INTERSTADIAL DEPOSITS WITH CHELFORD AFFINITIES FROM BURLAND, CHESHIRE

by

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Summary

A borehole drilled in 1959 near Nantwich, Cheshire proved an organic sequence beneath thick Devensian and possibly older glacigenic deposits. However, palaeontological work on this sequence was made difficult by poor core recovery.

A second borehole has since been drilled at the site and provides a detailed lithological sequence and data on the distribution of pollen and diatoms. The organic deposits are thought to have accumulated in either an abandoned river channel or a lake, possibly during the Chelford Interstadial.

Introduction

In 1959 the Geological Survey drilled a borehole adjacent to Burland Farm, [NGR SJ 6018 5333] west of Nantwich, Cheshire as part of a regional investigation of Triassic stratigraphy. A thick Quaternary sequence including substantial organic deposits, was encountered overlying the Triassic bedrock.

The organic deposits were proved from 27.4 to 37.5 m in the borehole beneath a thick glacial sequence. Samples from these organic layers were examined by P. Osborne and D. Bartley who wrote short reports on the Coleoptera and flora. The fragmentary material at their disposal did not provide any conclusive evidence regarding the age of the deposits. The work remained unpublished.

In 1980 a second borehole was drilled at the original site using a cable-percussion (shell and auger) rig. This has resulted in an improved lithological log of the sequence and in the recovery of enough organic material for further studies of its palaeoenvironmental significance and likely age. This paper describes the lithostratigraphy of the Quaternary sequence, and details the results of diatom and pollen analysis of the organic deposits. Also included are preliminary comments on the organic chemistry (Dr P. Cranwell) and the Coleoptera (Dr R. Coope and Dr B.J. Taylor) of the organic layers: more extensive accounts will be published elsewhere.

The upper part of the Burland pollen profile may be provisionally correlated with the sequence recorded at the Chelford Interstadial type site. Radiocarbon dating, which provides a minimum age › 47 000 aBP for the Burland organic deposits, tends to support this correlation.

Lithostratigraphy

The log of the original Burland borehole is given in the Nantwich (Sheet 122) Memoir (Poole and Whiteman 1966, pp. 106–107). It records a Quaternary sequence 38.1 m thick resting on Upper Keuper Saliferous Beds (Triassic). The limited recovery of core, especially from the organic parts of the sequence, resulted in the original log being rather brief. The redrilling of the borehole has enabled the construction of a more detailed lithological sequence (Fig. 1) despite the limitations of the shell and auger technique. In the new borehole the Quaternary sequence is 37.5 m thick and can be sub-divided into four units for purposes of description.

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1. **Basal Diamicton** (36.6–37.5 m)

A stiff pebbly clay, 0.9 m thick, occurs between 36.6 and 37.5 metres (Fig. 1) resting on Triassic bedrock. The matrix of the deposit is moderate reddish brown (10 R 4/6) and was largely derived from the underlying red mudstones of the Upper Keuper Saliferous Beds. The lithology of the pebbles which occur throughout the deposit is given in Table 1; flint and quartzose pebbles are the dominant constituents. The quartzose pebbles derive from Carboniferous sandstone and Triassic pebble-bed outcrops marginal and adjacent to the Shropshire-Cheshire Basin. Such pebbles are abundant within the Quaternary deposits of this area. The origin of the flint is more problematical. Flint is a minor constituent of many of the tills in the West Midlands. The small outcrop of chalk in Northern Ireland is a possible source.

Although this diamicton could be interpreted as having been produced by fluvial reworking of the Triassic bedrock, the origin of the pebbles argues rather for a glacial derivation. We therefore interpret this layer as a till. The suggested correlation of the overlying organic deposits with the Chelford Interstadial (see below) suggests that this basal diamicton at Burland may correlate with the thin tills and other glacigenic deposits that occur beneath the interstadial Chelford Sand Formation at Oakwood Quarry near Chelford (Worsley *et al.* 1983). The age of these glacial deposits is uncertain although they were tentatively assigned to the Wolstonian by Evans and Arthurton in Mitchell *et al.* (1973).

