Geologists and geographers must study considerable amounts of botany and plant ecology for the same purpose. Archaeologists, osteologists and human geographers would have to learn both geosciences, botany and plant ecology.

There is a difference in training people for proper microscope work and training those who are to treat the materials scientifically with publication as the final result. According to our tradition since von Post's days and according to our current experience it is perfectly feasible to train microscopists to make very skilful pollen counts, without having much botanical background. To guide the work, however, an expert should be at hand all the time, and the support of an excellent reference collection of modern pollen materials is a necessity.

To use analysis results coming from a professional microscopist one must be very familiar with pollen analysis from ones own experience. One also has to know the limitations of the skill of the microscopist to be able to judge how the determinations are. Receiving them in list form limits their usefulness for the discussion of the palaeoecological problems.

It is of course possible to develop « pollen analysis sub-departments » within institutes of any scientific branch but it is, however, a fundamental requirement that one possesses good reference collections of most plants growing in an area or region to be worked in. Pollen keys alone are certainly not enough. It is not, furthermore, to be recommended to let a pollen analyst sit isolated and alone hidden in an institute of predominantly other scientific occupation. The continuous development of the skill in determination of pollen requires the presence of at least one co-worker for discussions on details in the analysis. The lone worker tends to believe in his own determinations rather than to be sure of them.

Recommendation : It is advisable to let the professional pollen analysis expert do the job for you rather than to try to do it yourself.

Who should collect the samples ?

A pollen analytical investigation in operation starts with the field work. Since the time required for modern pollen analysis is sometimes considerable (one single sample can in the extreme take several days to carry out), it is essential that the field work is done very carefully to avoid contamination and other sources of error.

It is very easy to contaminate samples, and only the one who is to perform the microscope work is fully aware of this, since he doesn't like to have done weeks or months of hard work in vain. It is, therefore, preferable when the analyst can collect the field material himself. Since this is not always possible, an alternative could be to train the archaeologist for the work. The following procedure is suggested in that case.

1. Any cooperative archaeological-pollen analytical study should be planned by the two investigators together.
2. If it is assumed that the archaeologist will be the field collector, a short training should be given and written instructions should be handed over, specially designed for each new project.
3. If any sort of confusion arises during field work, new contacts must be taken with the pollen analyst before the final collection of materials. It is often advisable to collect box cores, at least 10 × 10 centimetres in section, through the deposit of interest and from top to bottom. The box can be made very simply from thin sheet-iron by the archaeologist, himself. Each box should not be more than 50 cm in length, for practical handling reasons (Fig. 5).
4. It is always advisable to collect field materials very generously. This is especially true where archaeological excavations are concerned and where the sampled material will constitute the only material available after the surrounding parts of the stratigraphy have been removed. It is always better to collect thousands of samples too many during the field campaign,

