Blelham Bog

[NY 366 006]

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Introduction

Blelham Bog, Cumbria (Figure 6.6) is an important site for providing biostratigraphical, lithostratigraphical and chronostratigraphical evidence for the major environmental changes that took place in northern England during the Late-glacial. It has been investigated in great detail by Harmsworth (1968), Evans (1970), Oldfield (1970), Pennington and Bonny (1970) and Pennington (1973). Its palaeoenvironmental record is significant for studies of the regional differentiation of the Late-glacial vegetation, lithostratigraphy and climate in Britain and north-west Europe. The site also is important because it shows evidence for both Flandrian and historical environmental change (Oldfield, 1970).

Description

The site is situated 3 km south of Ambleside and 1 km west of Windermere. The geology of the Blelham basin is composed of Upper Silurian flags and slates of the Coniston Series, which are overlain by glacial drift in which several kettleholes were formed during Late Devensian deglaciation. Blelham Bog is developed in one such kettlehole, in gravels laid down marginal to ice stagnation in the Windermere basin (Hollingworth, 1951). Blelham Bog joins Blelham Tarn at its eastern end, but is separated from it on the south by a wooded and rocky knoll. Currently the bog is relatively flat but Oldfield's (1970) core transects show that the underlying topography comprises two kettlehole basins ((Figure 6.7)a–d).

Kettlehole stratigraphy

The largest of the kettleholes occupies the eastern, unwooded part of the bog and extends westwards under the causeway. The detailed stratigraphy from four boring transects in this kettlehole are shown in (Figure 6.7). A generalized lithostratigraphy at the western kettlehole (intersected by transects A and B) shows: 7. surface rootlet peats

6. carr peats

5. fen-swamp peats

4. reed-swamp peats

3. coarser shallow-water lake muds

2. clays alternating with greenish, open-water nekron muds

1. basal gravels

The sequence in transect C is similar, with one important exception. At C the basal deposits do not show a simple threefold division (clay–mud–clay) but instead a microlaminated organic mud occurs between the lowest clay–mud boundary. Radiocarbon dates put this layer at *c.* 14 300 years BP (Godwin and Willis, 1964; Pennington, 1973, 1975a). The Late-glacial pollen diagram is shown in (Figure 6.8), which illustrates selected taxa as a percentage of the total pollen. The chemical profile is shown in (Figure 6.9). Diatom sequences in the Blelham basin have been reported by Evans (1970) and differences between the flora of the tarn and the kettlehole have been recognized.

Flandrian and historical environmental change

The pollen diagram for the Flandrian is illustrated in (Figure 6.10). The mire communities of the present bog overlie the Flandrian muds and peats, which accumulated in the two neighbouring kettlehole basins that developed in basal, Devensian gravels. A detailed description of the site, its present vegetation and the stratigraphy and pollen analysis of the subsurface mire was published by Oldfield (1970), who showed that the vegetation history inferred from the pollen and macrofossils in the deposits differed from that originally postulated when the National Nature Reserve was set up. When the site was acquired by the former Nature Conservancy in 1954 the vegetation of the western kettlehole was a wet *Betula–Alnus–Salix* carr and that of the eastern one an acid *Sphagnum–Molinia–Myrica* bog. It seemed possible at this time that these two ecosystems represented two stages in the hydroseral development from carr to ombrogenous bog. A lacustrine bog developed over the lake sediments of the two small kettleholes, which changed from open water in the early post-glacial period to fen, carr and then bog (Oldfield, 1970). However, instead of the postulated hydroseral succession leading to a raised bog, Oldfield (1970) showed that raised bog peat formed on top of mid-post-glacial carr peat and that there is then a hiatus in the profiles that indicates extensive cutting of this peat. This is supported by early 19th century maps and conveyances, which record turbary rights on the bog. So the historical vegetation history was shown to have been complex, resulting from extensive cutting of mid-Flandrian carr peats a few centuries ago, followed by flooding of these cut surfaces as draining and landscaping of the slopes around the bog diverted drainage water over its surface. Other changes in the vegetation dated by Oldfield (1970) to the period 1848–1888 can be attributed to the construction of the present causeway and the diversion of Fish Pond Beck, together with the effects of lowering of the level of Blelham Tarn by deepening and straightening of the outflow stream. Grazing also has influenced the vegetation pattern, and enclosure since 1956 shows recent changes consequent on the cessation of grazing. This history of local land use suggested by Oldfield from stratigraphical and documentary evidence has been confirmed by biological and geochemical analyses of a long core from the neighbouring Blelham Tarn (Pennington and Lishman, 1971).

