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# QUATERNARY NEWSLETTER

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## EDITORIAL

Please accept my sincere apologies for the belated publication of this issue — due neither to technical difficulties nor the late arrival of copy but to matters related to my work for the British Geological Survey — which have to take precedence over all my other activities. Such pressing issues have included, for example, the production of new BGS exhibit for *The Green Show* (at the National Exhibition Centre between 20–24 June); this will take as its main theme the concept of 'Geology & You' or 'Geology in the Service of Mankind' and will address itself to one of the most important issues of this century, namely the need to strike a balance between the exploitation of the natural resources and the preservation of the environment. Like a number of other BGS exhibitions (such as *Ancestral Voices — an introduction to building stones, Aspects of Geology and Scenery in England and Wales* and *Geology and You* (or the geology of the domestic house)), the new exhibit will be displayed at fora around the UK — provided we can either hire (on a long-term basis) or acquire a female tailor's dummy as this item, fully clothed and made-up, is the centrepiece of the exhibit!

In the meantime, thank you for all your letters. It was good to hear from Graham Jardine, former Secretary of the QRA who initiated this publication way back, as he says, in September 1970, and from K W Bond, General Secretary of the Cumberland Geological Society, who freely admits to skimming the Newsletter in order to 'crib' ideas for the Society's own newsletter. However, the main part of Ken Bond's letter is related to the Society's programme of excursions and the publication of a supplement to Dr R A Smith's '*Bibliography of the Geology and Geomorphology of Cumbria*'. Both items are referred to in full in the letters' section of this issue.

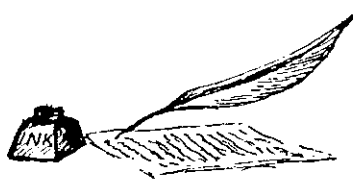
Finally, I received a letter from Esmée Webb (also reproduced in the letters' section) who feels 'so out of touch' in Western Australia — sorry Esmée, to hear of your plight. What about keeping us up-to-date with Quaternary news in your part of the world by becoming one of our foreign correspondents?

PS. A T Balkema

Thank you for your kind comments about our Newsletter. I shall include a note about your catalogue of books on the earth and space sciences in the next issue, if I may.

Brian J Taylor





## THE LIMITS OF THE LAST BRITISH ICE SHEET IN NORTHERN SCOTLAND AND THE ADJACENT SHELF

A M Hall and A J A Bent

### Introduction

Recently, several major reviews have proposed a revised model for the Late Weichselian glaciation of the Moray Firth region with an ice sheet of restricted extent terminating in the inner Moray Firth and leaving large parts of Caithness and Buchan ice-free (Fig. 1) (Sutherland, 1984; Bowen et al., 1986; Sejrup et al., 1987). This discussion paper assembles existing and new data on the Late Weichselian on-shore and offshore stratigraphy of this region which indicate that the last ice sheet extended well beyond the present coastline, covering the whole of the present land area: this interpretation supports traditional views of the extent of Late Weichselian glaciation in northern Scotland (Peach and Horne, 1881; Crampton and Carruthers, 1914).