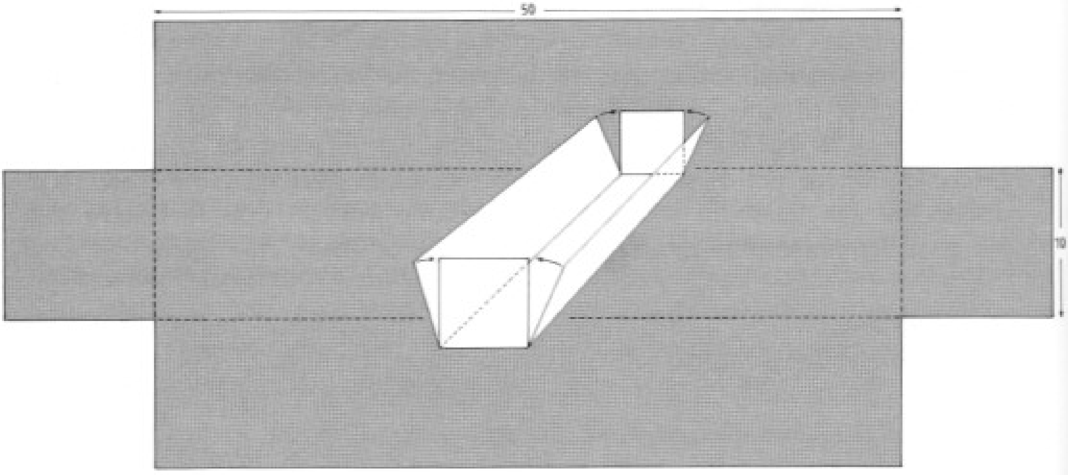

Fig. 5. A simple box-core may be made according to the sketch above. The box is to be pressed into the wall in the profile to be filled with material, and it is dug free thereafter. It is then to be wrapped up with several layers of plastic folie applied crosswise around the box and stored in a cool place. Its position in a profile should be marked. Do not forget to number it if it belongs to a series, and do not forget to note up and down of the core. Measures are in cm.

than to discover in the end of the laboratory investigation that you are short of one single sample, which could have been secured if you had considered the potential of your materials more unconditionally.

What materials are suitable for pollen analysis ?

One factor which may restrict the reliability of a pollen spectrum is the state of preservation of the pollen grains. The oxygen in the air or fungal or bacteriological attacks are the most serious threats to the pollen, and many environments of archaeological interest may show bad pollen preservation predominantly. Buried soils, settlement layers in terrestrial position often belong to this category as do grave sequences and substrata of graves.

Many pollen analytical textbooks give the advice that analysis on samples should be avoided if the state of preservation is bad. Even if the preservation is really bad, however, there may still be reasons for continuing with the work. This must be decided from case to case and will depend on what information the archaeologist hopes to receive from the investigation. It may, for instance, be possible to get a lot of important palaeoenvironmental informations from even very badly preserved settlement layers. It must be added that badly preserved pollen materials require much more work at the microscope, and the need for extractable information for the benefit of the investigation in combination with resources available must always guide the final decision whether the work should be carried out or not.

Not all settlement layers have, however, badly preserved pollen. It is not unusual that material recovered from medieval city layers, has been wonderfully preserved. This has, for instance, been the case with medieval material from the city of Uppsala, where the settlement was once founded on a riverside. Also in the case of soils, graves and other deposits of interest one may find reasonably well or well preserved pollen. This emphasizes that it would be a very good idea to perform test preparations and test analyses, the first thing you do, when new material is considered, in order to estimate the amount of work which has to be carried out at the microscope to solve or elucidate defined problems. After a pilot study, it will be possible to make up a budget for the palaeoecological part of the project, which gives you an opportunity to judge if you can afford to include it in your plans.

Summary : There are no or almost no samples, where pollen cannot be extracted. Some samples may be badly preserved and be very time consuming and thus expensive to develop. Other samples show extreme scarcity of pollen, and require specialized methods to recover sufficient and suitable materials. A pilot study should always be the first part of a combined investigation. The working hypothesis and the information extractable from the archaeological material will, then, be the foundation for a decision whether the geoarchaeological project is to be carried out or discontinued.

Calculating the costs of the pollen analysis part of a project

It happens rather often that an estimation of the costs for a pollen study to accompany an archaeological project is required. Such requirements are almost impossible to answer promptly and properly, at least not in the form of a definite sum for the complete work. The variations in materials of interest for analysis are so large that pilot studies are a necessary first step.

The likely costs for the whole project may be defined thereafter with more seriousness. The costs for a pilot study, however, can be defined promptly.

The archaeologist and the pollen analyst

It is certainly of mutual interest to both parties that no projects of « happy and blind planning » character are ever started.

The first thing to be clarified when collaboration is started is the thoroughly considered working hypothesis for the whole project. When the pollen analytical part of it is considered, a discussion must be initiated between the analyst and the archaeologist. It is important that the expectations of the archaeologist as to what information he needs from the pollen study or as to what information he thinks that it is possible to get from the pollen project are discussed. Considering the materials which can be expected to be made available for the study, the pollen analyst may then define what parts of the desired information he thinks can be provided under favourable conditions. It should also be clear what parts of the potential pollenanalytical sub-project can be looked upon as promising or less promising. Jointly they define the final project which should be built upon the following two important postulates :

1. What amount of work *at a minimum level* is required to get reasonable safe results according to the problems defined in the working hypothesis and on the basis of the information about the material quality gained from the pilot study ?
2. How much work is required for additional results ? What results ?

