Hawes Water

[SD 478 765]

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Introduction

Hawes Water is an important site because it is one of only four carbonate lakes in northern England and the only lake of natural origin remaining in Lancashire. The site contains a marginal sedimentary record up to 12 m in depth, dominated by authigenic carbonate precipitates, which extends from the end-Devensian through to the Late Holocene (15.0 to *c.* 5.0 ka). The comparative dearth of carbonate sedimentary archives in Britain, which are known to be particularly sensitive to both climatic and anthropogenic impacts on the landscape, makes the site particularly valuable. Hawes Water has been studied in great detail by Oldfield (1960a, b), who demonstrated its significance for the development of regional vegetation and studies of lake-level change during the Late-glacial and Holocene. The importance of the Late-glacial sediments has been highlighted by the recent work of Nash (1995), Nolan *et al.* (1999) and Jones (1999), identifying the existence of four sub-millennial climatic oscillations prior to the onset of the Younger Dryas. The existence of such events reflects a degree of climatic instability during the Late-glacial Stadial not recorded previously at sites in north-western England.

Description

Hawes Water is a freshwater marl lake situated within the Arnside–Silverdale Area of Outstanding Natural Beauty adjacent to the Gait Barrows National Nature Reserve and 2 km south-west of Silverdale village. Along with Malham, Cunswick and Sunbiggin Tarns, it represents one of only four carbonate lakes in northern England. Hawes Water and its smaller sister basin Little Hawes Water, which lies to the north-east, rest approximately 8 m above sea level, within a catchment of approximately 1.7 km^2. The main lake is *c.* 400 m in length and 225 m wide, reaching a maximum depth of 12 m towards the centre. It occupies a shallow depression within the local Carboniferous Limestone. The depression is thought to be pre-Devensian in age, possibly a polje (Vincent, 1985). The limestone crops out to the northeast of the lake, forming an extensive limestone pavement. In places it is overlain by thin glacial diamicton, comprising a fine-grained, clast-rich blue-grey clay, deposited under ice during the end-Devensian.

The lake is fed by ephemeral springs, the majority of which flow into the north-east part of the basin. It also receives drainage from Little Hawes Water via a stream that runs directly into the lake. The main outflow from Hawes Water is situated at the southern end of the lake, where it drains by seepage and stream flow on to Hawes Water Moss (Figure 6.33). The principal characteristics of the lake are presented in (Table 6.5).

A terrestrialized marl bench, currently supporting reed beds, fen carr and more importantly calcareous meadows, rings the modern lake. These marginal sediments were first studied by Oldfield (1960a, b), whose combined stratigraphical and palynological study revealed a record of uninterrupted lacustrine deposition from the end-Devensian through to the mid-Holocene (*c.* 15.0–5.0 ka). The marginal sediment stratigraphy is illustrated in (Figure 6.34). Despite its close proximity to the coast, low altitude and close proximity to Silverdale Moss (where marine sediments can be found), there is no evidence in the sedimentary record, for a marine incursion into the catchment (F. Oldfield, pers. comm., 2001).

Interpretation

The Late-glacial (c 15–10.0 ka)

The Late-glacial sequence is represented by a sequence of micritic carbonates deposited during the Late-glacial (Windermere) Interstadial, bounded above and below by clay-rich sediments corresponding to the end-Devensian and Younger Dryas cold periods (Figure 6.34). Identification of the upper clay unit as equivalent to the Younger Dryas has been confirmed recently by two ^{14}C AMS dates that bracket the unit (10 980 ± 60 and 9 600 ± 100 years BP) (Jones, 1999; cf. Pennington, 1975a).

The Late-glacial sequence was first studied by Oldfield (1960a, b), who undertook a detailed stratigraphical and palynological study. The results of the pollen analysis subdivided the Late-glacial into Jessen's classic tripartite pollen zonation scheme (e.g. Jessen, 1938), which was at that time being used as a chronostratigraphical framework to define the period. This work, along with that from Windermere (Pennington, 1947), Skelsmerg Tarn (Walker, 1955b), Helton Tarn and Witherslack (Smith, 1958c), represent the first published Late-glacial profiles for northern Britain.

Oldfield's initial pollen study has been updated recently by a higher resolution study (Jones, 1999; core HW1/1 — see (Figure 6.33)), which identified a total of seven LPZs (HW1–7, (Figure 6.35)). The results chart the development of the catchment vegetation from tundra (end Devensian, HW1) through to juniper scrubland (Early Interstadial, HW2) and then closed *Betula* woodland (Late Interstadial, HW3–4). The Younger Dryas (HW5) is characterized initially by the development of open grassland communities, which colonized the area after the destruction of the interstadial birch woodland. As the climate continued to deteriorate the grasslands were replaced by tundra communities, thus reflecting the severity of the climate.