Table 1 Percentage Composition of gravel-sized pebbles (+ 4–64 mm) in samples from the Burland borehole

Sample No.	Depth(m)	n	T. Slt	T. Sd	Lst	Arg	Aren	Ign	Fl	Qtz	Qtzt	Others
BUR 8	3.7– 5.0	104	36	6	9	17	4	15	1	6	4	2
BUR 12	8.8–11.0	193	40	4	3	15	17	1	4	11	2	3
BUR 13	11.0–14.2	176	27	11	6	18	11	2	7	12	1	5
BUR 15	14.2–18.0	177	40	14	2	8	12	4	4	11	1	4
BUR 42	36.6–37.5	48	-	-	-	-	19		20	42	19	-

Abbreviations

T. Slt = Triassic siltstone, T. Sd = Triassic sandstone, Lst = limestones, Arg = other argillaceous rocks, Aren = other arenaceous rocks, Ign = igneous, Fl = flint, Qtz = quartz, Qtzt = quartzites.

2. **Organic-rich Deposits** (27.7–36.6 m)

These deposits comprise a thick (8.9 m) sequence of organic silts and clays within which a thin peat layer occurs. The pebbles in the basal coarse gravel are probably derived from the underlying diamicton. Overlying this gravel are sandy silts which fine rapidly upwards into clayey silts. These silt-rich deposits contain pieces of wood and layers of comminuted shell. The deposits are olive grey (5Y 3/2) in colour.

The shell and auger drilling of these silts, which lay beneath the water table, destroyed any sedimentary structures that may have been present. However, short lengths of core from the original rotary-drilled borehole showed that the silts and clays contain numerous clasts of red mudstone and gypsum crystals up to 20 mm in diameter, including a high detrital input of material from local Triassic strata. Faint horizontal bands up to a few centimetres thick are present at several levels, reflecting subtle variations in the ratio of silt to clay. Ripple cross-lamination is also present within some of the more silty layers indicating the effect of weak currents.

A 1-m layer of peat (base at 30.5 m) is overlain by a sequence of greenish black (5GY 2/1) clays and silty clays between 27.77–29.5 m. These clays contain thin sand layers, wood and rarely, finely comminuted shell fragments. Clasts of red mudstone derived from the local Triassic bedrock and sporadic pebbles, including flint and quartzite, are also present.

Boreholes within five kilometres radius of the Burland borehole are sparse and do not enable the detailed form of the bedrock surface to be determined. However, the exceptionally thick (37.5 m) Quaternary deposits at Burland suggest that the lower parts of the sequence may fill a depression or channel. Remains of aquatic biota suggest that the organic sequence was deposited in a small lake or in a fluvial system.

3. **Proglacial Deposits** (18.9–27.7 m)

These deposits are 8.8 m thick and comprise a variable sequence of sands, silts and clays. The lower part of this sequence consists of rhythmically laminated deposits of overall greenish grey (5G 6/1) colour. From 27.2 to 27.7 m they comprise faintly laminated silty clay in layers 1–5 mm thick. From 26.0–27.2. m the deposit contains