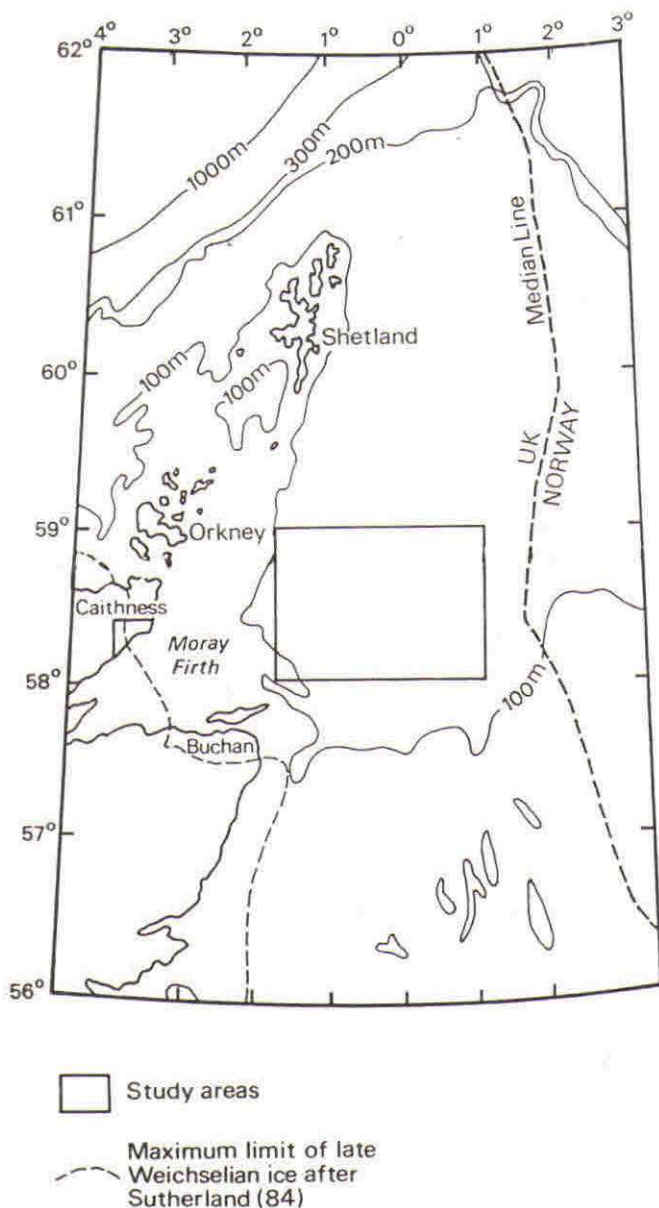
Until recently, it was widely held that the whole of Scotland as well as the whole of the northern and central North Sea basin was glaciated during the late Weichselian (e.g. Sissons, 1976). However, detailed studies of the North Sea sediments have revealed that the Scottish and Scandinavian ice sheets were not in contact during the Late Weichselian and were separated by a large marine embayment in which glaciomarine deposits were laid down, with dry land to the south (Cameron, Stoker and Long, 1987; Sejrup et al., 1987). Moreover, the discovery of late Middle to early Late Weichselian organic sediments covered only by solifluction deposits on St Kilda (Sutherland, Ballantyne and Walker, 1984) and northern Lewis (Sutherland and Walker, 1984) led to a realisation that the Late Weichselian ice sheet was less extensive than previously supposed. Speculation about the possible existence of an ice-free area in Buchan (Synge, 1956; 1963) throughout the Late Weichselian was also renewed after the discovery of peat dated to 26.4 ka overlain by solifluction deposits near Turriff (Connell and Hall, 1987). This chronostratigraphic evidence was combined with earlier, less reliable geomorphological criteria which suggested that surface till sheets in Caithness and Buchan were more weathered and disturbed by periglacial activity than those in other areas of Scotland as a result of these areas being ice-free during the last glaciation (Synge, 1956, 1963; Omand, 1973). This new model of restricted Late Weichselian glaciation in northern and north-east Scotland (Sutherland, 1984) has quickly gained a new and widespread acceptance (Bowen et al., 1986; Sejrup et al., 1987; Nesje and Sejrup, 1988) but has yet to be rigorously tested.

### Caithness

In Caithness, a tripartite drift sequence is traditionally recognised (Peach and Horne, 1881; Crampton and Carruthers, 1914). On the plain of Caithness, a shelly till was deposited by ice moving out of the Moray Firth. South and west of the margin of the shelly till there is a second till sheet deposited by ice moving out from the hills of southern Caithness and Sutherland. Both these till sheets are locally overlain in the main valleys by later deposits associated with hummocky topography and interpreted as marking the limit of a later advance of inland ice. Previously, none of the members of this drift sequence have been firmly dated. This has allowed speculation that the maximum limit of the Late Weichselian ice limit was marked by the morainic accumulations in the main valleys. By implication, the shelly till must predate the last glaciation. Some support for this view is provided by a date of >40 ka for shells from shelly till at Gill's Bay, Wick (Omand, 1973), although strictly this date is inconclusive (Sissons, 1981).