Pollen analysis at Hawes Water has been complemented by a high-resolution mineral magnetic and geochemical study (Nolan *et al.,* 1999), the results of which revealed the existence of two short-term, low-amplitude climatic oscillations during the Windermere Interstadial. These events were thought to be contemporary with the Aegelsee and Gerzensee oscillations identified at sites across the Swiss Plateau (Lotter *et al.,* 1992) and at several sites in the UK (Mayle *et al.,* 1999). Subsequent oxygen isotopic analysis of the bulk carbonate sediments (Nash, 1995; Jones, 1999) has extended the number of low-amplitude events to four, producing a record directly comparable to the high resolution Chironomid record from Whitrig Bog, Southern Scotland (Brooks and Birks, 2000). The impact upon the lake-catchment system appears to have been muted in most cases, with none of the events producing a discernable inwash horizon. Within the pollen record (Figure 6.35) each event is characterized by a decline in arboreal pollen (AP) and an expansion of herbaceous taxa. The fourth event, prior to the onset of the Younger Dryas (LPZ HW4) appears to have been severe enough to prompt the partial loss of woodland cover, leading to the re-expansion of grassland communities previously dominant in the catchment during the latter stages of the end-Devensian.

(Table 6.5) Limnological characteristics of Hawes Water

Hawes Water	
Dimensions	~400 x 225 metres
Elevation	8 metres above sea level; distance to sea ~5 kilometres
Water depth	Marl shelf ~1.2 metres; maximum ~12 metres
Lake volume	~390 000 cubic metres
Water supply	Direct precipitation (~1350 mm/a), spring, groundwater
Water temperature	Surface water 5–1*8°C;* deep water –5–8°C
Catchment area	1.77 km^2
Residence time	2–6 months?
	Seasonal
Carbonate precipitation	Biogenic (skeletal): gastropods, bivalves, ostracods, Chara
	Biologically mediated (plants/microbial)
Sediment record	'Marl': (bio)micrite, clay, peat, gyttja

Early to mid-Holocene (10.0–c. 5.0 ka)

The Early to mid-Holocene sedimentary record is dominated by the formation of the carbonate bench system. The bench system reaches a maximum thickness of 10–12 m at the southern end of the lake. It is composed of almost pure carbonate (95% CaCO$_3$) with very little detrital or organic components, reflecting the predominantly autochthonous sedimentary regime in the lake during this time. The bench is capped by a sequence of marginal fen peats, with the contact between the two units effectively marking the previous margins of the lake.

Carbonate precipitation rates during this period are estimated to have been as high as 2 mm year^{-1}. The sediments are rich in shell remains, particularly molluscs and gastropods, primarily *Lymnaea peregra* and *Pisidium nitidium.* Sparks (1962), who studied the stratigraphical distribution of this shell material, found them to be 'the most monotonous' he had ever encountered.

A detailed pollen diagram for the Holocene marginal sediments was published by Oldfield (1960a) (Figure 6.36), which recorded the classic Holocene sequence from tundra to mixed deciduous woodland. Using the pollen data from Hawes Water and several other sites around southern Lakeland, Oldfield (1965) highlighted for the first time the potential problems associated with the use of local pollen zones (LPZs). He demonstrated that, on a countrywide scale, LPZs could not be used as a chronostratigraphical tool for dating the Holocene, as advocated by Godwin (1956). Concentrating on the boundary between zones VI and VIIa, the 'Boreal–Atlantic transition', (pinpointed by the spread of *Pinus),* Oldfield highlighted a marked discrepancy in the timing of events between southern and northern Britain. In south and eastern England, the spread of *Pinus* (usually at the expense of *Betula),* occurred before the decrease in *Ulmus* and *Corylus* frequencies. However, at Hawes Water and other sites around north-west England, the *Pinus* rise was seen to occur after the rise in *Ulmus* and *Corylus* and was never entirely at the expense of *Betula.* This research was of considerable importance at the time of publication because palaeoenvironmental studies relied heavily on LPZs for intersite correlation, radiocarbon dating being a technique still very much in its infancy.

The existence of marginal sediments provides clear evidence of significant changes in the lake level at Hawes Water during the Holocene. Pollen and stratigraphical data from the northern perimeter (Transect B, Oldfield, 1960a, b) indicate that the lake-level was at its highest during the early Holocene, with the lake covering the field to the north of the present-day lake, and extending south towards Hawes Water Moss (Figure 6.33). More recent stratigraphical investigations of the southern end of the basin confirm Oldfield's initial conclusions and have identified the former Late-glacial lake level (Jones and Gedye, unpublished data). The Late-glacial lake appears to have been lower then that recorded during the early Holocene (Figure 6.33) but higher than the present lake.