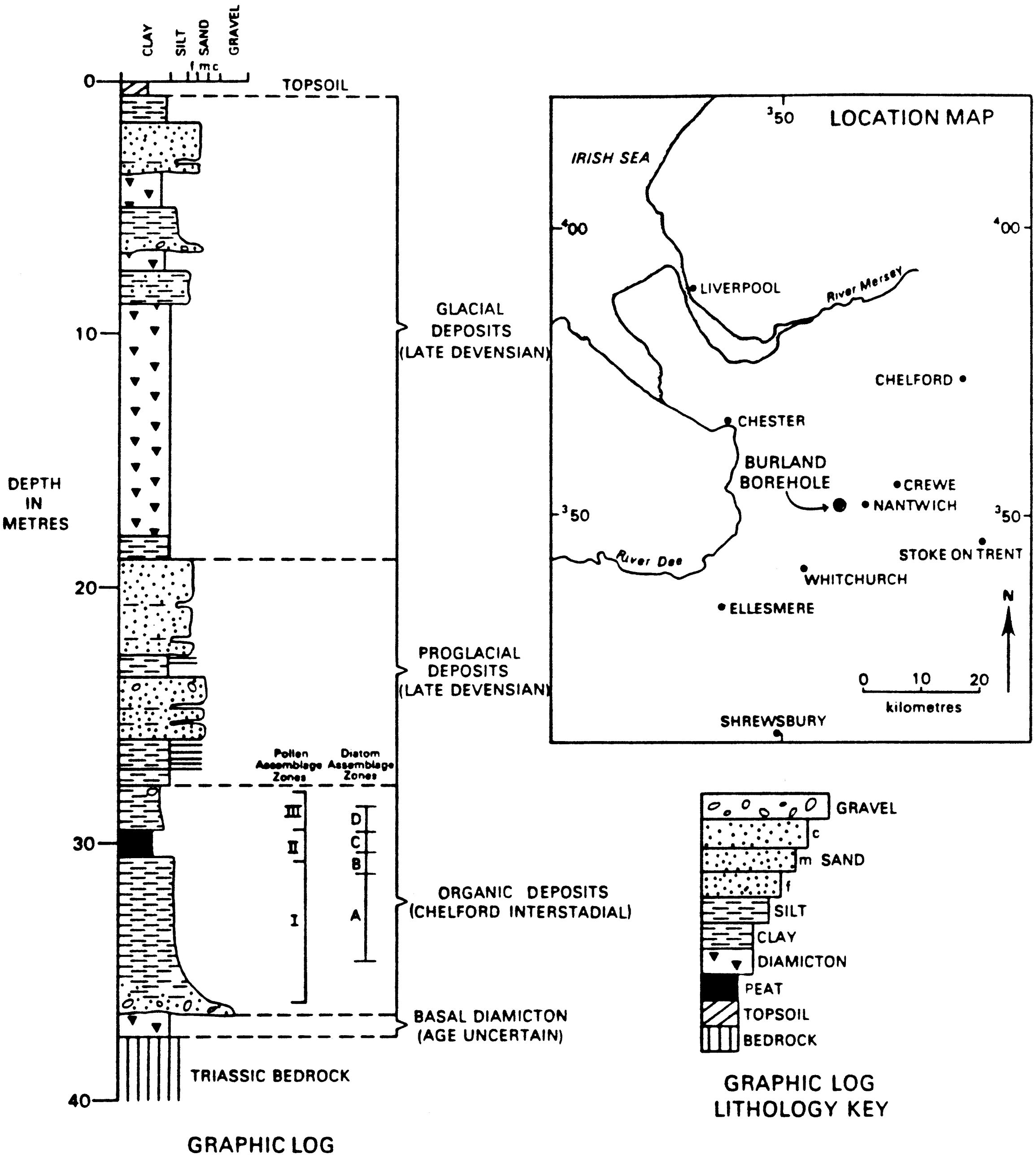

Fig. 1. Location map and lithostratigraphy of the Burland borehole.

numerous distinct clay-silt couplets each with a basal layer of sand commonly one grain thick. Many of the couplets have an upper darker clay layer sharply overlying lighter coloured silts; some resemble the "Case 7" varves of Sturm (1979). Individual rhythmites are commonly 1–3 mm thick, although some appear composite and larger units occur. If the individual units are annual varves, then about 600 years would have been required to form these lacustrine deposits.

The upper part of the proglacial deposits comprise sands with subordinate thin layers of silt and clay, some of which are massive and contained pebbles whilst others are pebble-free and finely laminated. The sands are commonly clayey and poorly sorted, containing thin seams of pebble and rare abraded shell fragments. Shell material has been reported from Devensian glacial deposits by Thompson and Worsley (1966) and interpreted as a derived marine fauna. Overall the sands are moderate brown (5YR 4/4) in colour, generally medium to fine-grained and comprise rounded quartz grains with numerous fragments of grey and red Triassic siltstone, fine sandstone, gypsum and aggregates of quartz grains cemented by pyrite. The more clayey and cohesive parts of the sands display small-scale cross bedding. The sediments are interpreted as proglacial, glacifluvial and glacilacustrine deposits, laid down ahead of the advancing Late Devensian ice-sheet.

4. **Glacial Deposits** (0.3–18.9 m)

Between 18.0 and 18.9 m the borehole encountered a silty clay in which sand laminae 1–3 mm thick picked out small-scale folding and faulting. The silty clay is moderate brown (5YR 3/4) in overall colour and characterised by numerous slickensided and sometimes striated surfaces interpreted as shear planes. Initially the deposit, which is over-consolidated was probably a glacilacustrine rhythmite, subsequently sheared and deformed, probably by an overriding ice-sheet. It may be termed a deformation till after Elson (1961); such subglacial sediment deformation has been observed by Boulton (1979).

A 10.5 m-thick uniform massive over-consolidated stony diamicton overlies the deformed beds between 8.5 and 19.0 m. This deposit is a moderate brown (5YR 3/4) calcareous sandy clay studded with numerous pebbles. It contains rare lenses of sand and silt up to 20 mm thick. The composition of the pebbles for three diamicton samples (BUR 12, 13 and 15) shows abundant material of non-local origin (Table 1); the deposit is regarded as a lodgement till.