Recent mapping in SE Caithness has shown that the tripartite drift sequence relates to three main stages of glaciation (Hall and Whittington, 1989) (Fig. 2). In the lower valleys of the Berriedale and Dunbeath Waters, inland tills underlie shelly tills and demonstrate an early advance of inland ice to an unknown limit north of Latheron (Stage A). At a few sites in these valleys, however, the inland and

Figure 1 LOCATION



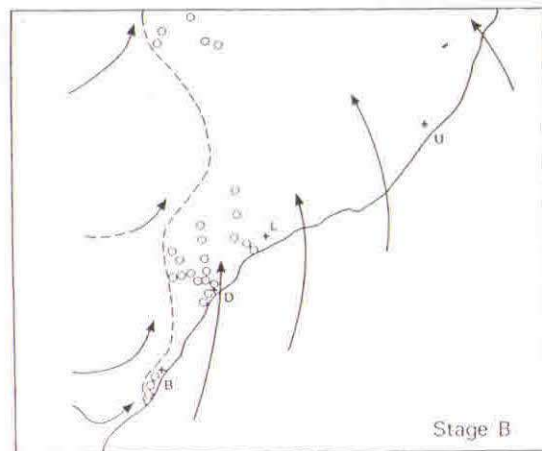
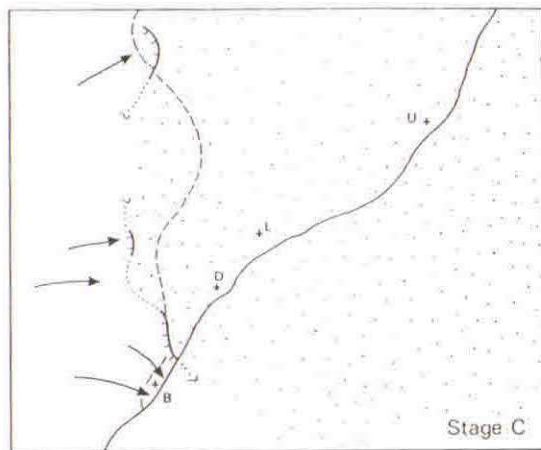
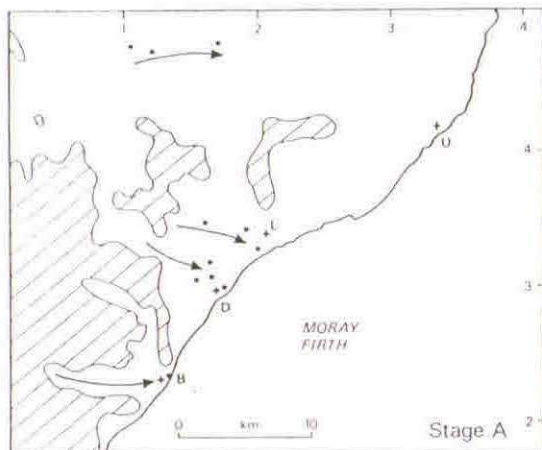


Fig 2 Main Stages of the Late Weichselian glaciation of South-East Caithness:

- Key
- Ice flow lines, based on till clast lithology and striations
  - - - Ice limit, based on drift limits and morphology
  - Inland till underlying shelly till from Moray Firth
  - Shelly till
  - < Western limit of the shelly till
  - Ice-free area
  - ▨ Ground over 180 m
- B Berriedale L Latheron  
D Dunbeath U Ullhyster



shelly tills are intercalated. This evidence, together with records of striations left by inland ice immediately west of the margin of the shelly till (Crampton and Carruthers, 1914), demonstrate that advance of Moray Firth ice caused a northward diversion of inland ice (Stage B). Around Berriedale, including the area previously occupied by shelly till ice during Stage B, loosely consolidated, sandy tills which form hummocky terrain were deposited during a final, localised and minor readvance of inland ice (Stage C). Crucially, nowhere is evidence seen within the till sequence of interbedded sediments, weathering profiles or periglacial features that might indicate subaerial exposure of the tills during or between the three flow stages. Accordingly, the tills are attributed to a single, complex phase of glaciation. There is strong circumstantial evidence that this phase dates from the Late Weichselian:

- 1 The tills are frequently overlain by periglacial slope deposits up to 2.6 m thick. Peats overlying till and underlying gelifluctates from two sites have been dated to the Windermere Interstadial (Hall and Whittington, 1989). These dates indicate that many of the periglacial slope deposits found in Caithness date from the Loch Lomond Stadial, as in Buchan (Connell and Hall, 1987), and not from earlier periglacial episodes.
- 2 Exposed bedrock ridges of Devonian sandstones and mudstones in the shelly till area retain many examples of striated surfaces (Peach and Horne, 1881; Crampton and Carruthers, 1914). There is no evidence that these surfaces were exposed to intense frost action throughout the Late Weichselian.
- 3 Isoleucine epimerisation ratios for shells in till from Latheronwheel indicate a Middle Weichselian age for the shells and hence a Late Weichselian age for the till (Bowen and Sykes, 1988).