Interpretation

Late glacial sequence

The significance of the western kettlehole stems from the Late-glacial sedimentary sequence. In 1961, when Oldfield found this long Late-glacial succession Quaternary stratigraphers accepted a Late-glacial pollen zonation of I, II and III (e.g. Godwin, 1956; Mitchell *et al.,* 1973) and equated the organic interstadial deposits of Windermere with zone II (see (Table 6.2)). They were aware of the possible existence of an earlier interstadial (e.g. Walker, 1966b) that would subdivide zone 1 (e.g. Bartley, 1962). Oldfield's demonstration of the microlaminated organic deposit in the silty clays below the main organic interstadial at Blelham Bog suggested that here was a horizon that might correlate with the Bolling Interstadial of mainland Europe (Iversen, 1954). However, Evans (1970), working on the diatom sequence, obtained the first ^{14}C date on the microlaminated mud (14 330 years BP), which was much older than the Bolling dates of continental Europe. This indicated that southern Cumbria had become ice-free at what was then considered to be a surprisingly early date, but subsequently this date was confirmed by ^{14}C dates from North Wales (Coope and Brophy, 1972), by duplicate dates and by consistent dates above the lowest dated horizon (Penn ington and Bonny, 1970). At this time sediments accumulating in the nearby, higher altitude site of Blea Tarn indicate snow-bed communities dominated by *Salix herbacea.* Pennington and Bonny (1970) obtained ten further dates from this Late-glacial profile (Figure 6.11) and percentage pollen diagrams analysed by different workers from the western kettlehole showed a highly reproducible stratigraphy (Evans, 1970; Pennington, 1970; Pennington and Bonny, 1970).

The main organic interstadial layer coincided with a 'woodland biozone' pollen zone, dominated in the lower parts *by Juniperus* and in the upper part by *Betula.* The lower microlaminated organic layer was not consistently distinguished by any distinctive pollen assemblage, although by selection of samples it was possible to suggest a possible increase in *Betula* percentages, and some were certainly *Betula nana* pollen. Subsequently absolute pollen analysis was carried out on the samples using a technique developed by Bonny (1972), where pollen diagrams based on grains per cubic centimetre (pollen concentration) and estimates of grains deposited per cm^2 per year (pollen deposition rates) were produced (Pennington, 1973), with the conclusions summarized in Pennington and Bonny (1970). All deposits below the main interstadial layer, that is those dating from before 13 000 years BP, accumulated at a time of very low pollen deposition. This profile was interpreted as indicative of a single Late-glacial interstadial between *c.* 13 000 and 11 000 years years BE Comparison with a ^{14}C dated profile from Cam Loch in Sutherland (Pennington, 1975a) was used to suggest that vegetation changes at corresponding dates (13 000 and 11 000 years BP) in these two regions of western Britain having different vegetation patterns, should be interpreted as indicative of climatic changes at these dates (Figure 6.11).

The lower (microlaminated) mud is approximately 40–50% organic content and is of a type not found elsewhere in Cumbria. It contains well-preserved remains of green algae, insects and material resembling decomposed lichen thalli. Although no arctic or subarctic insects were found in it by Coope (unpublished), Harmsworth (1968) found arctic species of Cladocera. In all the sediments older than 13 000 years BP, rates of total annual pollen deposition estimated from the ^{14}C dates never exceeded 200 grains cm^{-2} year^{-1}, which is comparable with rates from the present-day tundra (Davis *et al.,* 1973). In the overlying deposit of the main interstadial layer, total annual deposition increases to 2000–3000 grains cm^{-2} year^{-1}, comparable with present-day rates from open woodland. This woodland biozone is composed mainly of *Juniperus* and *Betula.* Above the interstadial layer, a 5 cm grey clay layer is correlated, on its characteristic *Artemisia* pollen content as well as its stratigraphical position, with the upper varved clay at Windermere. Within this grey clay, which has been interpreted as a solilluction deposit, annual pollen deposition falls to *c.* 500 grains cm^{-2} year^{-1}, indicating that woodland disappeared completely during the Loch Lomond Stadial. This was the first British site at which it was shown that the Late-glacial climatic oscillation, deduced from stratigraphy and from vegetational changes inferred from percentage pollen diagrams, coincided with real changes in the amounts of annual pollen deposited, by comparison with modern deposition rates, and which confirmed the tundra–woodland–tundra environments. The small size of this kettlehole (*c.* 50 m diameter) and its enclosed character suggest that the calculated pollen-deposition rates are representative of airborne pollen input from local vegetation, with minimal need to allow for such complicating factors as waterborne pollen components, redistribution of pollen within the water body and localization of sediment accumulation (see Likens and Davis, 1975).