The upper-most part of the glacial deposits (0.3–8.8 m) is a sequence of stratified clayey sands and silts interbedded with diamicton layers (Fig. 1). The stratified sediments are commonly poorly sorted and, where clayey, are commonly calcareous and contain small shell fragments. The matrix of the diamicton layers and their pebble composition (Table 1–BUR 8) appears to be lithologically similar to those of the thick underlying diamicton and so are also regarded as tills. We regard this sequence as the product of ice-sheet stagnation and supraglacial sedimentation.

In the absence of any data to the contrary, it is assumed that these glacial deposits were laid down by the Late Devensian ice-sheet that covered the Shropshire-Cheshire basin between 25 and 14 Ka (Worsley, 1985).

Diatom Analysis

Fifteen samples from between 25.2 and 35.5 m were analysed for diatoms and other siliceous remains. The results are summarised in Table 2.

Table 2 Diatom Assemblage Zones of the Burland Borehole

Diatom Assemblage Zone	No. of Samples	Depth (m)	Observations
-	6	25.2–29.5	No diatoms recorded
D	3	29.5–30.5	Many diatom fragments, occasionally identifiable, chrysophyte spores and grass silica present between 29.7 m and 30.3 m.
C	2	30.5–31.3	Many identifiable diatoms and fragments; occasional freshwater sponge spicules and chrysophyte cysts.
B	2	31.3–32.1	Few diatoms; sponge spicules present
A	2	32.2–35.5	Very few diatom fragments; sponge spicules present between 34.0 and 35.5 m

Interpretation and discussion

An abrupt transition, from peat containing diatoms below 29.5 m to clay devoid of diatoms above, indicates a distinct change in sediment source. Diatoms in all samples from below this horizon are eroded in appearance and there is a high proportion of fragmented specimens. Their generally poor condition suggests that much of the material may have been transported. Organic geochemical analysis of a sample from the silty clay (31.3—31.6 m) also indicates that this sediment was derived from both terrestrial and aquatic sources (having relative proportions characteristic of a mesotrophic lake), but few marker compounds indicative of aquatic biota were found in a peat sample from 30.0–30.3 m depth. (Dr P. Cranwell, pers. comm.).

All the samples that contain diatoms appear to represent essentially the same assemblage, which is diluted by clay minerals in the sections above 30.5 m and below 31.3 m depth. Two adjacent samples from between these depths, ie. one from the uppermost part of the silty clay and one from the transition to peat, contain enough diatoms for an assemblage analysis to be made from each. Taxa occurring at a frequency of 1% or more are listed in Table 3. Although the samples are similar in composition, the chief difference is that the upper one is dominated by *Fragilaria elliptica*, a tiny form (Haworth, 1975) that is not at all conspicuous in other samples. This diatom is common in early post-glacial sediments and is either a planktonic form or benthic among aquatic weeds in lakes. The predominant diatoms in both samples are those of shallow waters: *Cocconeis, Epithemia* and *Rhoicosphenia* spp. are typically epiphytic on littoral water weeds (algae, mosses or higher plants). *Fragilaria* spp. abound both amongst weed and on sediments, and are dominant in the minerogenic environments typical of the early Flandrian (Haworth, 1975). *Navicula* and *Gyrosigma* spp. are benthic dwellers that glide on the sediment surface. Only a few specimens of a planktonic form, *Cyclotella comta*, were seen: lack of planktonic forms is typical of the interstadial deposits of the Late Devensian, even in deep lakes. Possibly other planktonic algae which do not leave remains in sediment may have dominated the flora. Although chrysophyte cysts occur in many samples, no scales were observed.

Table 3 Percentage composition of diatom assemblage in two samples from DAZ 3 in Burland borehole