If a Late Weichselian age is accepted for the tills of SE Caithness, then it is clear that the maximum ice limit during this glaciation must lie outside this area.

### Moray Firth

The stratigraphy of the outer Moray Firth has been studied using seismic records and borehole cores (Bent, 1986). Of particular interest is the discovery of a submerged topography of drift ridges and hummocks trending north-south (Fig. 3a and b). Washed pebbly muddy sands with striated clasts, interpreted as flow tills, extend west from the area of ridges and form the ridge itself. Immediately east of the ridge, layered sands and muds with dropstones pass eastwards into silty muds with decreasing numbers of dropstones and a more abundant indigenous micro-fauna. The dinoflagellate cyst assemblage contains high proportions of *B. tepikiense* together with specimens of *Spiniferites elongatus* Reid suggesting harsh climatic conditions associated with the Weichselian glacial maximum (Andrews et al., in press). The area of ridges shows deformation structures on sparker records and is interpreted as an ice-pushed ridge, here named the Bosies' Bank Moraine, and the muddy sediments to the east are interpreted as proximal and distal glaciomarine deposits. Sedimentary characteristics and morphological features in this area can be confidently attributed to glacial and glaciomarine processes related to a grounded tidewater glacier bordering a shallow epeiric sea. The glaciomarine deposits east of the moraine are correlated on the basis of seismic stratigraphy and faunal content with the Late Weichselian Marr Bank and Swathway Formation (Cameron, Stoker and Long, 1987). We therefore conclude that the Bosies Bank Moraine marks the maximum eastern extent of the Late Weichselian ice sheet in the Moray Firth.

During the early stages of deglaciation, glaciomarine sediments were deposited in front of a retreating ice margin. These sediments probably correlate broadly with the glaciomarine silts at St Fergus dated to 15.3 ka (Hall and Jarvis, 1989). This phase was succeeded by isostatic uplift of and marine regression from the previously glaciated area west of the Bosies' Bank Moraine and subaerial dessication of sediments on the moraine. Exposure implies that the ice sheet retreat in this part of Scotland took place prior to the wasting of the main Laurentide and Scandinavian ice sheets when global eustatic sea levels were still low.

### Buchan

Three major ice streams crossed parts of Buchan during the Weichselian from the eastern Grampians, Moray Firth and Strathmore. Tills derived from the west are found underlying deposits of the coastal