Late-glacial pollen zone interpretation

In the Late-glacial at Blelham the sequence of pollen zones described is illustrated in (Table 6.2) and (Figure 6.11). Prior to 13 000 years BP in pollen zone 'Ba' there was a grass sedge tundra with much *Rumex acetosa* and low percentages of juniper, interpreted as the product of prostrate shrubs dependent on a winter snow cover. The pollen concentration was low at tundra deposition rates. At Blelham in the Windermere Interstadial (*c.* 13 000–11 000 years BP) the lowest boundary of the main organic layer falls at *c.* 13 000 years BP and corresponds with a general climatic amelioration in north-west Europe. Above this horizon there is a rapid rise in the annual deposition rates of all the major pollen taxa and a particularly large increase in juniper, which was thought to be an immediate response to the improved climate by plants already pres ent in the area. Through pollen zone 'Bb' there is a progressive increase in birch, which indicates a steady dispersal of tree birches towards the site. The overlying birch-pollen assemblage zone (Bc), in which the maximum Late-glacial percentages of birch are found, can be interpreted as representing the time of maximum extent of birch woodland. The juniper was suppressed by the superior competitive ability of the birch. There is no evidence of a vegetation recession between the juniper pollen zone and the birch maximum but a progressive unidirectional vegetation succession in response to climatic amelioration. All this took place during the continental Bolling Interstadial (13 000–12 000 years BP). The maximum temperatures were probably in this period, supported by evidence from the percentage of tree pollen, the higher rates of annual pollen deposition (1000–3000 grains cm^{-2} year^{-1}) and the beetle record. At Blelham there was then a change to a zone of lower deposition rates of birch and juniper (equivalent to the Older Dryas, (Table 6.2), zone Ic) and this small absolute decline was the result of a fall in temperature sufficient to affect pollen production by thermophilous plants but not sufficiently low to increase soil movement by freeze-thaw processes. This can be concluded because there is no evidence for either a relative or absolute increase in pollen of taxa of disturbed ground, such as *Artemisia.* The value of absolute pollen diagrams can be appreciated with regard to this phase. In (Figure 6.8) there are only small changes at 419 cm and no separate pollen assemblage zone was originally distinguished. Absolute pollen analysis, however, shows up the real difference with respect to pollen content between the samples from 419 to 415 cm and those below 419 cm. From 419 to 415 cm there are pronounced minima in concentration and annual deposition rates of *Betula, Juniperus, Filipendula* and *Myriophyllum alterniflorum,* all comparatively warmth-demanding plants. The *Rumex* pollen is raised in the absolute pollen diagram in this narrow zone, which is barely perceptible in the percentage diagram.

This minor recession ended the warmest period in this interstadial and it led from then on to a fluctuating climatic environment, but on the whole with declining temperatures in pollen zone 'rid' (dated at Blelham to 11 800–11 000 years BP). This zone shows an interplay between birch and juniper, which responded to the fluctuating climate, and at the same time there was a rise in deposition of open-environment herb pollen. The ecological equilibrium of the established birchwoods was broken and there was increased soil erosion. There is back-up evidence for this pollen record from interpretation of beetle remains at sites such as Glanllynnau, Windermere and St Bees (Coope and Brophy, 1972; Coope and Joachim, 1980). At the first site, ^{14}C dating shows that deposition in a kettlehole took place from *c.* 14 000–10 000 years BP The beetle remains indicate that at *c.* 13 000 years BP an intensely cold continental climate suddenly gave rise to a period with summer temperatures at least as warm as those of today. At the time though the landscape was entirely devoid of trees. From 12 000 to *c.* 10 000 years BP there was a progressive deterioration in the temperature curve and the period of birch forest is shown to have a less thermophilous fauna than that of the previous pollen zone. The climatic amelioration at 13 000 years BP was widespread and synchronous, whereas the earlier Bolling seems to be metachronous. It represents the local arrival of birch woodland at each locality and it took a period of time for the migration of tree birches from their glacial refuges.

In the Younger Dryas ((Table 6.2), zone III), sediments at Blelham indicate a return to glacial conditions in the upland Lake District and four pollen assemblage zones coincide with this period. The two *Artemisia* zones (Be and Bf) coincide with a solifluction clay. There is a fall in birch and juniper pollen rates to under 100 grains cm^{-2} $year^{-1}$, which indicates the disappearance of local woodland and pollen is often scarce. There also are occasional leaf macrofossils of *Salix herbacea,* a plant that is found only on mountain summits in the Lake District today. The later two zones (Bg and Bh) coincide with the second half of the period, when there was a rapid temperature rise, a stabilization of the land surface by a vegetation cover, expansion of sedges, grasses and herbs at the expense of the more open community plants, and mud became increasingly organic, and this becomes transitional to the Flandrian when birch percentages expand.

Comparison of the Late-glacial profile from Blelham Bog with other profiles made it possible to develop hypotheses on two problems in the Late-glacial period. Firstly, the comparison with Cam Loch (Pennington, 1975a) included consideration of whether the Late-glacial interstadial in western Britain was a single episode or divided. The minimum in pollen deposition rates of *Betula at c.* 420 cm at Blelham Bog is dated to *c.* 12 000–11 800 years BP (Pennington, 1975a) and therefore an hypothesis was tentatively suggested that this represented a temporary deterioration in the environment at the time of the Older Dryas recession, dated by Mangerud *et al.* (1974) to about this time period. The reality of a temporary decline in the pollen deposition rates of *Betula* at this time was then confirmed by the ^{14}C-dated absolute pollen diagram from Low Wray Bay, Windermere (Pennington, 1981). Secondly, the question of the reliability of ^{14}C dates from deposits formed under water, bearing in mind the possibility of the incorporation during aquatic photosynthesis of ^{14}C-deficient carbon from the lithosphere, was considered by comparing the dates of pollen zone boundaries in the diagrams from Blelham Bog and Low Wray Bay (Pennington, 1977). One site is an enclosed, small kettlehole in which much of the organic content of the sediments would be expected to be derived from aquatic production, whereas the other is at the margin of a large lake receiving inflow streams where the presence of macroscopic plant remains, such as birch fruits and catkin scales, proves the input of terrestrial origin organic material. An unlikely combination of errors would be required to explain the very similar ages of pollen zone boundaries at these neighbouring locations in terms of errors resulting from the incorporation of ancient carbon. Accordingly the view is that the ^{14}C dates from Blelham Bog show no evidence of error and are acceptable as a radiocarbon chronology for the Late-glacial stage of the Late Devensian.