	30.5–30.8 m	30.8–31.3 m
Achanthes lanceolata (Bréb.) Grun.	+	1
A. minutissima Kütz.	1	-
A. cf. *peragalli* Brun	1	-
Amphora ovalis var. *libyca* (Ehr.) Cleve	2	2
A. ovalis var. *pediculus* (Kütz.) Van Heurck	2	3
Caloneis bacillum (Grun.) Mereschkowsky	-	1
C. fasciata var. *fonticola* (Grun.) Petersen	-	2
Cocconeis placentula Ehr.	11	18
C. placentula var. *euglypta* (Ehr.) Grun.	7	16
Cyclotella comta (Ehr.) Kütz.	+	2
Epithemia turgida (Ehr.) Kütz.	1	4
E. zebra (Ehr.) Kütz.	1	3
Eunotia lunaris (Ehr.) Grun.	-	2
Eunotia pectinalis (Kütz.) Rabh.	-	3
Fragilaria brevistriata Grun.	1	-
F. construens var. *binodis* (Ehr.) Grun.	2	-
F. construens var. *venter* (Ehr.) Grun.	+	2
F. elliptica Schumann	52	7
F. pinnata (Ehr.)	8	-
Gomphonema angustatum (Kütz.) Rabh.	+	2
G. gracile Ehr.	+	1
Gyrosigma acuminatum (Kütz.) Rabh.	+	3
Navicula lanceolata (Agardh) Ehr.	+	2
N. radiosa Kütz.	+	2
Nitzschia spp.	1	4
Rhoicosphenia curvata (Kütz.) Grun.	1	2
Synedra cf. *ulna* (Nitzsch) Ehr.	1	4
Other	6	14

The presence of freshwater sponge spicules in samples from the silty clay suggests that the site of deposition was either a shallow lake or a slow-moving river. The diatom assemblage consists, in the main, of taxa found more commonly in alkaline than in acid water, although more *Eunotia* and *Pinnularia* spp., typical of the acidic waters of, for example, Sphagnum peat pools, were found in the topmost peat sample. Occasional specimens of *Anomoeoneis sphaerophora* (Kütz) Pfitzer and *Nitzschia opiculata* (Gregory) Grunow *sensu* Hunstedt (1930), which are more usual in water of high salinity or conductivity, were found in DAZ3 and were presumably derived from habitats affected by local salt deposits.

Pollen Analysis

Samples of the organic-rich deposits between 27.7 and 36.2 m in the borehole contained countable pollen. The resulting profile (Fig. 2) can be divided into three distinct Pollen Assemblage Zones (see Fig. 1), the main characteristics of which are as follows:-

Pollen Assemblage Zone Burland I (PAZ Bu I). A pine-birch zone (30.8–36.2 m) is characterized by high values for *Pinus* 39–62% Arboreal Pollen (AP) and *Betula* (37–61% AP), and by the virtual absence of other tree pollen taxa. Herbaceous pollen makes up between 16% and 38% TDP (Total Determinable Pollen).

PAZ Bu II. A pine-birch-spruce zone (29.5–30.8m) is characterized by maximum values for *Picea* (up to 21% AP) and *Pinus* (up to 70% AP). Percentages of *Betula* are lower than in Zone I, reaching a minimum of 16% AP for the profile. Percentages of Gramineae and Cyperaceae are higher than in Zone I, as is total herbaceous pollen (between 21% and 54% TDP).

PAZ Bu III. A birch-pine-alder-juniper zone (27.7–29.5 m) is characterized by maximum percentages of *Betula* (up to 80% AP) and by declining values for *Pinus* and *Picea*. *Alnus* reaches a maximum (10% AP), as do values for *Juniperus*, ericaceous taxa, Cyperaceae and the spores of Polypodiaceae and *Sphagnum*. Total herbaceous pollen comprises 40–46% TDP.

Interpretation and Discussion

The biogenic profile begins after the establishment of pine-birch forest: there is no evidence of earlier, pioneer vegetation of 'late-glacial' type.

Many of the herbaceous taxa recorded from PAZ Bu I are likely to have formed tall herb communities around the open water in which the aquatic taxa recorded were living. There is little evidence of plants of open ground in the pollen record, so vegetation cover was probably fairly complete. *Picea* appears to have become established at the expense of *Betula*, since percentages of the latter decrease as those of *Picea* increase in PAZ Bu II. The transition between PAZ Bu I/II is abrupt and is marked by peaks in percentages of Gramineae and Cyperaceae pollen. Conditions at the site of deposition may have been responsible for these features since changes in water level, for example, could have favoured the expansion of such plants as *Phragmites* and reedswamp sedges. The high proportion of degraded pollen at this horizon also suggests that some alteration occurred in the deposition and/or preservation of pollen.

