3.2.2 Pollen diagrams and ancient climates

The usefulness of fossil pollen to the scientist is that the types and proportions of pollen in a sample, such as Figure 3.10, can be compared with those produced by vegetation growing in present-day climates. The climate at the time the sample was formed can then be inferred. This brings us back to the main thread of this section, which is the pattern of temperature change on the Earth through time.

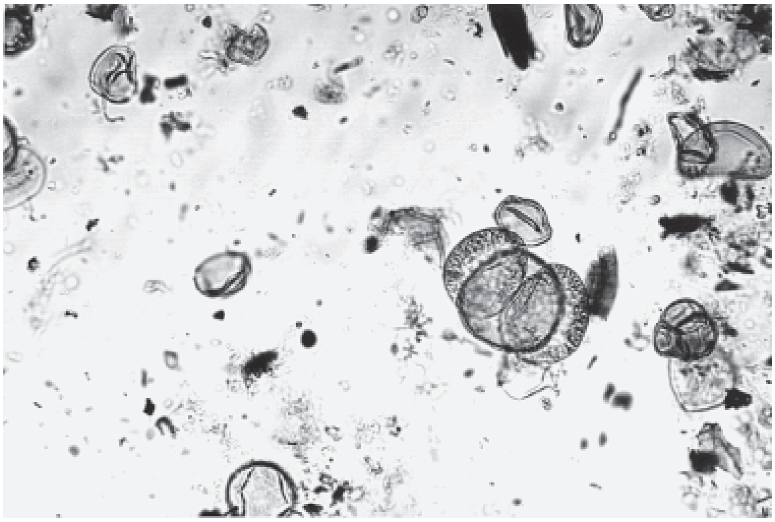

Figure 3.10 Pollen grains that have been carefully separated and extracted from a sample of clay from Marks Tey, near Colchester, Essex, seen magnified by a microscope.

By collecting a series of pollen samples of different ages from a given area or site, and inferring the climate that produced each sample, we can arrive at a picture of how climate (or just temperature) changed over time. Samples of different ages are obtained by taking samples from different depths below the surface of a peat bog or lake bed. In the case of the peat bog, successive layers of organic matter grow and decay on the surface, progressively burying older peat. Likewise on the lake bed, the most recently deposited silt covers previously deposited layers of silt. So, by boring down into the deposits it is possible to extract a column, or core, of material, which will be a layer-by-layer record of sedimentation and pollen accumulation over time (Figure 3.11). The deeper the sample in the core the older it will be. The age of a sample, in years, is worked out using specialist techniques such as radiocarbon dating (borrowing a method used by archaeologists to date ancient wooden and cloth artefacts), but it is the results rather than the dating techniques that are of interest here.

Samples of a few cubic centimetres are extracted from the core at accurately measured distances from the end that had been at the Earth's surface. Each sample is then carefully treated to liberate the pollen grains. The pollen from each sample is examined under a powerful microscope, and every grain of pollen is identified and counted. Several hundred grains are identified and counted in each sample and the proportions of the different types calculated. The rewards of such a painstaking gathering of facts are the insights obtained into past vegetation and climate.

Evidence of changing climate is indicated by changes in the proportions of different pollen types as we progress upwards through a core. It is easiest to make sense of the results by using a diagram, rather than a table containing a long list of the numbers, representing the percentages of different types of pollen grain at different depths in

(a) (b)

Figure 3.11 (a) Scientists obtaining a core of sediment from the bed of Lake Igelsjoen, Sweden. (b) Part of the extracted core showing alternating dark and light layers of silt that were deposited 5 000 years ago. The scale is marked in centimetres.

the core. An example is Figure 3.12, which shows how the amount of birch pollen (expressed as a percentage of the total tree pollen present) varies with the depth in a core taken in the bed of a lake at Hockham Mere in Norfolk; the scale on the left-hand edge of the diagram gives the depth. Figure 3.12 may at first seem hard to interpret, but it is basically just another graph, so you need to look carefully at the scales and the axis labels. This graph may look odd because the vertical scale of depth increases as you go down the page, whereas graph scales usually increase upwards. Also, you may be used to the horizontal axis being longer than the vertical, not the other way around as here. However, the way the axes are arranged should help you to picture the core as a long stack of samples extracted from the ground. In this case, the vertical scale shows that the core goes to a depth of a little over 8 m. From other evidence, we know that the deepest layers were deposited some 10 000 years ago. Shallower layers are progressively younger towards the top. The percentage of birch pollen present at any depth is read from the horizontal scale, and the variation in the percentage is emphasized by the convention of using shading.