Interpretation of the chemical analysis of the Late-glacial succession

A summary of the chemical analysis of the sediments is shown in (Figure 6.9). The maximum accumulation of biogenic sediments should take place under the ecologically stable interglacial climates and the minimum concentration of organic matter under glacial conditions, when all the soils have been destroyed by glacial erosion and deposition consists of rock flour and minerogenic sediments. Also, in periods of high erosion rate, soil material rich in potassium, sodium and magnesium is rapidly transferred to lake basins, whereas in periods of low erosion rate these elements are rapidly removed from the surface of the catchment by leaching. What material is transferred to the lakes is relatively poor in the above minerals. For Blelham the Late-glacial profile analyses show relatively high concentrations of the erosion indicators in both pre-interstadial and post-interstadial deposits. The minimum concentration is in the interstadi-al deposits, where the maximum values of total carbon shows the maximum humus accumulation in the maturing soil profiles.

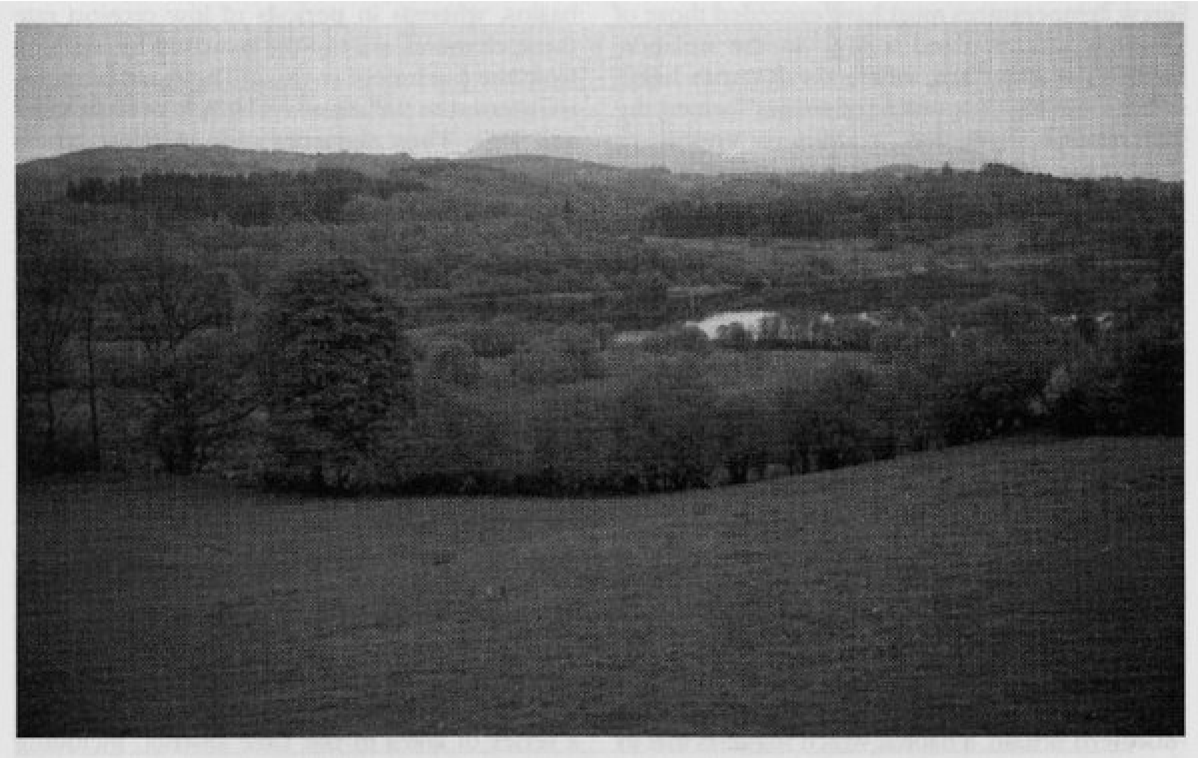
Interpretation of the Flandrian succession