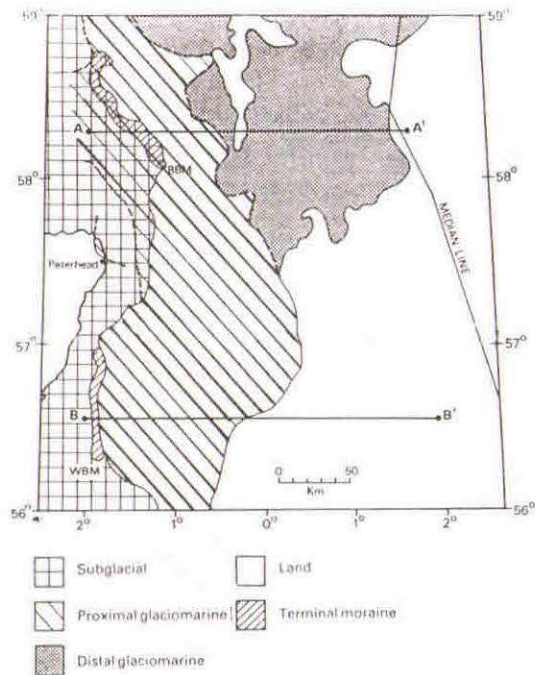


Fig 3a Late Weichselian Sedimentary facies in the west central North Sea

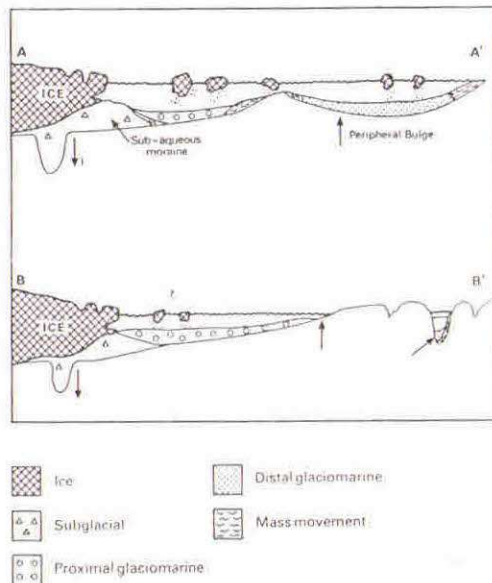


Fig 3b Development of Sedimentary facies associations

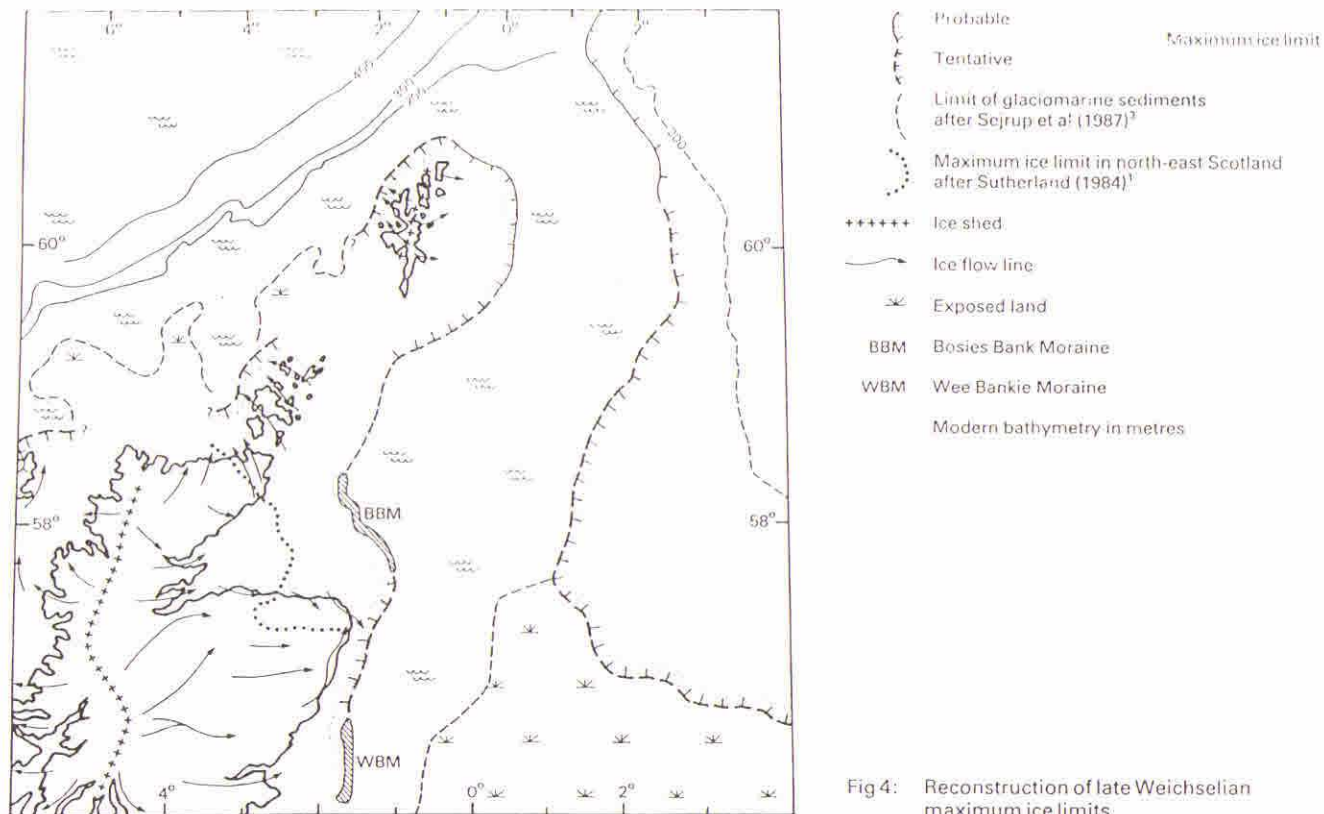


ice masses between Ellon and Peterhead and point to an early advance of inland ice beyond the present coastline. Ice streams from the Moray Firth and Strathmore ice sheets later invaded coastal districts and deposited the complex sequences of glacial, glaciofluvial, glaciolacustrine and glaciomarine sediments of the Blue-Grey and Red Series (Jamieson, 1906; Hall and Connell, 1990). During at least the later stages of this phase, inland ice had retreated westwards and thick fine-grained deposits were laid down in lakes ponded against the margins of the coastal ice masses (Hall, 1984). The timing of the existence of this ice-free enclave has been controversial. The late Middle Weichselian peat overlying inland till and overlain by solifluction deposits near Turriff indicates that the inland till here predates the Late Weichselian and that the ice-free enclave lasted throughout the last glaciation (Hall, 1984; Sutherland, 1984). An alternative view is that the ice-free area developed during Late Weichselian deglaciation (Clapperton and Sugden, 1977). The Late Weichselian maximum ice limits presented here indicate that ice extended ca. 25 km from the present coastline of Buchan and therefore preclude the existence of an ice-free area throughout the Late Weichselian. Projection of theoretical ice sheet profiles for rigid glacier beds (Nye, 1952) give ice thicknesses of c. 1 km in central Buchan. Even the more realistic adoption of lower ice gradients and basal shear stresses for ice movement across deformable sediments (Nesje and Sejrup, 1988), in this case the thick Quaternary