7. An Introduction to Palynology and the Vegetational History of Peatlands

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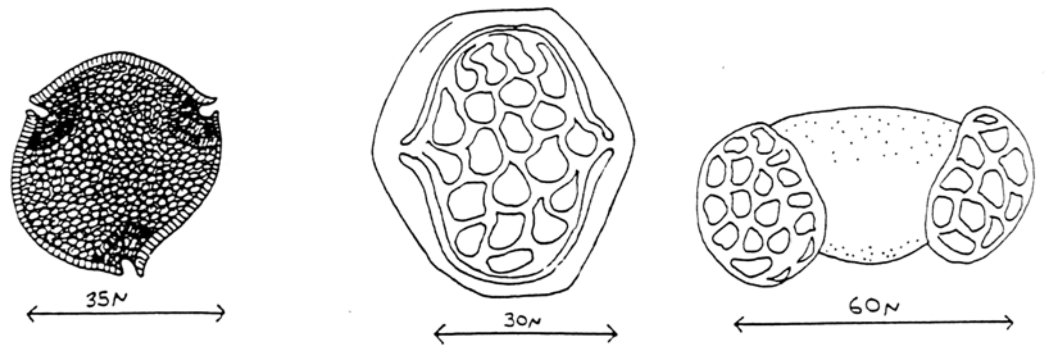
Introduction

Palynology is the study of fossil pollen grains and spores. It can be utilised for a number of purposes including the dating of sediments, reconstructing palaeoclimates, elucidating plant colonisation history and the development of plant communities, illustrating the influence of early man on his environment and, more recently, as a criminological technique. One area in which palynology has been particularly valuable is in reconstructing the environment at, or near, the onset of peat growth and the subsequent spread of peat over large areas of the British Isles during the last 8000 years. This paper aims to illustrate the basic principles of palynology and to describe peat bog development.

Basic Principles

Pollen grains and spores are microscopic particles (10-70 microns in diameter), produced in large quantities by flowering plants and cryptogams, and dispersed over large distances by the wind, water or insects. The outside wall of pollen grains is made of sporopollenin, a complex organic substance which is highly resistant to decay. An anoxic sediment (eg. waterlogged peat, lake sediments, soils) with minimal microbial activity will preserve the outer coating of each grain and prevent it from decomposing. Fossil spores and pollen can therefore be collected and different taxa identified using a number of criteria including grain morphology, size, and surface patterns such as the number of furrows and pores they have (Fig. 1)



Lime (Tilia)	Ivy (Hedera helix)	Pine (Pinus)
Three pores	Three furrows	Two air sacs
Thickened outer coating	Three pores	No pores
Pitted pattern	Reticulate pattern	

Figure 1 Examples of pollen grains and their characteristics

As the sediment and plant debris in a peat bog or lake accumulates over time, the sediments incorporate the pollen produced by the contemporaneous vegetation. The sediments at the base of the peat bog are the oldest and will therefore contain the pollen from the earliest vegetation. Similarly, the youngest sediment and the most recent pollen will be at the top of the sequence. By extracting a sediment core and identifying the pollen from the peat layers, we can study vegetation change through time. The main assumption is that the abundance of fossil pollen grains is a true reflection of the pollen producing vegetation at any particular time. If there is enough organic material, the sediments can also be dated using radiocarbon dating, so the results will indicate when major environmental changes (eg. the introduction of a new species or extensive deforestation) occurred at one particular locality. Data from a number of sites can be integrated to reconstruct the regional vegetation.

Methods and Analysis

Sediment cores can be collected using a variety of instruments, each designed for a specific type of environment. Peat bogs are usually sampled using a "Russian" corer, which contains a chamber that collects sediment from a specified depth. A whole series of cores is taken from the surface of the peat bog through to the bedrock or gravel at the base. The cores are extruded from the corer in the field, wrapped in plastic and aluminium foil, labelled and then transported to the laboratory. The core material is stored at 4° C. to prevent it from drying out and to stop mould from growing; the latter may contaminate and affect any radiocarbon dates obtained later.

In the laboratory the cores are carefully described and a core log is prepared. Samples from the core can be prepared for X-ray treatment, dating, chemical and physical analysis, macro-fossil analysis and palynology. For palynological work, small sediment samples are extracted from the core at regularly spaced intervals and then processed using a series of acids and sieves to remove unwanted organics and mineral material. The pollen grains and spores are concentrated into a residue that is then studied under a microscope. The grains are counted and identified using a magnification of around X400, although for critical grains, oil immersion and a magnification of XI000 is sometimes utilised. The total number of grains (the pollen sum) counted from each sample depends on the specific aim of the work, but usually ranges from 500 - 2000 grains per slide. Grains are identified by comparison with modern reference material, pollen identification keys and photographs.