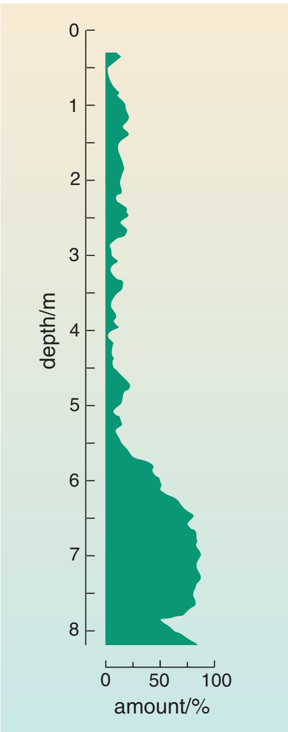

Figure 3.12 A diagram showing how the amount of birch pollen (as a percentage of the total tree pollen present) in samples from a core taken at Hockham Mere varies with depth.

At Hockham Mere, pollen grains are also found from Scots pine, elm, oak, lime and alder trees. The percentages for these can be plotted in the same way as in Figure 3.12. Doing this and setting the results out side by side gives Figure 3.13. A plot, such as this one, showing the proportions of different pollen types through a vertical sequence of samples, is called a **pollen diagram**. The diagram for tree pollen from Hockham Mere (Figure 3.13) shows some striking changes in the proportions of pollen types and hence in the proportions of different trees growing near the site over the past 10 000 years or so.

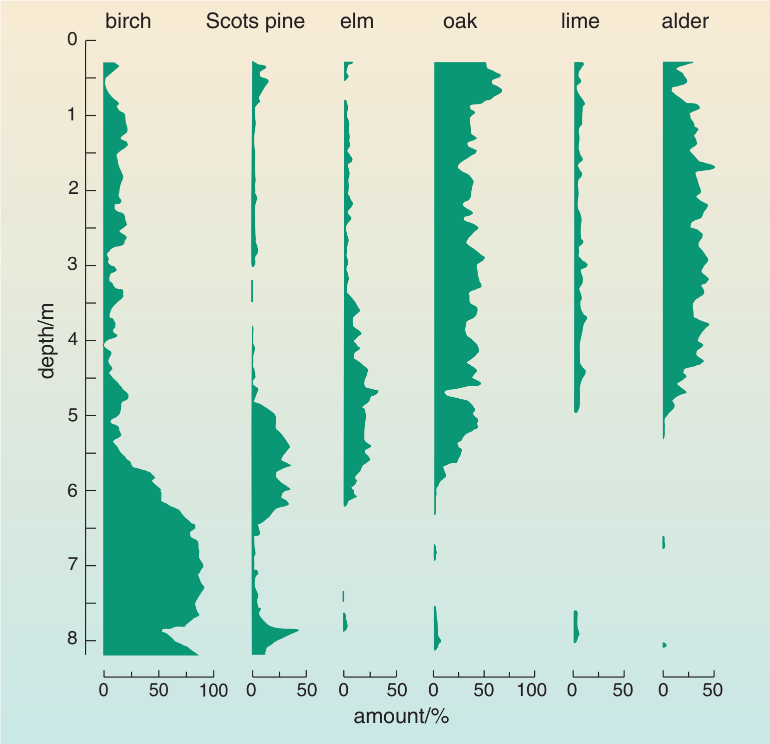

Figure 3.13 A tree pollen diagram from Hockham Mere.

- As the percentage of birch pollen declines, what increases?