It is clear from the stratigraphical evidence that the Early Holocene was characterized by the gradual infilling of the basin by the progradation of the carbonate bench system and hydroseral encroachment of the marginal peat deposits. Pollen analysis of the peat–marl contact shows a distinct younging trend lakewards for both the peat and carbonate sediments (Figure 6.37). This declining trend was reversed during the mid-Holocene by a substantial rise in lake-level, as reflected in the stratigraphical record from Transect B by the deposition of carbonate sediments atop the fen peat (Figure 6.34). A precise date for this increase is not yet known but pollen analysis places it at some point during or just after LPZ Vic, during the alder rise.

The next major phase of lake-level change appears to have been the decline to that of the present day. The absence of marginal late-Holocene sediments suggests that no further increases in lake-level occurred. The timing of the fall is unknown at present but must postdate the date for the top of the marginal sequence, which Oldfield (1960a, b) dated to LPZ VIIb, sometime after the elm decline, *c.* 5500–5700 years BP (Skog and Regnel, 1995).

The situation is complicated owing to the loss of marginal sediment through peat cutting, producing an 'artificial' date in places for the top of the marginal sediments.

The mid-Holocene fall in lake-level prompted a dramatic shift in sedimentation patterns. Analysis of a 3 m Mackereth core from the modern lake reveals sedimentation during the latter half of the Holocene being dominated by organic-rich gyttja (J.D. Marshall, Liverpool University, pers. comm. 2001) with a carbonate content of <10%. There is no evidence for renewed bench formation during the latter stages of the