There is a contrast between the Flandrian vegetational history at Blelham and that recorded for upland areas. This can be seen in (Figure 6.10) where the changes in the forest composition at the elm decline are similar to other sites, such as Blea Tarn, and the presence of a silt band in the deposits, accompanied by a lack of fern spores, suggests the same type of soil erosion. However, at Blelham a long phase of undisturbed secondary forest with *Fraxinus, Mercurialis* and very little Gramineae and *Plantago lanceolata* followed. There is then a distinct clearance phase, accompanied by an influx of silt that shows all the characteristics of a Landnam clearance as described by Iversen (1941). This is a temporary forest clearance, followed by more or less complete regeneration, with short-lived maxima of first, grass and herbs and then, the pioneer tree species, notably birch, followed by other components such as oak, which regenerates completely. This indicates that in the valley woods of the Lake District, the Neolithic to Bronze Age clearances essentially were temporary and were followed by complete forest regeneration, except that in each episode the elm reduced one further stage and it did not regain any ground. Above the Landnam phase there is evidence for a second clearance with an increase in grass and pasture herbs and the first appearance of bracken. The main forest clearance is indicated by a clearly defined band within the top metre of sediment, with cereal pollen and a peak of *Plantago lanceolata* and weeds. Pennington (1965) suggests that this late clearance is the result of the Viking land-takes, recorded by the place names of the two farms that occupy the immediate drainage basin (Tock How and Low Wray). The curve for *Ilex* in (Figure 6.10) shows a contrast with the continental curve for this plant, and its expansion after the Landnam phase is interpreted as reflecting the more open character of the secondary forest and the resistance of *Ilex* to grazing. In the oceanic Lake District climate there seems to have been no climatic control (Pennington, 1965). The diatom flora from the kettlehole shows no increase in the ratio of planktonic to non-planktonic forms during the early Flandrian, whereas in the tarn, non-planktonic taxa also dominated at this time. The open water of the tarn was calcareous and included *Cocconeis diminuta* and *Achnanthes suchlandtii* during this period. A water depth of at least 12 m has been estimated for the later Boreal period. An increase in *Eunotia* in the kettlehole has been linked to the development of an increasingly acidic environment by the end of the Boreal period. By the middle of the Atlantic period, the pelagic zone of the tarn included over 70% of planktonic forms and their increase has been thought to be the result of increased amounts of organic compounds and of nitrogen, probably as a result of woodland growth, with *Alnus* being responsible for the enhanced levels of nitrogen. Alkalinity was reduced in the tarn during the Atlantic period, when *Eunotia* and *Frustulia* species either appeared or expanded in occurrence. Although such a trend also characterized the late Flandrian, the tarn water remained alkaline. However, a phase of eutrophication can be identified close to the present day and species such as *Asterionella formosa* and *Cyclotella glomerata* are diagnostic of this, with inputs to the lake from fertilizers and sewage the most likely cause. The formation of Sphagnum peat in the kettlehole in the late Flandrian is indicated by a suite of acidophilic diatoms, such as *Eunotia, Frustulia* and *Pinnularia.*