The final project definition should include which of these levels has been chosen, and the economic limits for it.

Pollen analysis in archaeogeology

The cultural landscape

The cultural landscape may be defined as the result of separate or successive transfers of resources from nature to man. The cultural landscape is, then, a sort of a monument over a quantity of labour that man has carried out in nature for his survival. It may also be described as the environmental answer to immissions or extractions of compounds made by man in nature, each of them disturbing the ecosystems. Not only agricultural impact, but all sorts of human activities will then be counteracted by nature within the range of the ecological reactions. The result will be the landscape aspect, which is dynamic, and which mirrors the functionalistic, and so living, relations between man and nature.

During the history of man each era has produced its specific cultural landscapes. Each of them depended on the amount of resources which could have been extracted from them. They were related to the contemporary technological levels both in rural and urban life. The landscape, however, changes constantly under the influence of resource removal. The landscape, which is no longer productive, will pass a number of regeneration stages, where the ecosystems try to adapt to natural conditions anew.

The cultural landscape is not seldom treated in a way that suggests that it is considered to be an almost homogeneous phenomenon : *the* Cultural Landscape. The diversity of the landscape is seldom acknowledged. This is true for palaeoenvironmental descriptions, and for conservational considerations too, at least generally.

A model of the real development of *the* Cultural Landscape would contain a number of contemporaneous sub-landscapes. Within the agricultural landscape types, for instance, there are fields and pastures of various kinds, areas exclusively used for hay production, cultivated « forest fields », and so on ; in the transport landscapes you would distinguish between airfields, electric power pole lines, roads or railways, harbours, each of them representing their own sub-landscapes ; the urban landscapes would show a number of types too, just to take modern examples.

What I have demonstrated here is a horizontal diversity of *The* Cultural Landscape. There is, however, a vertical diversity too, namely along the historical time axis, and there is a constant change of landscape types into new ones in succession. Many of the new ones take over the exact position of the older ones, while others may utilize environments that until then had not been used in the production processes (Figs. 6, 7 and 8).

As was pointed out above, it must be kept in mind, all the time, that *The* Cultural Landscape is our document over the result of the output from nature for the support of the contemporaneous society. A number of factors determine the details in the landscape design : size of output required, technological level of the utilizers, preferred products, administrative situation, religious codes, and so on. *The* Cultural Landscape is composed of numerous cultural landscapes and both *the* Cultural Landscape and the cultural (sub-)landscapes have a limited life span. They will be replaced by new types resulting from the impact of new methods, changes in output volumes, and so on. This transfer is a continuous process.