Holocene. The marked decrease in carbonate precipitation in the lake is likely to be linked to the drop in lake level, increasing the extent of the marginal peat deposits and the rate of organic inwash to the lake. Increased levels of organic decomposition would lead to increased CO_2 production, which effectively would 'acidify' the lake, causing the carbonate precipitates to re-dissolve back into the water column. A similar situation has been observed within the modern lake system.

Ongoing research

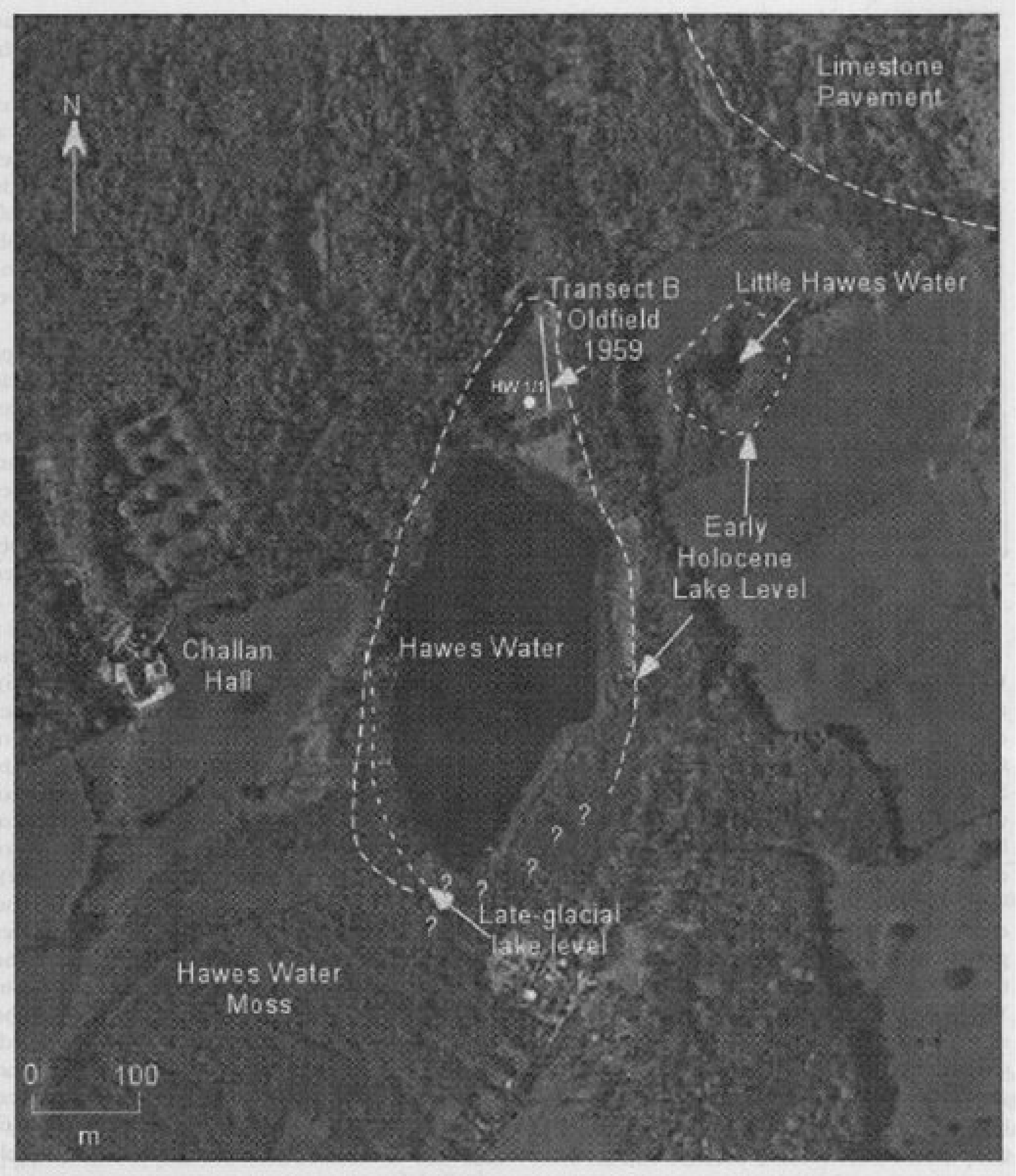
The full Holocene sediment sequence is currently being reanalysed as part of a NERC project 'A high-resolution lacustrine record of Holocene climate change' (J.D. Marshall (co-ordinator), Liverpool University, Earth Sciences). The project aims to produce the first high-resolution Holocene stable isotope record (δ^{18}O, δ^{13}C, 1 cm contiguous sampling resolution) for northern Britain, one of only a handful in Europe. The isotopic work on micritic carbonate and ostrocods is supported by a parallel study incorporating pollen (F. Mann, Edge Hill College), and Chironomids (B. Lang, Edge Hill College). A daily monitoring programme of the lake system also has been undertaken since 1999, collecting data on 4-hourly temperature records, and monthly measurements of the isotopic composition of lake waters and precipitates. Initial results have identified a number of climatic oscillations, particularly during the early Holocene, that are evident within both the isotopic and Chironomid records. Two such oscillations have been linked tentatively to the Pre-Boreal and 8.2 ka events. It is hoped that these investigations will shed light on some of the unan swered questions with regard to the lake-level history of Hawes Water.