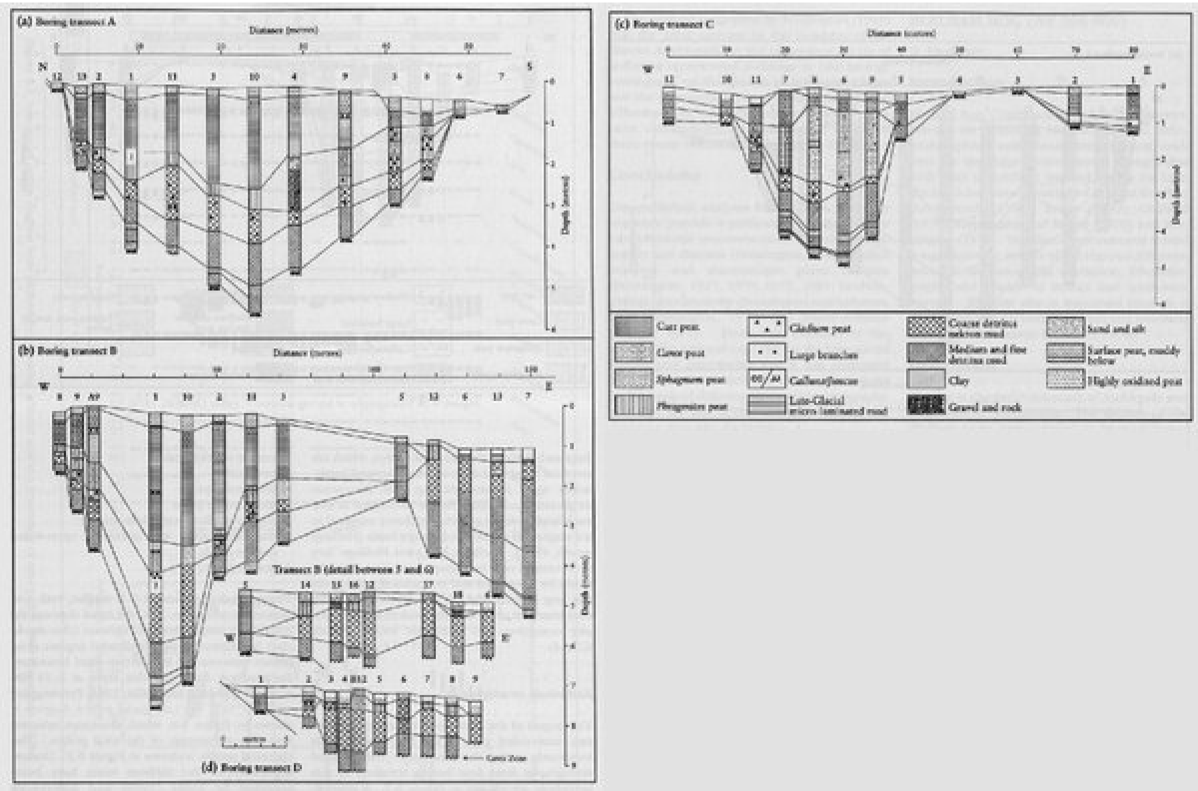
Conclusions

The importance of this site lies mainly in the relatively high organic character of its Late-glacial layers, which accumulated in an enclosed environment, partly under anaerobic conditions. Its chronology has been established by extensive ^{14}C dating and it has been shown that an early climatic amelioration indicated by organic muds with tundra-type plant communities was caused by the onset of a maritime climate, which suggests that 'the regional differentiation of climate now apparent in the warmer winters and higher precipitation of western Britain came into being as soon as the Weichselian/Devensian ice retreated' (Pennington, 1975a). There were warmer conditions here than during the same interval in Holland and Scandinavia. The sediments at this site have recorded important palaeoenvironmental changes throughout pollen zones I–III in the Older Dryas, the Allerød and the Younger Dryas. Regional differentiation of palaeoclimate is possible during these periods, with important differences demonstrated between Blelham Bog and continental north-west Europe and between Blelham Bog and the nearby high-altitude site of Blea Tarn. It is one of the most important sites in Britain, where crucial evidence from a wide range of chemical, lithological, palynological, chronostratigraphical and palaeoclimatological techniques have been used to gain a better understanding of Late-glacial environmental changes, not just in northern England but also in north-west Europe. The site was used to reinforce the view that chronostratigraphy was the best method for correlating Late-glacial sequences. There also are important Flandrian and historical changes documented in the bog stratigraphy.