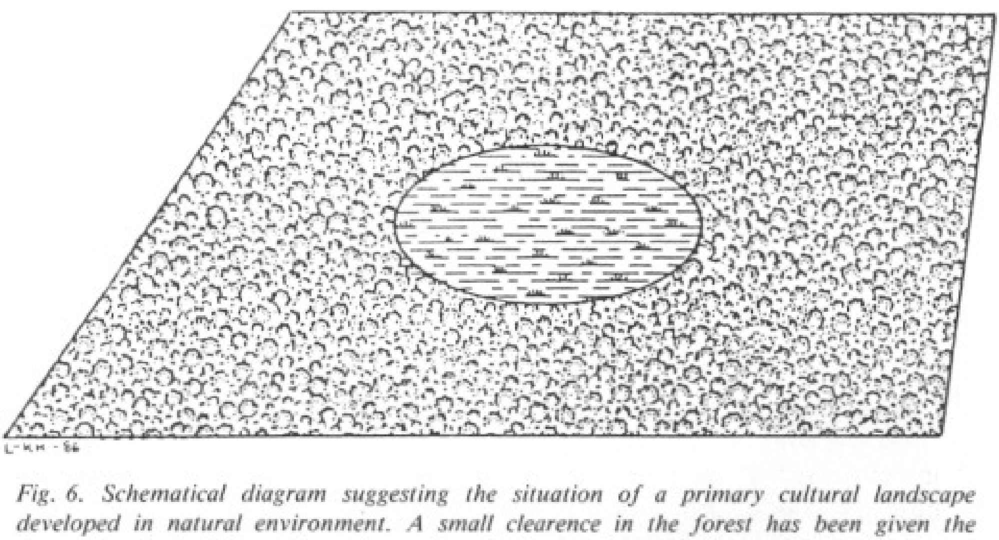

Fig. 6. Schematical diagram suggesting the situation of a primary cultural landscape developed in natural environment. A small clearence in the forest has been given the form of a circle. The settlement may have both agrarian and other activities (Königsson, 1984 and 1987).

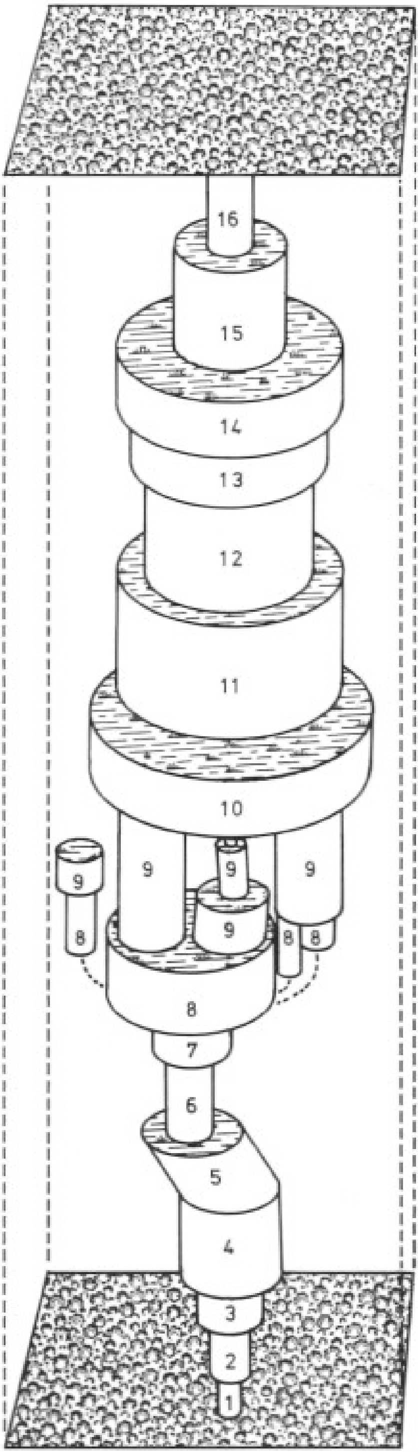

Fig. 7. The primary settlement in fig. 6 and its theoretical development over a certain time span till its final abandonment. Each step has been generalized or idealized so that changes in the treatment of the settlement area have been marked with alterations in the areal extension. The model describes an agrarian occupation of the area, but can well be used for non agrarian occupations (Königsson, 1984 and 1987).