The sedimentary record at Hawes Water also has been the subject of an ongoing study into the radiometric dating of carbonate lake sediments. This followed pilot work on the uranium-series signatures of lake waters and sediments to investigate the controls on radionuclide (^{238}U, ^{234}U, ^{232}Th and ^{230}Th) flux to Hawes Water and their transfer to the sediment column. The lake was seen to be buffered from the seasonality observed in radionuclide input as a result of changes in the prevailing hydrological regime (Blake *et al.,* 1998). In addition, a seasonal change in the mechanism of lake sedimentation was observed, from allochthonous organic input during winter to autochthonous carbonate formation during summer. Subsequently, Holocene sediments from the margin of Hawes Water and a shallow-water island populated by charophytes were studied in order to develop a novel technique for dating lake sediments using 226Ra. The results suggest that the application of this dating method is valid for up to 5000 years under the initial conditions of radioactive disequilibrium displayed at the present sediment–water interface. The sedimentation rate for the mid- to late Holocene determined using the decay of excess 226Ra was less than half that obtained from 210Pb dating of sediments deposited during the past 150 years or so (Fairclough, 1999).

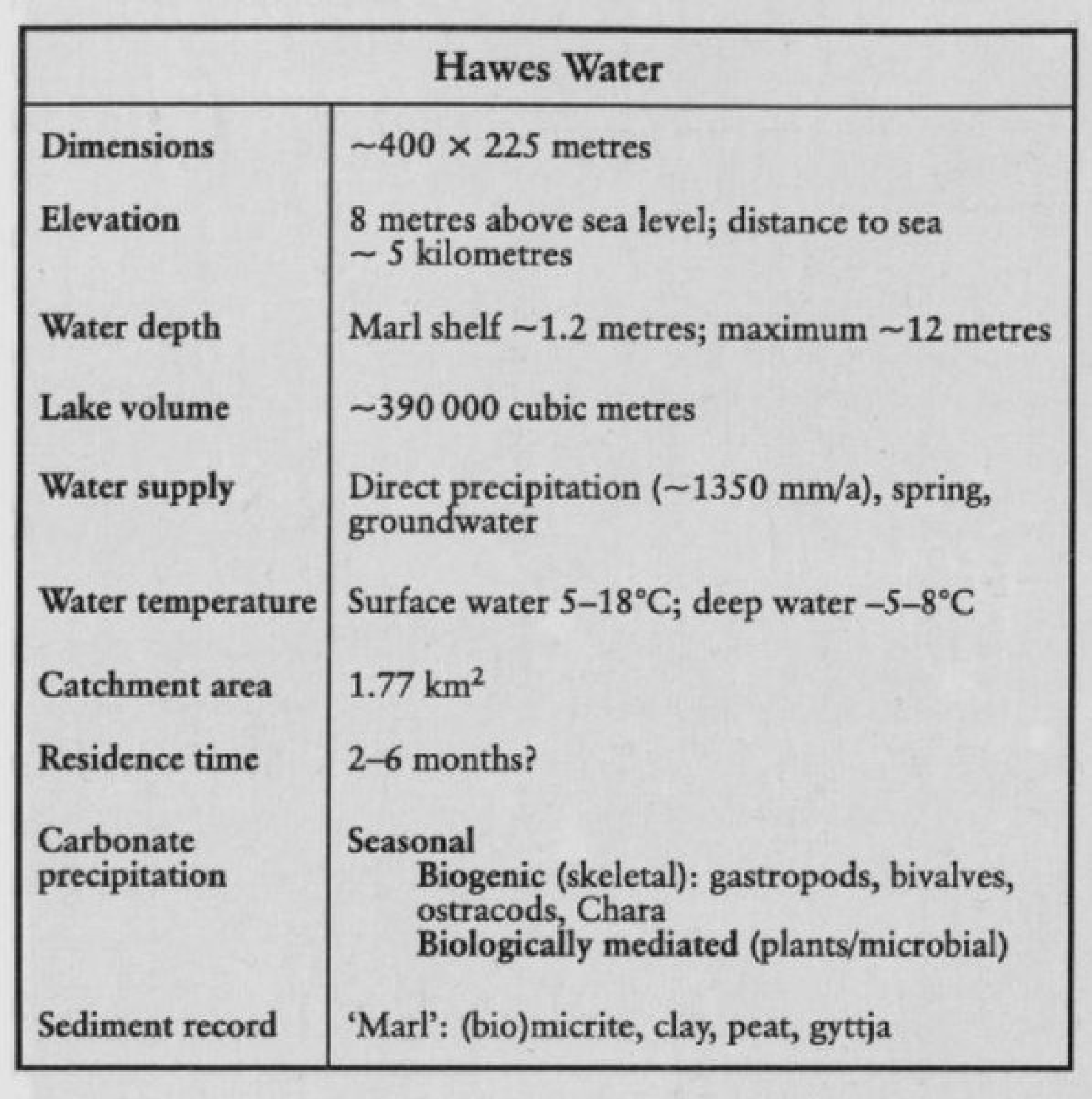
Conclusions

Hawes Water is an important site because it is one of only four carbonate lakes in northern England and the only lake of natural origin remaining in Lancashire. Its marginal sedimentary record presents a record of uninterrupted lacustrine deposition dating from the end-Devensian through to the mid-Holocene (*c.* 15.0–5.0 ka). Analysis of the Hawes Water sediments has provided information on the development of regional vegetation and lake-level change for the Late-glacial and Holocene. The importance of this sedimentary archive is further re-inforced by the carbonate nature of the sediments, which are known to be particularly sensitive to climatic and anthropogenic impacts. The sensitivity of the Hawes Water record is best exemplified by the identification of four short-term climatic fluctuations during the Late-glacial, recording a degree of climatic instability previously unrecorded at sites in England.

References



(Figure 6.33) Aerial photograph of Hawes Water and its catchment. The position of Transect B (Oldfield, 1960a, b) and core HW1/1 (Jones, 1999) are recorded. The provisional location of the Late-glacial and Holocene lake levels also are noted.