The transition between PAZ Bu II and III is even more abrupt: percentages of *Pinus* and *Picea* decrease and those of *Alnus*, *Corylus*, Ericaceae, Compositae, *Succisa*, Polypodiaceae and *Sphagnum* rise immediately at the zone boundary to maxima for the profile. It is unlikely that this rapid shift in pollen spectra is wholly a reflection of vegetational change. More probably, the PAZ Bu II/III boundary (which coincides with a sharp stratigraphical change from peat below to clay above) marks the level in the profile at which recruitment to the deposition site of chiefly local and contemporary pollen became augmented by significant proportions of pollen derived from soils and drift in the area. Many of the taxa that peak just above the PAZ Bu II/III boundary are those with relatively thick exines which resist destruction and are often preserved preferentially in minerogenic deposits from which more fragile pollen taxa have disappeared. An increased contribution of allochthonous material would also account for the high proportions of degraded pollen and pre-Quaternary spores found in these samples. The upper limit of PAZ Bu III is drawn arbitrarily at the level above which samples were too poor in pollen to count.

Some aspects of the PAZ Bu III pollen spectra may indicate real vegetational change, for example the increasing curve for Cyperaceae pollen and the high percentage of *Juniperus* found in the topmost countable sample. Neither of these taxa is notably resistant to destruction (in comparison with those mentioned above), so it may be that there was a temporary response by herbs and light-demanding shrubs like juniper to an environmental change that reduced tree cover. Possibly, fire terminated the local development of boreal forest around this site, since the samples from 28.3 to 29.5m contain many small black fragments which may be charcoal. There is stronger evidence, however, that the environmental change manifested at the PAZ Bu II/III boundary was predominantly climatic, since samples from above this horizon are from clays which become laminated above 27.7 m depth: these are thought to be the sediments laid down in a proglacial lake. No countable pollen was found in the laminated clay. The most likely explanation for the sequence of events above the PAZ Bu II/III boundary is that climatic deterioration ended the dominance of boreal forest, brought about an increase in the erosion rate of the local land surface, and provided open conditions which could be exploited, temporarily, by non-tree vegetation until its eventual extinction by the onset of glacial conditions.