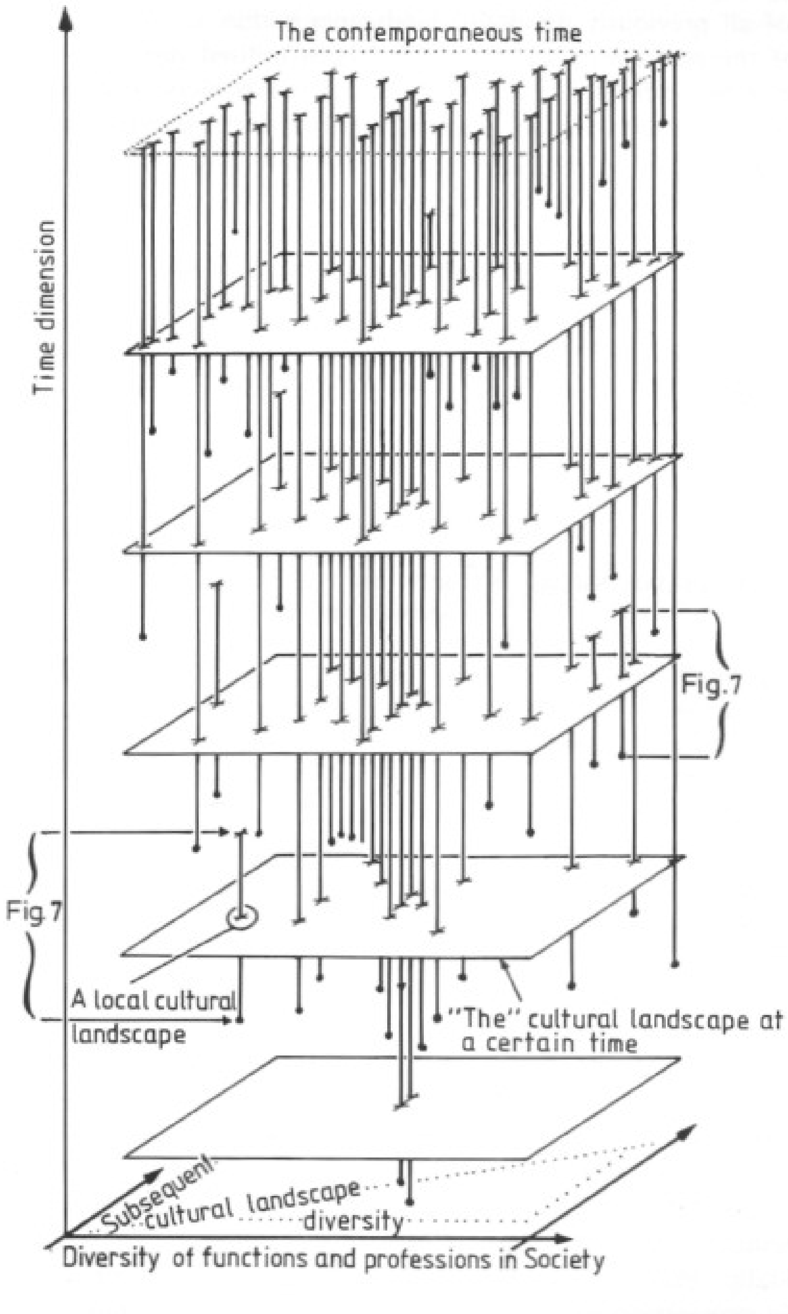

Fig. 8. Diagram showing the development of the cultural landscape and its composition of a number of subsequent sub-landscapes. The model in fig. 7 may be recognized in many situations in this diagram, such as the ones marked as non-persisting landscape examples.

However, most cultural landscapes in their aspects and even details do not only depend on the present day situation, but also on the accumulated effect of all previously developed landscapes within a narrow area. Selected parts of the resources of a region have been utilized through the conscious and successive efforts made by farmers, cattle holders, industry etc., and each new landscape has used additional parts of the original natural wealth.

In most cases small remnants or relicts of many of the past landscape types remain as exotic details in the otherwise functionalistic and dynamic contemporaneous stage. This stage is still to a surprisingly large extent determined by the initial stages, and both the abiotic and the biotic background factors have become influenced by them.

The ecological potential is, then, dependent on the entire development from its beginning in a completely natural environment. The ecological response of the landscape to new human impact or changed amount of impact can only be judged against its historical development — its environmental history.