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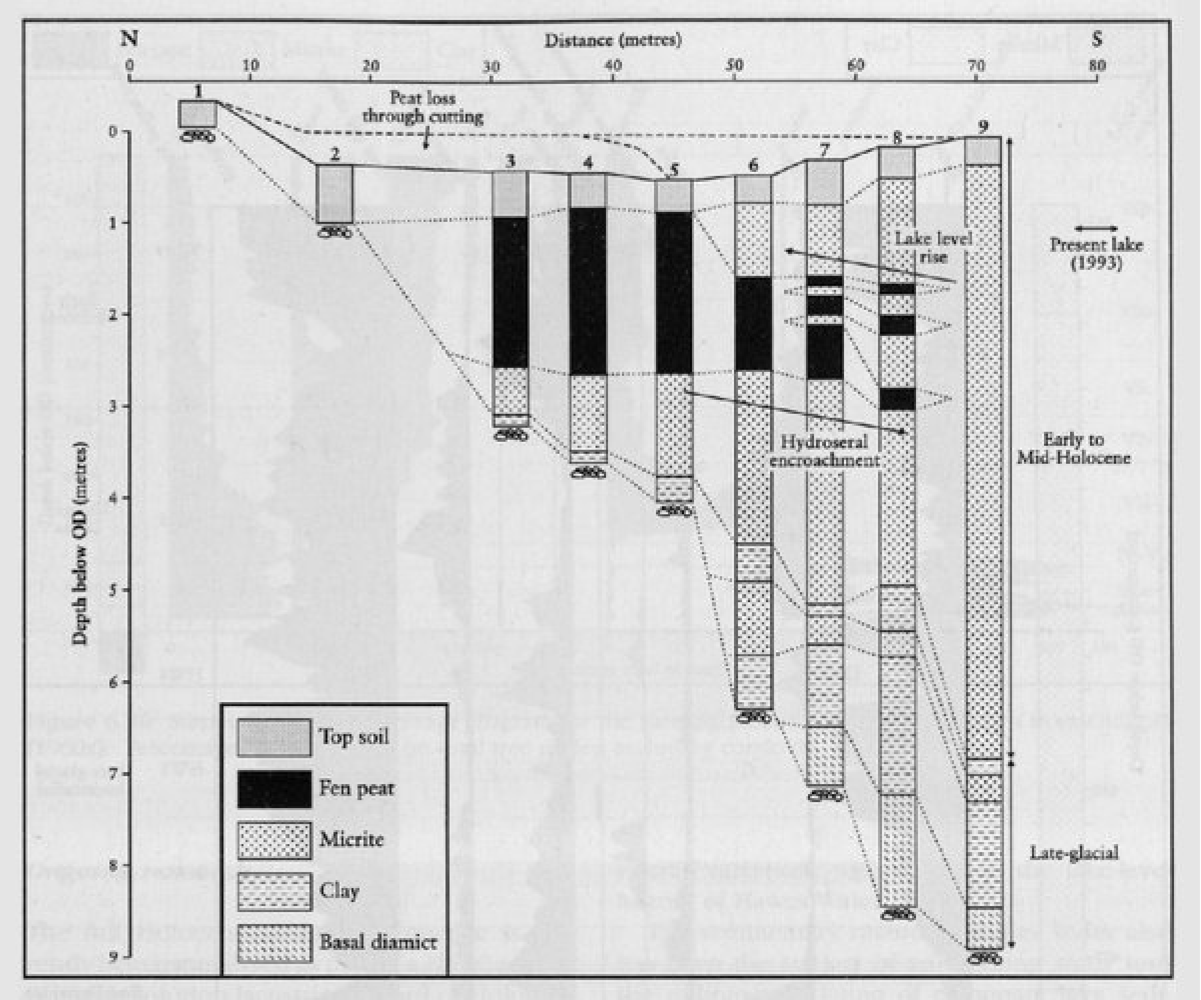