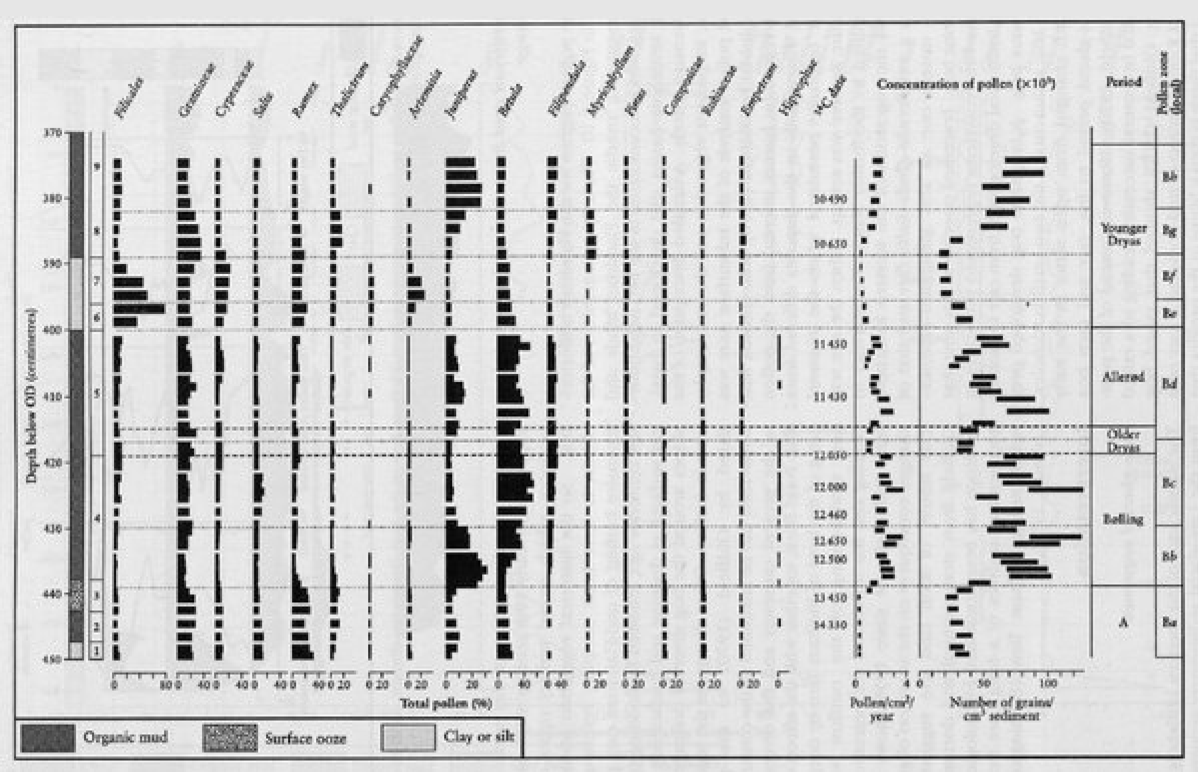
References



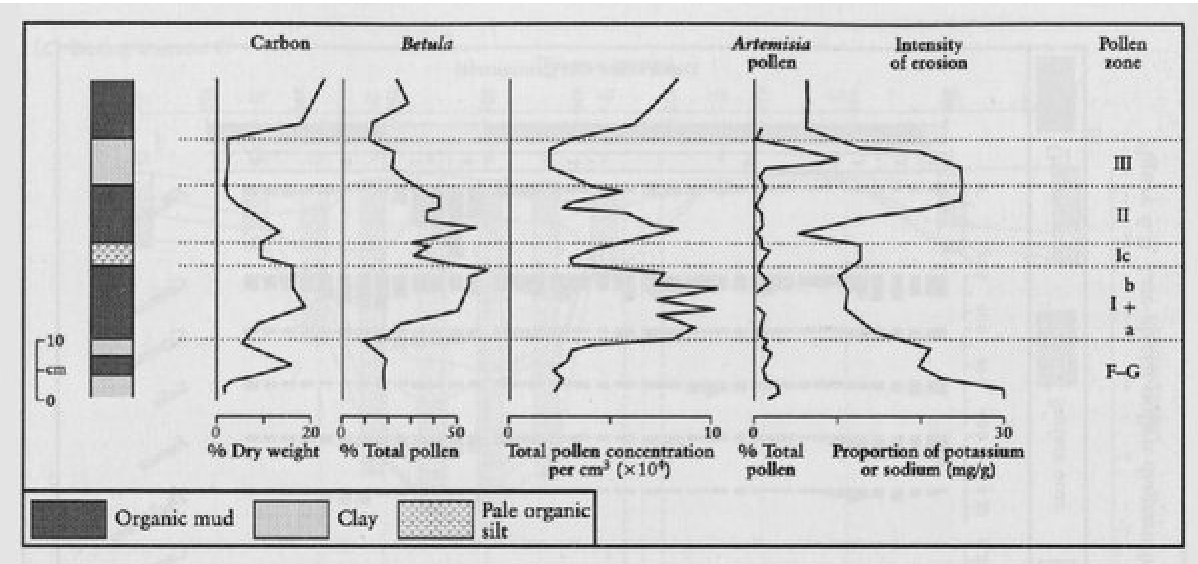
(Figure 6.6) Blelham Bog, looking to the north-east. (Photo: D. Huddart.)



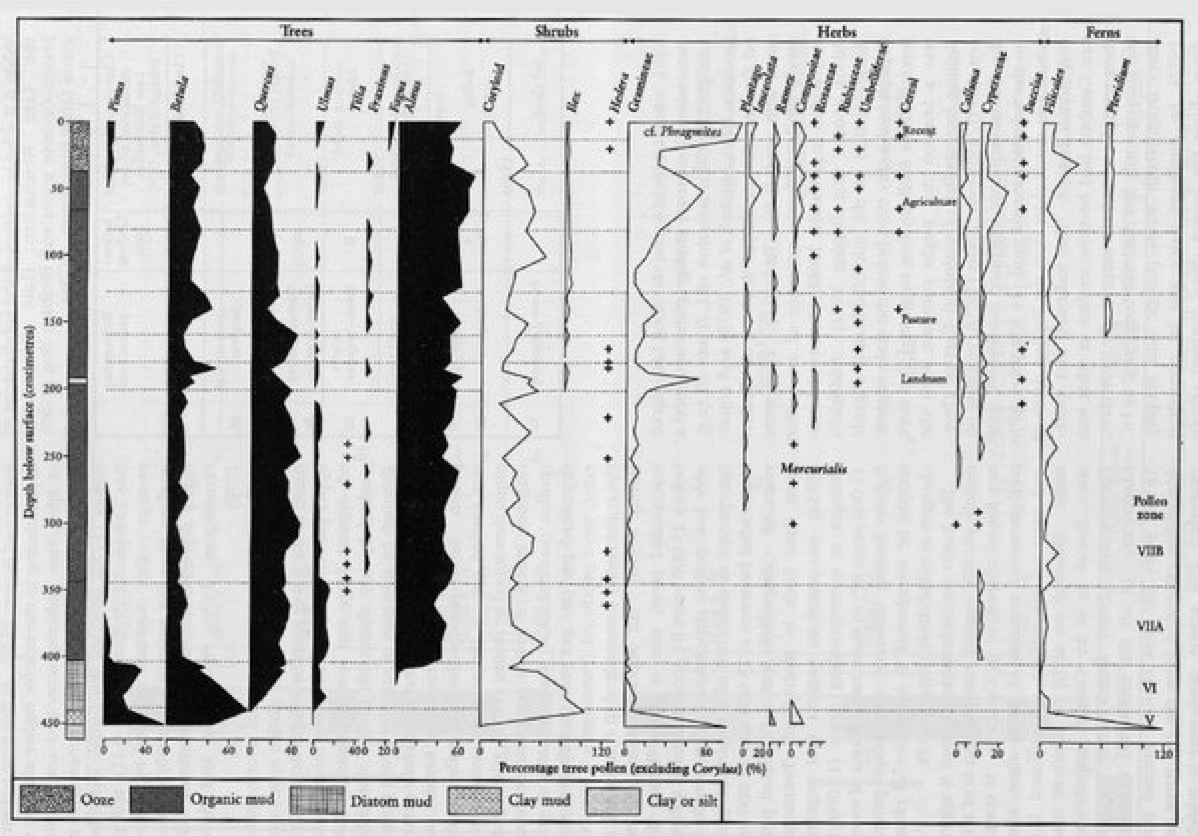
(Figure 6.7) a, b and d Stratigraphy at boring transects A, B, and D (after Oldfield, 1970). (See (Figure 6.7)c overleaf for boring transect C and key.) c. Stratigraphy at boring transect C (after Oldfield, 1970).