THE GEOARCHAEOLOGICAL INTEREST IN THE DEVELOPMENT OF CULTURAL LANDSCAPES

Very small parts of our globe are untouched by human impact today. The test programs for nuclear weapons, catastrophes in nuclear power stations, burning of fossil carbons or hydrocarbons have transmitted waste to the atmosphere, which affects all living tissues and all soils in the world. However, the human influence upon the earth and its inhabitants is nothing new, it is only the amount which has reached harmful levels today.

The influence began when man started to manipulate nature to facilitate his food supply. This happened some ten thousand years ago, and it has been called the Neolithic Revolution. It was probably the most fateful moment in the history of the world, since it was the start of the development which leads to the present situation, when man can no longer control the effects of his manipulations, and therefore is a threat to life on earth as a whole.

While all this happens, however, much of the natural development of the globe continues. Sometimes it is only very difficult to distinguish between truly natural factors in the development, since the results of the so called cultural factors hide them or disguise them. It is, then, necessary to find methods, where they may be separated from each other and described individually. This is the only way to find out how the various factors in the dynamic ecosystems cooperate or counteract, and such knowledge is really indispensable for the judgement of coming consequences of the obviously inevitable continued technical development. This is the ultimate aim of the archaeogeology in my view.

It should perhaps be added that the information gained in investigations of the landscape since the Neolithic Revolution, has to be judged against the potential development of the natural landscape in its undisturbed state. It is only when this is done that the human impact can be identified. Thus, the results of studies of the vegetational development during the Pleistocene interglacial periods is the prerequisite for the investigations of the cultural landscapes and for the Holocene palaeoecology (Miller, 1986).

THE RESEARCH STRATEGY FOR POLLEN ANALYSIS IN GEOARCHAEOLOGY

Most of the investigations of the development history of cultural landscape types which are made with pollen analysis, concern what I would like to call « the average landscape reflection ». The diagram material used is then mostly worked out from sediment cores from lakes or comparatively large bogs of fen-lands, where quite extensive areas around the sampling sites are represented in the pollen sedimentation. The *landnam* phase is mostly recognizable in a first defined period of human impact. The changing land exploitation intensity is demonstrated as landscape development curves, where the more open aspects are interpreted as « increases » of the « amount of culture » itself. This is an expansion which is explained by more extensive areas being grazed, under plough, or else deforested. The overgrowth of a landscape is, then, described as the reverse, namely a deterioration of the culture. Alternative explanations and interpretations are, however, possible.

In addition to this, certain pollen types are shown, interpreted as specific indicators of cultural landscapes : pollen from plants grown for crops ; plants dependent on cleared areas for their existence ; plants, which are favoured by open and light-intensive conditions and which therefore increase in abundance under such circumstances (cf. Berglund and Jasiewiczowa, 1986).

General trends in the historical development of the cultural landscapes may be demonstrated on the basis of these results, and this has been done for many type regions in Sweden, for instance (e.g. Nilsson, 1948 ; Fries, 1951, 1958 ; Florin S., 1938, 1958 ; Florin M.-B., 1958 ; Berglund, 1966 ; Königsson, 1968 ; Påhlsson, 1977 ; Widgren, 1983 ; Göransson, 1977, 1986). A further increase in the number of investigations of this traditional type will, of course, add to our knowledge of the landscape history mainly in the form of extended and therefore more detailed and reliable base material for consideration of regionally valid developments. To isolate, for instance, climatic trends in the landscape development may be difficult in regional diagrams only, and we must look for supporting investigations for this. If we knew, namely, how the climate has changed, then it would be much easier to judge and evaluate the role of the other ecological factors.

Shore displacement investigations have traditionally been used for palaeoclimatologic investigations, and the assumption that the ocean levels are sensitive indicators of climatic changes is behind this (cooler world climates mean glacier and ice cap growth and so lower ocean levels, warmer the opposite). There are, however, some doubts about the usefulness of such investigations today, since satellite measurements have shown a complicated pattern of the geoid gravity fields, demonstrating that the ocean levels are not at all so « equally levelled » as has been thought before. There is also new knowledge of tectonics, which has also complicated the situation. Still knowing this, shore displacement studies must go on, and they are important instruments for palaeoclimatic investigations.