sediments and soft Mesozoic mudstones of the Moray Firth, still produces ice thicknesses in central Buchan of up to 500 m. Further evidence of full ice cover in Buchan during the Late Weichselian maximum is provided by the glaciomarine silts rising to ca. 7 m OD north of Peterhead and deposited at ca. 15.3 ka BP (Hall and Jarvis, 1989). The low global sea levels around this date mean that these silts can only have accumulated whilst this part of Buchan remained depressed from a recently removed ice cover of considerable thickness.

### Late Weichselian maximum ice limits

Data from the key areas of south-east Caithness, the Moray Firth and Buchan indicate that the last Scottish ice sheet was much more extensive than recently proposed. It is likely that the ice sheet extended over northern Caithness and Orkney. It has long been known that shelly diamicts extend across much of Caithness and Orkney. Existing descriptions indicate that these diamicts are glacial rather than glaciomarine deposits as the diamicts rest on striated bedrock surfaces, contain striated clasts, locally show strong clast fabrics and include relatively little water-lain sediment (Peach and Horne, 1880, 1881; Crampton and Carruthers, 1914; Omand, 1973; Rae, 1976). In south-east Caithness, the shelly till is of Late Weichselian age (Hall and Whittington, 1989). As yet there is no stratigraphic evidence that more than one shelly till exists in northern Caithness, although two superposed shelly tills occur at Den Wick, Mainland, Orkney. Hence on present evidence it is likely that almost all the shelly tills of Caithness and Orkney form a single till sheet deposited by ice moving out of the Moray Firth in the Late Weichselian. The maximum limit of Late Weichselian ice in northern Scotland, therefore, probably lies at least as far north as the Orkney-Shetland channel.