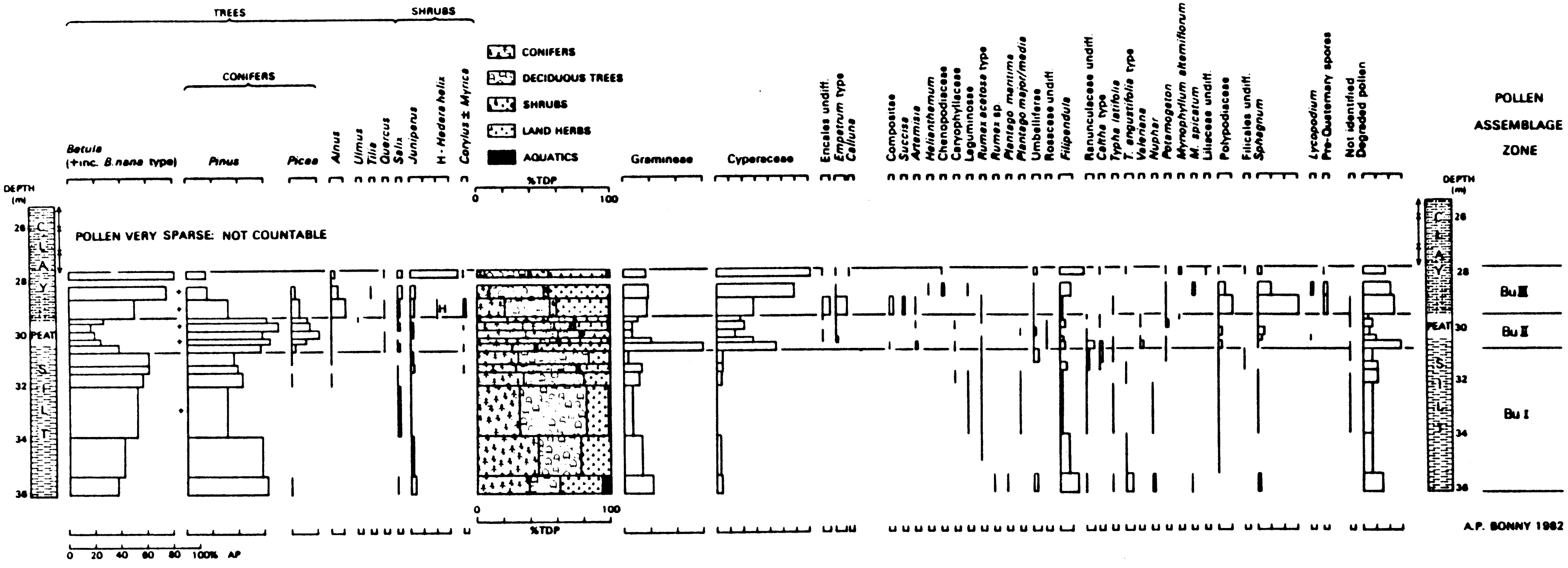

Fig. 2. Pollen diagram from Burland borehole. Individual pollen and spore taxa are plotted as percentages of total Arboreal Pollen. Summary diagram included shows groups of taxa plotted as percentages of Total Determinable Pollen.

Correlation of Pollen Profile

The pollen profile from Burland is incomplete since it lacks evidence of pioneer vegetation and passes upwards into minerogenic sediments which contain an admixture of derived palynomorphs. However, it shows clearly the development of boreal forest with an accompanying ground flora of predominantly damp and aquatic habitats.

The chief feature of the diagram (Fig. 2) is the rise of the curve for *Picea* pollen during the period when *Pinus* pollen percentages are at a maximum. This circumstance has not been recorded from interglacial successions, but is found in the interstadial profile from Chelford (Simpson & West 1958), which the diagram from Burland (only 30 km distant) resembles in many respects. The diagram from Chelford does not include the pre-*Picea* phase shown at Burland (PAZ Bu I), neither nor does it include problematical pollen spectra of the type that characterise PAZ Bu III. The whole of the Chelford profile can be correlated most readily with PAZ Bu II, representing the period when *Pinus-Betula-Picea* forest was the dominant vegetation, although *Picea* pollen percentages are higher at Burland (up to 21% AP) than at Chelford (up to 8% AP).

Other similarities between the sites in respect of tree pollen are the occurrence in low frequencies of *B. nana* pollen as a proportion of total *Betula* throughout the *Pinus-Betula-Picea* phase, and the occasional presence of the pollen of thermophilous trees, ie. *Alnus, Ulmus, Carpinus, Quercus* and *Corylus*, presumably recruited by long-distance transport. Diagrams of both sites indicate the presence of the herbaceous vegetation of conifer forest (eg. *Empetrum*—although the incidence of Ericaceae is higher at Chelford), of damp habitats (eg. *Filipendula* cf. *ulmaria* and *Valeriana*, probably *V. dioica*) and of forest pools (eg. *Caltha* type, *Myriophyllum* and *Typha*). Neither site shows much evidence of the local presence of open ground, although such taxa as *Artemisia* and *Helianthemum* occur in low frequencies.

Simpson & West (1958) considered that the geographical affinities of the vegetation represented at Chelford lie with the northern conifer-birch region, more specifically with the type of forest found between 63° N and 60°N in Finland, north of the limit for deciduous thermophilus trees, but south of the northern pine forest limit. Certainly, modern pollen spectra from lake sediments in this region (eg. Prentice 1978) resemble in many respects those from Chelford and from PAZ Bu II at Burland. The latter correspond best with spectra from the northern subregion of Finnish boreal forest, although percentages of *Betula* are rather lower at Burland. Pollen assemblages of PAZ Bu I (not represented at Chelford) show reasonably good agreement with spectra from lakes farther north in Finland where birch forest is dominant. Both PAZ Bu I and Bu II have higher proportions of Non Arboreal Pollen (NAP) than are evident at the Finnish sites which they most resemble, and some different taxa are present. This is perhaps a reflection of local pollen recruitment at Burland, where the NAP is composed largely of taxa from damp habitats likely to have been close to the site of deposition.

From the present distribution of the flora and vegetation recorded, Simpson & West (1958) deduced that climatic conditions during the boreal forest phase represented in the Chelford profile were similar to those of central Finland today. The present distribution of the Coleoptera found as fossils at this site (Coope 1959, 1977) also suggest this: a continental climate with average July temperatures around 15 °C is indicated, being slightly cooler than the Cheshire Plain at the present day. Similar conditions are likely to have been obtained during the period of *Pinus-Betula-Picea* forest at Burland (PAZ Bu II) since the Coleoptera present in the peat layer show definite affinities with the Chelford assemblage (Dr R Coope, pers. comm.). The analogy between the pollen spectra of PAZ Bu I and those of northern birch forest in Finland suggests, however, that the preceding pine-birch phase at Burland was characterized by an even cooler regime.