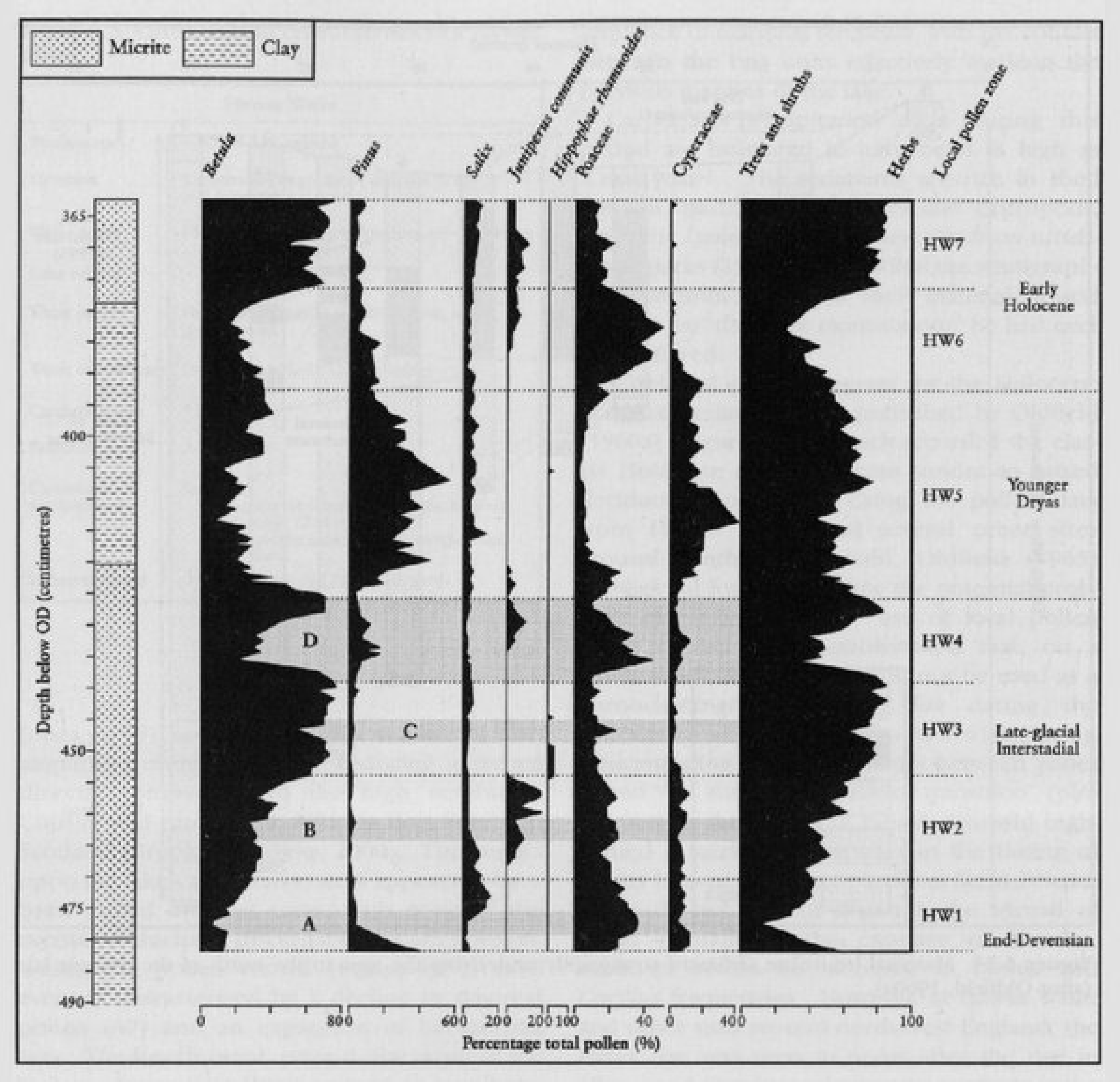
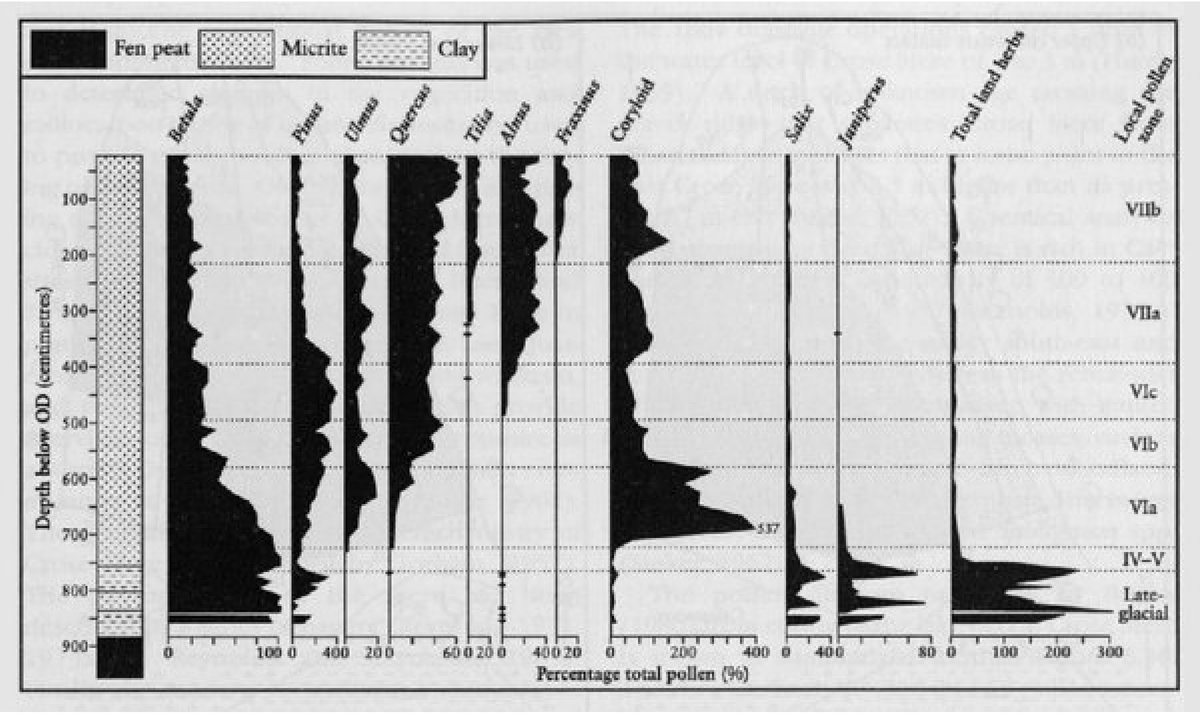