For each prepared sample the relative abundance of each preserved pollen type is recorded. The final data are plotted by computer in graphic form making it easier to identify changes in both pollen types and frequencies throughout the core. The vertical axis plots depth down the core, and is roughly equivalent to a time-axis as the oldest sediments are conventionally placed at the base of the graph (Fig. 2). Any radiocarbon dates available are also shown on this axis. Along the horizontal axis the different taxa are plotted as a percentage of the pollen sum (Fig. 2).

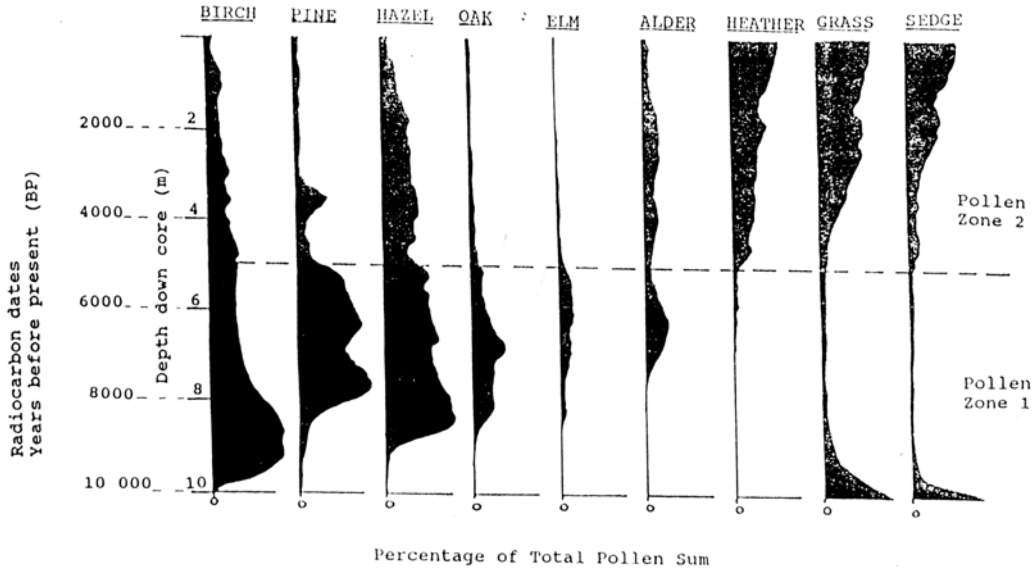


Figure 2. A generalised pollen diagram of selected taxa showing the main vegetational changes over the last 10 000 years. Pollen zone 1 shows a period of forestation after the Loch Lomond Stadial. Birch was one of the first trees to become established but this was quickly folllowed by pine, hazel, oak, elm and alder. By 5000 years BP a mixed temperate forest was established in all lowlying areas. Pollen zone 2 begins at 5000 years BP. The pollen frequencies for the tree taxa are reduced, marking the beginning of permanent deforestation. Increases in heather, grass and sedge pollen indicate the rapid spread of heathland and blanket peat.

Pollen diagrams are often divided into sections, where each “zone” is characterised by a particular set of pollen types or “assemblage”. The pollen zones are to simplify descriptions and aid comparison with pollen diagrams from other sites. Changes in pollen type and abundance in the core can then be interpreted as a reflection of changing vegetational communities.

To interpret the final pollen diagram in terms of plant assemblages, it is necessary to look at modern vegetation for analogies. Statistical methods can be used to compare modern pollen profiles from a variety of environments with fossil pollen diagrams so that the similarities can be measured numerically. The fossil pollen record may also contain individual species which at present have a limited geographic distribution controlled by factors such as soil type or climate. These ‘indicator’ species are important because it is then possible to be more specific about the palaeoenvironment.

Palynology is therefore a useful technique for biologists interested in charting vegetational assemblages, archaeologists wanting to reconstruct the environment, climatologists interested in past climates and also geologists who use it as a method of correlation or for studying plant evolution. With increasing concern about our changing climate and threats to the environment, there has been renewed interest in palynology and it is increasingly used as part of international and interdisciplinary studies to help us chart climate and environmental change.

Peat Bog Formation

Peat bogs are an important feature of our landscape for a number of reasons. They support a wide variety of relatively rare plants, birds and insects, and are also important in the carbon-dioxide cycle, absorbing large volumes of carbon-dioxide from the atmosphere. The growth of these areas of wilderness can be reconstructed by studying the peat layers, plant macrofossils and the pollen record. Peat is an accumulation of plant materials (rootlets, stems, flowers, seeds, pollen, wood) which are only partially decomposed and occurs in areas where plant debris accumulation is greater than vegetation decomposition. These areas are often waterlogged and anaerobic habitats with a deep layer of waterlogged peat supporting a surface layer of living vegetation. There are two distinct types of peat bog which are distinguished by their formation, morphology, water supply and plant life.