A revised maximum limit for the last ice sheet can now be defined (Fig. 4). Evidence currently exists for two Late Weichselian terminal moraines in this part of the North Sea, the Bosies' Bank Moraine and the Wee Bankie Moraine (Holmes, 1977) off Stonehaven. The extent of the marine basin separating the Scottish and Scandinavian ice sheets is defined by the distribution of the glaciomarine deposits of the Marr Bank and Swathway Formations (Holmes, 1977; Cameron, Stoker and Long, 1987) and provides an important constraint on the eastern extent of the ice margin. It is notable that the tills deposited by the grounded Moray Firth ice lobe west of the Bosies' Bank Moraine do not occur below the present 100 m bathymetric contour and that glaciomarine deposits in the outer Moray Firth and west of Orkney and Shetland rarely occur above this limit. This accords generally with estimated relative sea levels of -100 to -130 m at the last glacial maximum at ca. 18 ka BP (Jansen et al., 1979). Recent work on tidewater ice sheets and glaciers has shown that sea level exerts a fundamental control on the position of the glacier front as calving rates increase logarithmically with water depth (Brown, Meier and Post, 1982). The last Scottish ice sheet is known to have terminated in sea water north-east of Shetland (Cameron, Stoker and Long, 1987) and at the Bosies' Bank and Wee Bankie moraines and the widespread distribution of glaciomarine deposits in the outer Moray Firth (Fig. 3a) and west of Orkney and Shetland (Sejrup et al., 1987) suggests that termination in tidewater was widespread. The ice sheet is unlikely to have advanced far beyond the present 100 m bathymetric contour, as rapid calving in the marine basin would have produced unsustainable ablation. Therefore, where no other evidence is



available, it is suggested that as a first approximation the ice sheet limit can be placed at this contour. This approximation ignores the potential complexity of isostatic/eustatic effects in the corridor between the Scottish and Scandinavian ice sheets, notably the likelihood of peripheral bulging beyond the ice sheet margins (Fig. 3b), and may over-estimate the actual extent of the ice sheet as no ice-free land areas are recognised on the Scottish shelf west of the 100 m bathymetric contour.

The Bosies' Bank Moraine extends northward towards Fair Isle. This island apparently lay at the southern part of the Shetland ice dome during the Late Weichselian (Flinn, 1978). Ice limits off Shetland are from Long and Skinner (1985) and suggest a markedly asymmetric ice dome. Ice from the Moray Firth passed WNW across the northernmost of the Orkney islands (Peach and Horne, 1893) to terminate in the marine embayment west of Orkney (Cameron, Stoker and Long, 1987). It is uncertain whether Orkney and Shetland ice were contiguous.

A remarkable feature of this reconstruction is the manner in which ice flow lines diverge away from the Moray Firth. Previously, this divergence has been attributed to diversion due to the presence of Scandinavian ice in the North Sea (Peach and Horne, 1881; Flinn, 1978). It now seems accepted, however, that Scandinavian ice did not cross the North Sea in the Late Weichselian (Cameron, Stoker and Long, 1987; Sejrup et al., 1987). Similar divergent ice flow to that in the Moray Firth occurred during the Late Weichselian as ice moved out of the outer firths of Forth and Clyde (Sutherland, 1984). Abrupt changes of ice flow directions are known from the last Laurentide ice sheet where ice moved from rigid to deformable beds (Fisher, Reeh and Langley, 1985). The divergent ice flow lines of the last Scottish ice sheet are probably a related effect reflecting movement from topographically constrained upland channels with rigid beds to open lowlands underlain by large thicknesses of deformable sediments.

The sequence of Late Weichselian glaciation in northern Scotland can also be tentatively reconstructed. Between 30 and 25 ka BP ice sheet build-up began in Scotland. The first ice to advance into Caithness and Buchan came from neighbouring upland areas, as shown by the presence of inland tills underlying tills and other deposits derived from the present beds of the Moray Firth and North Sea. Assuming a vertical thickening rate of 0.3 m per year (Price, 1983) this stage could have been reached within 5 ka of the start of ice sheet build-up. By the glacial maximum, however, ice discharge from the western parts of the ice sheet via the Moray Firth had increased sufficiently to allow incursion of this ice stream into Caithness and northern Buchan to deposit shelly tills and cause diversion of inland ice. The strengthening of ice flow out of the Moray Firth may reflect a drop in effective precipitation over eastern highland areas as ice build-up progressed. The timing of the maximum expansion of the last ice sheet in northern Scotland is not known. However, deglaciation was already well-advanced by 15.3 ka, with retreat of ice from the Buchan coast around St Fergus (Hall and Jarvis, 1989) and deposition of broadly contemporaneous glaciomarine deposits in the inner Moray Firth west of the Bosies' Bank Moraine in front of a retreating ice margin (Bent, 1986). Subsequent marine regression in the Moray Firth probably occurred prior to the rapid rise in global sea levels after 14 ka BP (Ruddiman and McIntyre, 1981). This interpretation conforms with earlier suggestions that rapid wastage of the Scottish ice sheet took place whilst the climate remained still very cold (Sissons, 1981; Sutherland, 1984; Bowen et al., 1986) and apparent early deglaciation on Tayside, prior to 14 ka BP (Browne, 1980). In Caithness, withdrawal or stagnation of Moray Firth ice was followed by a minor readvance of inland ice (Crampton and Carruthers, 1914; Hall and Whittington, 1989).