(Figure 6.8) Late-glacial pollen diagram from Blelham Bog showing selected taxa as a percentage of total pollen (after Pennington, 1975a).



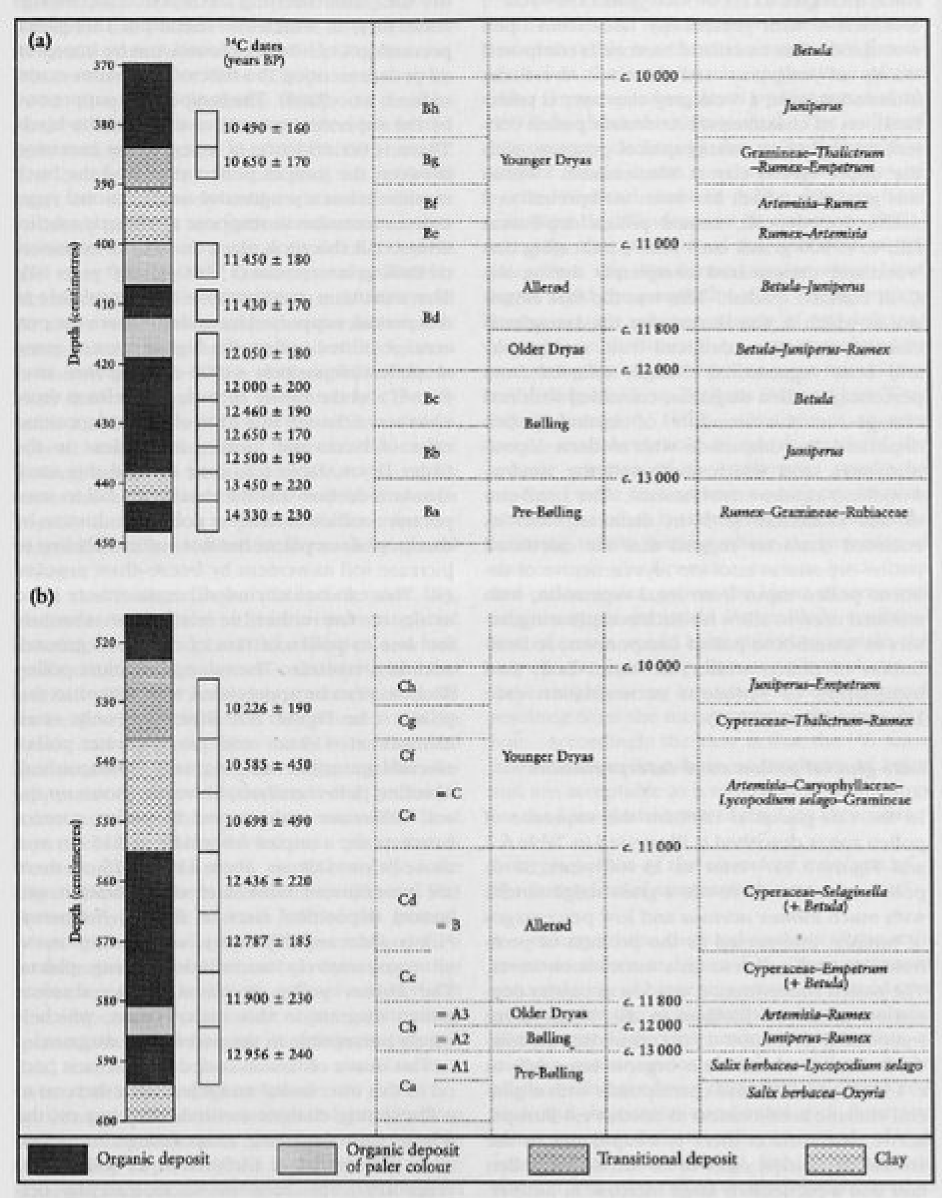
(Figure 6.9) Pollen and chemistratigraphy from Blelham Bog in the Late Devensian climatic oscillation (after Pennington, 1975a).



(Figure 6.10) Flandrian pollen percentage diagram of Blelham Bog, typical of the vegetational history of the valleys of the southern Lake District (after Pennington, 1975c).

Chronostratigraphical subdivision of the Late Weichselian (Mangerud *et al.*, 1974)		Jessen–Godwin zone	Belham Bog pollen zone	
Chronozone	^{14}C date (years BP)			
	10 000			
Younger Dryas		III	*Juniperus*	Bh
			Gramineae–herbs–*Empetrum*	Bg
			Artemisia–Rumex	Bf
			Rumex–Artemisia	Be
	11 000			
Allerød		II	*Betula–Juniperus*	Bd
	11 800			
Older Dryas		Ic	*Betula–Rumex*	
	12 000			
Bølling		Ib + Ia	*Betula*	Bc
			Juniperus	Bb
	13 000			
Full glacial			*Rumex*–Gramineae	Ba

(Table 6.2) Chronostratigraphical subdivisions of the Late Weichselian (Late Devensian), Jessen—Godwin zones and Blelham Bog pollen zones (after Pennington, 1975a).



(Figure 6.11) Pollen zones and chronology in the Late-glacial (after Pennington, 1975a): (a) Blelham Bog; (b) Cam Loch, Sutherland.