- Scots pine, elm and oak pollen all become more abundant in the depth interval between 6.5 to 5 m (Figure 3.13).

So, the pollen diagram shows birch giving way to Scots pine, elm and oak, with lime and alder making an appearance at about 5 m depth. We also see Scots pine declining in abundance at around 5 m, and elm declining at around 3.5 m. To think about what these observations mean, and whether they are related to temperature, answer the following question.

- From your general knowledge, which of the following factors can influence the types of tree that can grow in a given area: temperature; rainfall; the amount of human pollution in the atmosphere (e.g. resulting in acid rain); other activities of human civilization; altitude (i.e. the height of the area above sea-level)?

- *All* of the listed factors can, to some extent, influence what types of tree (if any) can grow.

For example, the relatively cold, wet climate of mountainous northwest Scotland sustains birch and Scots pine forest — or did until much of the land was cleared for grazing sheep — whereas the natural woodland of comparatively warm, dry lowland southeast England sustains oak and beech. Acid rain may kill trees, although some types are more susceptible to pollution than others. Conifers, for instance, are often more damaged by air pollutants than deciduous trees because the needles of conifers, which are retained all year round, act as efficient air filters, trapping pollutants within the plant.

Let's now consider which of the five factors could have changed during the 10 000 year period in order to bring about the changes indicated by the pollen diagram in Figure 3.13.

A significant change in the altitude of Hockham Mere is unlikely over this time-scale, and anyway there is no evidence that this took place, so we can dismiss this possibility. Pollution such as acid rain is a phenomenon that became important only in the 20th century, so this cannot explain the much older changes in vegetation observed in Figure 3.13. Archaeological evidence for the spread of Neolithic farming activities and forest clearance coincides with the time level at which elm declines in importance (about 3.5 m depth), but there is no evidence for ancient Britons removing or introducing particular types of tree *before* then. We must conclude that these earlier changes in vegetation were caused by changes in the climate. By comparing the climatic conditions under which woodlands of different compositions grow at present, it has been found that the changing composition of woodland in the vicinity of Hockham Mere indicates a warming over time. As the temperature increased, Scots pine, elm, oak, lime and alder became established. The different rates at which these trees appeared, and the decline of birch and Scots pine, reflect additional biological factors related to the processes of plant migration and competition, but the main stimulus for change was a change in climate.

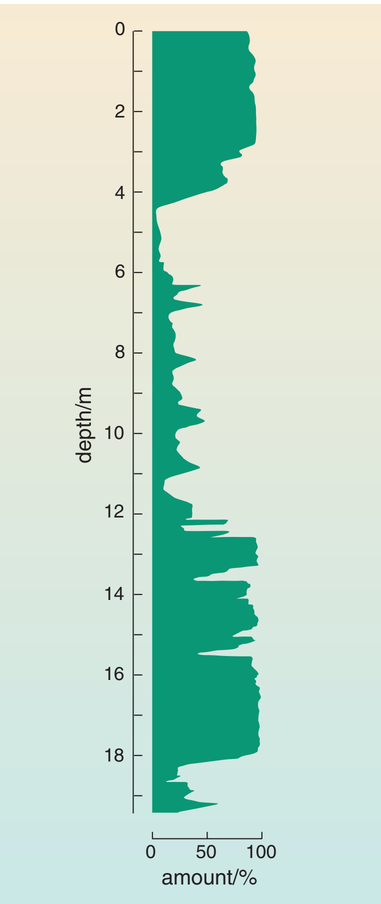

Figure 3.14 A pollen diagram for Grande Pile, France, showing the percentage of tree pollen.

Extending this approach to look at even longer pollen records of temperature variation simply requires cores that penetrate into older layers. The most remarkable such core, providing a record over the past 140 000 years, is from Grande Pile in the Vosges region of eastern France. Figure 3.14 is a pollen diagram for this core, simplified to show only the total percentage of tree pollen present; pollen grains from other plants make up the remainder of each sample.