Studies of the development of ancient lake levels and the changes in the river courses are also important tools for palaeoclimatology, but also the environments where such studies can be carried out have been influenced by the activity of Neolithic man and his descendants. Much of the sediment sequence information is as obscure as the information in the landscape development diagrams. Both agriculture and pasture produce increased sediment growth in lake basins, changes in river courses and river profiles, but that does not mean that studies of such objects should be abandoned, on the contrary. I could continue to list investigation types where the natural development has been disguised by the consequences of human interference in the landscape.

It is probable that the future archaeogeological investigations of cultural landscape history will have to approach the problems differently from what has been described above. The regional investigation types will have to continue, but they must be supplemented by other information types too in order to be interpreted with the human factors and the other palaeoecological factors separated from each other.

Detailed information of the history of the land use in restricted landscape sectors will be demanded by physical planners, archaeologists, and human geographers. Information on ancient societies and details of their land treatment, household economy, administrative organization, etc., will be requested. It will not only be of interest to follow the transfer of virgin lands in the *landnam* procedures into the primitive slash-burn cultivation and successive pasture, but also to describe the palaeoecology of the repeated change in treatment of the same field. It is important to follow its development into alternative cultural sub-landscapes: permanent ploughlands and pastures, forest meadows, overgrowth periods, cottage grounds industrial sites, air fields, etc. It will also be of interest to describe the palaeoecological consequences of the diversified development of, and changes within, the environments of small farmlands *contra* large estates, isolated farms *contra* villages. To study the establishment and abandonment of settlements, seasonal units such as shieling sites or saamic camps *contra* permanent settlements in the same regions etc., would be of value. It will be important to study industrial sites, particularly ancient mining or processing furnace environments, the establishment of new recreation centres, the ancient *contra* modern forestry in areas with good documentation of methods and techniques practised. The list may be extended considerably (cf. Königsson, 1986).

The advantage of marginal localities

Marginal zones and marginal sites are interesting objects for studies, when separation of natural factors from human is aimed at.

Marginal zones were also attractive for ancient man since the geographical situation between or close to two or more nature types offers a larger abundance of both species and individuals than is available in uniform environments. Climatic changes will get more prompt responses in the border zones, and they will tend to shift positions, one advancing into the area previously occupied by the other. Man and his settlements will have to move along with the zone shifts if he is to continue his way of living, or he has to change methods to meet the needs for food if he wants to stay where he was living. In both cases this will be possible to follow in the pollen analytic geoarchaeological studies (cf. Königsson, 1986).

The importance of studying the marginal sites has long been quite clear to archaeologists working with hunting-fishing-gathering societies. The impression is, however, that the archaeology of later periods has been less concerned about this important fact.

ARCHAEOLOGISTS, ARCHAEOGEOLOGISTS AND GEOARCHAEOLOGISTS

It is clear that the archaeologists and the palaeoenvironmentalists have joint interests. It is, thus, logical and natural that close cooperation takes place. It is, then, important that they learn to use a language which is comprehensible for both groups. Consequently, training in archaeology should be as natural to the geologists with palaeoenvironmental interests as training in basic Quaternary geology should be for all archaeologists. To realise this means that results of joint projects, or projects of joint interest, must be made available to both groups. This can be achieved in many ways: joint societies or clubs, joint publication series, joint courses in the education centres.

A series of such courses has been held in the Nordic countries, organised by the Nordic Collegium of Ecology. (The Collegium is organised and financed by the Nordic Council of Governments). Marginal regions have been especially used for these courses, such as the Great Alvar plain of the island of Öland in the Baltic (Königsson, 1968; Enckell, Königsson and Königsson, 1979), or the mountainous area on both sides of the Norwegian-Swedish frontier in the Norwegian province Sör-Tröndelag and the Swedish province Härjedalen (Königsson, 1986).

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Lars-König Königsson
Department of Quaternary Geology
Box 555
S-751 22 UPPSALA, Sweden

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