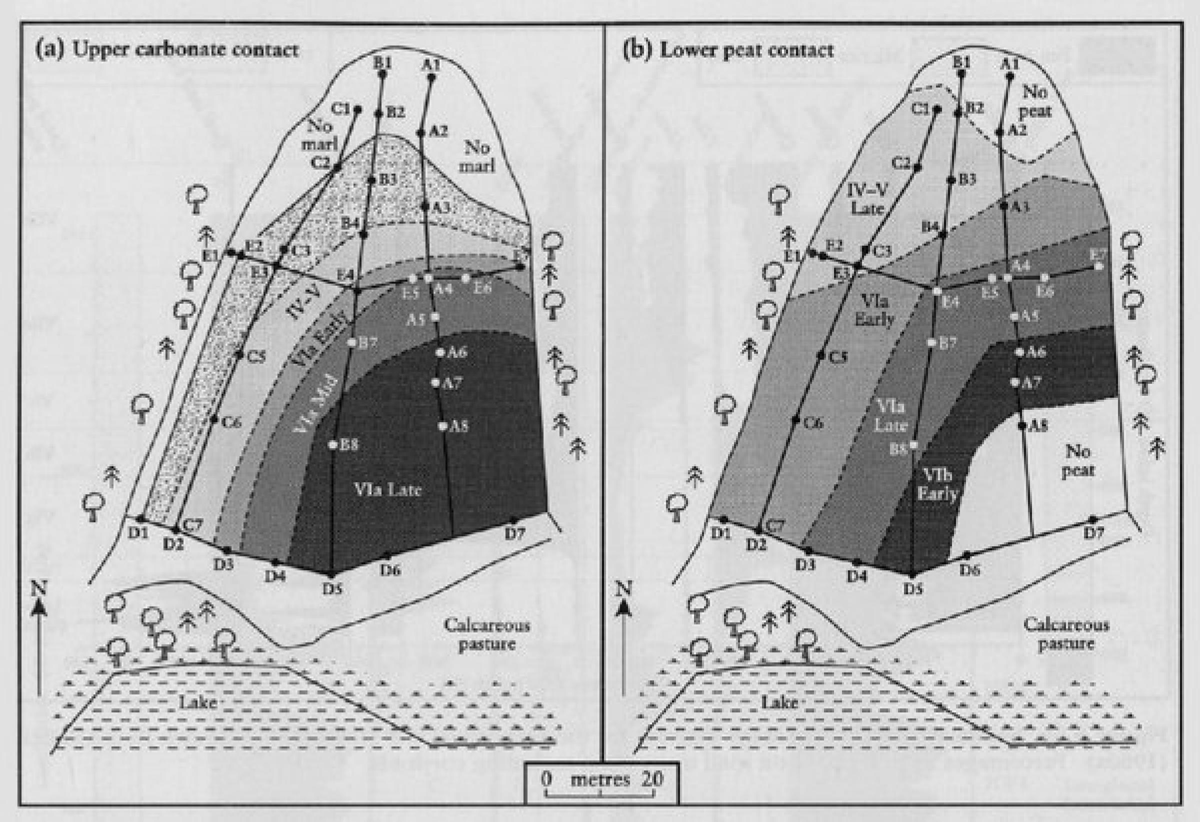
(Figure 6.34) Marginal lacustrine sediment stratigraphy underlying the area to the north of the present lake (after Oldfield, 1960a).



(Figure 6.35) Simplified Late-glacial pollen diagram from core HW1/1 (Jones, 1999). The four short-term oscillations (A–D) identified within the oxygen isotope record are highlighted in grey.



(Figure 6.36) Summary pollen percentage diagram for the Late-glacial and Holocene. Redrawn from Oldfield (1960a). Percentages are calculated on total tree pollen excluding coryloids.



(Figure 6.37) Dating of the peat–marl contact from the north field. A1–E7: location of core samples. (A) Lakeward younging charting the progradation of the carbonate bench system. (B) Subsequent hydroseral encroachment of the marginal peat deposits.