The interpretation of pollen records to reveal insights into prehistoric climates is a scientific triumph. But so far in this section we have been taking only a qualitative approach; in other words, we have been avoiding putting numbers on temperatures. We have also been rather cavalier in assuming (rather than confirming) that climate plays an important role in determining which plants can grow in any given area. This seems a reasonable assumption based on general knowledge, and indeed a careful assessment does reveal that climate really is important. In particular, the climatic variables that influence plant growth and reproduction are the most important, and these include winter temperature, summer temperature and rainfall (which influences soil moisture). This means that we can now become quantitative and start to assign particular temperature values to times long before thermometers were invented, complementing the historical information in Section 2.

The method of assigning temperatures requires the calculating power of a computer, but basically relies on making observations of present-day climates and flora (the mix of plant types present in an area) so that the temperature conditions required for particular sets of plants to thrive can be identified. The results can then be applied in reverse, starting with a mix of plants found in an ancient pollen sample and inferring the temperatures appropriate for those plants. Applying these techniques, the 140 000 year pollen record from Grande Pile has been converted into the 140 000 year record of long-term mean temperature displayed in Figure 3.15, where a 'long term' is a period much longer than a year. Notice that the results are shown as a shaded band rather than a thin line. This is because there is some uncertainty in estimating the temperature for each pollen sample, and the result must be expressed as falling within a likely range of temperatures rather than as a definite value.

Figure 3.15 is plotted in the same style as the pollen diagrams, that is, with age increasing downwards. The results from the oldest, deepest, part of the core are found towards the bottom, and the results from the youngest, shallowest, part are found towards the top. This convention conveys the idea that information about older times is more deeply buried in the original core. The horizontal axis shows that temperature increases to the right.

Figure 3.15 reveals a number of cold periods separated by warmer periods, all of different durations. Mean temperatures during the warmer periods were similar to those of today. The colder periods had temperatures some 6 to 10 °C colder. The transitions between cold and warm periods occurred over relatively short time-spans, so these were periods of rapid temperature change.

- Considering the past 140 000 years as a whole, is the mean temperature higher, lower or the same as the recent long-term mean temperature?

- Figure 3.15 shows short periods where the temperatures were the same or slightly higher than at present. For longer periods the mean temperature was much lower than recently. Overall, the mean temperature in this part of Europe was lower than recently.

Putting this another way, we have found that although we take the recent temperatures for granted, they are unusual with respect to the conditions over the past 140 000 years.

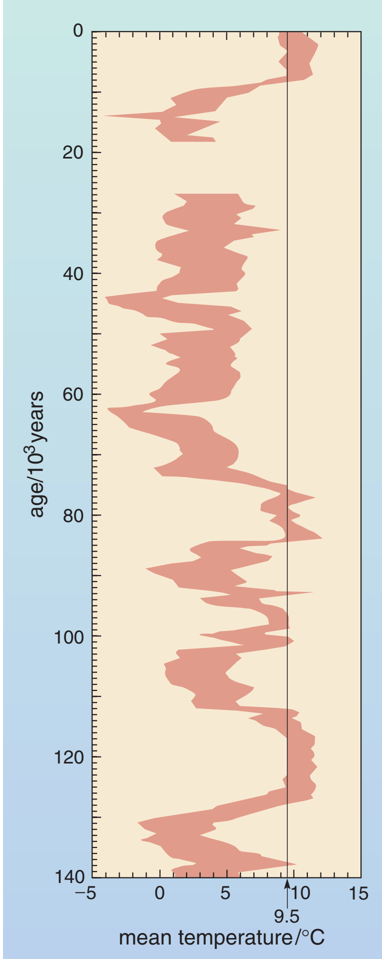

Figure 3.15 The long-term mean temperatures inferred from the Grande Pile pollen record. The gap in the record is a consequence of the sediment and pollen in this part of the core having become disrupted and mixed during its original deposition to such an extent that a meaningful temperature cannot be calculated. The long-term mean temperature at Grande Pile in modern times is 9.5 °C. Note that the vertical axis is labelled 'age /10^3 years'. This means that the numbers read from the vertical scale must be multiplied by 10^3 years; for example 20 on the scale means 20×10^3 years.