Another site in the West Midlands, Four Ashes (Staffordshire), shows similarities with the profile from Chelford (and so with that from Burland) in respect of the assemblages of pollen and Coleoptera recovered from two detrital mud lenses at the base of gravels assumed to be of Early Devensian age (Morgan 1973; Andrew & West 1977). A third British deposit with possible affinity to Chelford and Burland has been described by West *et al.* (1974) from Wretton, Norfolk. Here, a pollen spectrum with high percentages of *Betula, Pinus* and *Picea*, but with very little NAP was thought to provide evidence of the local presence of boreal forest of the type represented at Chelford. However, Coleoptera from this site indicate a harsh climate of arctic severity and an extremely barren landscape with scant vegetation cover (Coope, 1975). It now seems that the Wretton pollen spectra resulted from the long-distance transport of tree pollen to a site where local pollen was extremely low. Lacustrine sandy muds and peat containing a *Pinus-Betula-Picea* dominated pollen assemblage, from Roosting Hill, Beetley, Norfolk have also been tentatively correlated with the Chelford Interstadial by Phillips (1976).

Of the continental European sites at which there is palynological evidence of interstadial conditions, that most likely to be correlated with Chelford (and so with Four Ashes and Burland) is the Brørup Interstadial of Jutland, Denmark, although in the view of Andersen (1961), this remains to be proved.

Radiocarbon Dating

Radiocarbon dating was attempted on four samples from the organic deposits in the Burland borehole. The results are as follows:-

Sample			Depth	Date (yrs. B.P.)
SRR 2117	A	Peat	29.5–29.7	30,780 + 360 −340
SRR 2118	B	Wood fragments	34.0–36.8	24,930 + 280 −280
SRR 2371	C	Peat	30.0–30.3	40,110 + 880 −790
SRR 2371	D	Peat	30.3–30.5	›47,200

Samples A and B, submitted first, gave ages in reversed stratigraphical order although there was no reason to suppose that the samples had been affected either by contamination with modern material or by any kind of hard-water error which could have increased the apparent age of the peat relative to that of the wood fragments. Furthermore, while both dates indicate that the organic layers formed before the maximum extension of the Devensian ice-sheet, neither was as old as might have been expected from the close resemblance between the pollen assemblages from Burland (PAZ Bu II) and Chelford, where the oldest finite 14C age from the Interstadial sediments has been dated at c. 60 Ka. In view of these uncertainties, the submission of two further samples was invited. These (C and D) were rather small, but yielded significantly older dates which are best regarded as an indication of the minimum age of the deposits (Dr D. Harkness, pers. comm.). Hence it is possible that the organic layers at Burland may have been formed during the Chelford Interstadial (Worsley, 1980).

The 'true' age of the type Chelford Interstadial deposits is likely to be older than 65 Ka and a pre-Devensian age for these deposits still cannot be completely discounted (Worsley, 1985).

Conclusions

The 37.5-m sequence of Quaternary deposits proved in the re-drilled Burland borehole is interpreted as follows:

Above the Triassic bedrock, the thin layer of stony clay which contains clasts of non-local origin is thought to be a till, probably of pre-Devensian age. Overlying it is a thick sequence of organic deposits—silty clays and a thin peat layer—which represent the infill sediments of a lake or an abandoned river channel that supported a varied aquatic biota. The pollen record from this section shows evidence for local pine-birch forest into which spruce migrated. The pine-spruce-birch character of the profile indicates a possible correlation with the record from Chelford, and 14C-dating results from the Burland deposits are not inconsistent with this interpretation.

Organic silts and clays of mainly terrigenous origin, containing much reworked and degraded pollen, overlie the peat. These are interpreted as the result of increasing soil erosion attendant upon climatic deterioration. The sequence passes upwards into laminated clay-silt sediments that were probably formed in a proglacial lake. There are no diatom deposits associated with this water body. The overlying sands, which contain thin layers of silt and clay, are interpreted as proglacial outwash deposits.

The outwash deposits are overlain by over-consolidated glacilacustrine sediments, much sheared and deformed, which are interpreted as a deformation till produced by an over-riding ice-sheet. This deposit is overlain by a massive, stony diamicton (also over-consolidated), interpreted as a lodgement till. The upper-most part of the glacial deposits is a sequence of stratified clayey sands and silts interbedded with diamicton layers: this is regarded as a product of suraglacial sedimentation in association with the stagnation of the Late Devensian ice-sheet.

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