1) Fens and Raised Peat Bogs

These are raised peat deposits which have developed naturally, in lowland waterlogged hollows, since the last ice age. The Loch Lomond Stadial was the last major cold period in the British Isles, ending around 10,000 years ago when in Scotland the glacial ice melted leaving hummocky moraines and shallow lakes. Some of the lakes were initially fed by streams which drained the unstable, mineral-rich soils. Pioneering vegetation (birch, willow, herbaceous taxa) fringed lake edges, fen vegetation developed in the waterlogged habitats and floating aquatic communities occupied the shallow water. As this vegetation died, the remains formed a thin layer of peat on the lake bottom which provided an organic substrate for other plants to colonise. Gradually the peat layer thickened and as the water shallowed the fen vegetation spread outwards into the lake. Peat accumulation continued and eventually the substrate was raised above the water table.

With the peat raised above the water table, the only water supply is now rainwater which is poor in nutrients resulting in oligotrophic conditions. Acid-tolerant species invade and a raised bog is formed composed of a living plant community rooted in partially decomposed, waterlogged peat material. Sphagnum moss is often abundant on a raised peat bog, and acts as a sponge, drawing water upwards to the bog surface to create the characteristic domed appearance of a raised bog (Fig. 3a)

2) Blanket Bogs

Blanket bogs are usually associated with upland areas and form where there is poor drainage associated with high rainfall and low evaporation rates. Poor drainage may result from clay-rich soils or the formation of an “iron-pan”. In areas of high rainfall, exposed soils are susceptible to leaching and elements are flushed from the upper horizons of the soil profile. These elements then re-precipitate further down the soil profile to form an impervious ("iron-pan") layer which prevents further drainage and thus results in continued waterlogging. Some of the vegetation then dies and accumulates as peat because decomposition rates are slowed by lack of oxygen and minimal microbial activity (Fig. 3b). Peat growth is therefore not controlled by the distribution of topographic hollows and many blanket peatlands have developed over what was previously thick woodland.

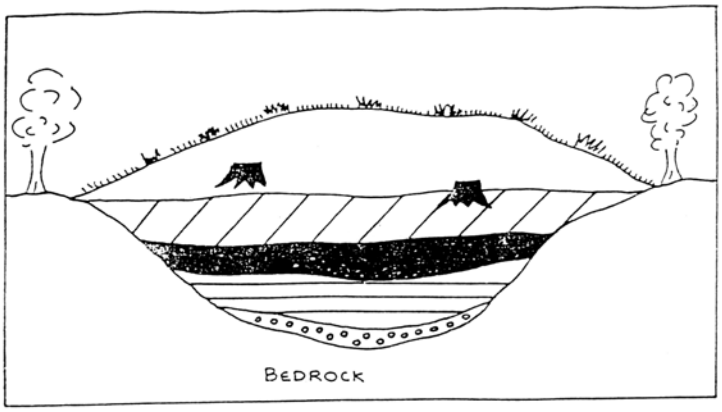


Figure 3a. A generalised section through a raised peat bog. The bog is constrained by the topography and the only water source is rainfall. The fossil tree stumps indicate periods of drier weather when the bog surface dried out and pine was able to invade. Peat bog growth then resumed when wetter weather returned.

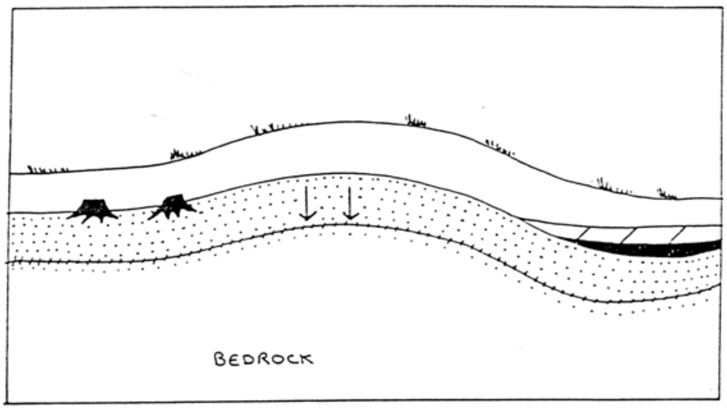
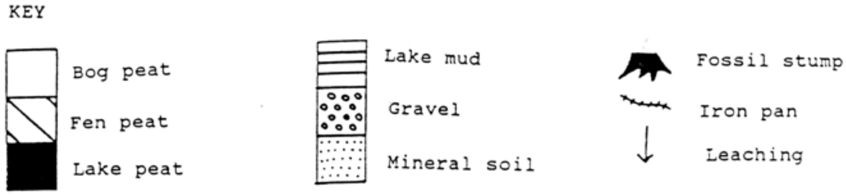


Figure 3b. A generalised section through a blanket peat bog. The peat covers the landscape and develops in areas of high rainfall and poor drainage. The formation of an iron pan results in waterlogging and encourages the process of peat formation.



Peat bogs are sensitive to climatic change and variations in the water table. A reduction in precipitation may cause the bog to dry out and trees (eg. birch, pine) can colonise the bog surface. If precipitation rates increase again, the trees are killed by waterlogging and are replaced by characteristic bog vegetation. Preserved tree roots can often be seen in peat bogs and "reactivation surfaces" can be identified in the peat stratigraphy (Fig. 3).

Pollen diagrams are extremely variable from site to site reflecting local changes in altitude, topography, soils, geology and microclimate. Despite this a broad picture of vegetation change and peatland initiation across Scotland can be inferred, as summarised below.

After the ice of the Loch Lomond Stadial had melted much of the Scottish Highlands formed an open barren landscape with raw mineral soils which underwent high erosion rates. The substrate was initially colonised by mosses, lichens and herbaceous taxa but as the climate improved there was a gradual transition from grasslands to scrub and then finally to a tree-dominated landscape. Juniper, birch and willow were the pioneering trees but hazel quickly spread from the west coast and by 8500 years before present (BP) was established throughout Scotland (Fig. 2). Elm and oak arrived in southern Scotland by 8000 years BP and slowly spread northwards. Pine has an unknown origin but was established in the north-west by 8000 years BP and had spread to high altitudes and on to acidic soils in the far north-west by 5000 years ago. Alder was one of the last taxa to become established in Scotland but was successful in water-logged habitats and replaced much of the pine forest. By 5000 years BP much of Scotland was therefore forested. Sheltered lowland areas had open oak-elm-birch forest but mixed deciduous-coniferous woodland dominated in the upland areas. Pine was common on upland plateau areas such as Rannoch Moor. On the west coast, on the highest mountain tops and in the far north-east, vegetation was restricted by exposure to the south-westerly winds and the colder temperatures. The fens and raised peat bogs of Scotland were well established by this time.

Decline of Forests and Spread of Peat Blanket

The decline of Scottish woodlands began after around 5000 years BP and there was the spread of blanket peat over much of the Highlands (Fig. 2). It is not exactly clear if the spread of peat actually caused the death of the woodlands or if peat cover extended as a result of the woodland demise. At many sites in Scotland the pollen diagrams show a decline in the Pine population followed by the spread of the peat. At exposed sites in the Highlands today it is possible to see 'fossil' stumps from these original pine forests at the base of the peat profiles. A number of reasons for this drastic and complex change in vegetation have been forwarded and include:

1) A natural degradation of pine populations due to soil acidification;
2) A change in climate which either prevented the regeneration of Pine or which increased precipitation rates resulting in waterlogging;

3) Neolithic interference with the forest ecosystem resulting in increased soil erosion and waterlogging.

When the forest died and soil waterlogging increased the conditions were then suitable for the formation of blanket peat.

There is evidence that blanket peat was already forming at exposed sites from 8500 years ago but it was not until around 5000 years BP that there was such a drastic and widespread vegetation change. For this to occur, many authors have invoked climatic change as the main cause of blanket peat initiation. However at some sites there is clear evidence that humans influenced the local vegetation and may have caused the deforestation which resulted in peat initiation. At each site the pollen data record local events, including an increase in precipitation rates, the breakdown of soils and increased and permanent damage to the forests from increased burning, felling and grazing. With the coincidence of so many changes over such a short time it is difficult to pinpoint the exact cause of peat initiation. At upland sites in the north-west of Scotland it is possible that climate was the primary cause of the vegetation change but at other sites it would appear that a combination of factors were involved; climate changes resulted in woodland degradation followed by the spread of moorland and bog, a situation further accelerated by human activity.

As yet there is no definitive answer as to the cause of the spread of blanket peat in Scotland. It would appear that each site is specific and the cause may have varied locally, with a number of factors operating together; early man may have accelerated a situation that had already been initiated due to a change in climate. Whatever the cause of such widespread deforestation and environmental disaster it has left us with the barren and wild landscape that is so characteristic of the Scottish Highlands and which we fight so hard to protect.

Further Reading

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