The reconstruction of the last ice sheet presented here represents a return to earlier views of ice extent in northern Scotland (e.g. Sissons, 1976). At the maximum of the last glaciation, the Scottish ice sheet terminated in tidewater along much of its margin in northern Scotland and fluctuating sea level probably exerted a fundamental control over its extent. The outer parts of the ice sheet moved across deformable beds and almost certainly had low ice surface gradients similar to those recently proposed for the outer parts of the last Scandinavian ice sheet in the eastern North Sea (Nesje and Sejrup, 1988). Almost all the present Scottish land area was covered at the Late Weichselian glacial maximum, the only significant exception being the small enclave on Lewis (Sutherland and Walker, 1984). During the Late Weichselian, an early advance of inland ice was followed by incursion of Moray Firth ice streams probably immediately prior to the glacial maximum. The timing of the onset of deglaciation is unknown but ice had retreated ca. 25 km from its maximum position off the present Buchan coast by 15.3 ka. A minor readvance of inland ice occurred in Caithness during deglaciation (Hall and Whittington, 1989) but no equivalent event has yet been recognised south of the Moray Firth. However, complex deposi-

tional sequences laid down during deglaciation are known from coastal areas between Aberdeen and Elgin (Synge, 1963; Peacock et al., 1968; Peacock, 1971; Hall and Jarvis, 1989) which offer great scope for future research in tracing the pattern of events during ice sheet decay and retreat.

### Acknowledgements

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## **'CATASTROPHIC' DRAINAGE AND THE QUATERNARY RECORD**

### **I. CRITERIA FOR DEFINING 'CATASTROPHIC' DRAINAGE**

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#### **Introduction: The Problems**

This paper raises some important questions that Quaternary scientists should now be considering in the light of growing evidence from North America and Europe that 'catastrophic flooding' dominated the meltwater drainage regimes during ice-sheet deglaciation. First, despite the widespread use of the term 'catastrophic' there is no satisfactory or universal definition of this type of flood event. Second, an increasing number of sites in the UK are being interpreted as originating from 'catastrophic' flood events during ice-sheet deglaciation, although no definitive criteria have yet been proposed for the identification of such events in the Quaternary record. In addition, the wider environmental significance of 'catastrophic' drainage during deglaciation over large areas of the UK has not been addressed. These two major issues are considered in Parts I and II, respectively, of this paper; in both cases, guidelines are proposed for Quaternary scientists working in areas of possible 'catastrophic' drainage.

#### **Definition of 'catastrophic' drainage**

##### **Rationale**

The recent publication of at least three volumes of papers concerned solely with floods and their geomorphic effects (Mayer and Nash, 1987; Baker, Kochel and Patton, 1988; Bevan and Carling, 1989) appears to reflect the increasing realisation that high magnitude events are of great importance in modifying the earth's surface. However, few papers even attempt to define what is meant by 'catastrophic' except in the vaguest terms. Hence, Mayer and Nash (1987) describe 'catastrophic' floods simply as floods of "high magnitude and low frequency, devastating or resulting in significant changes in stream channel or stream valley characteristics". Cooper et al. (1990) describe catastrophic sedimentation events as those of low frequency and high intensity that can be considered as geologically instantaneous. Shulmeister (1989) classifies flows that are able to suspend cobble-sized material as 'catastrophic', while Shaw and Sharpe (1987) regard sudden glacial outburst floods with 'catastrophic' events. Definitions like these are conspicuously unhelpful to geomorphologists working in the Quaternary record. It is clearly essential, therefore, that we identify the criteria by which an event or a deposit is considered to be of 'catastrophic' origin.

The major issues that arise in developing the criteria for distinguishing 'catastrophic' events from 'normal' or 'exceptional' events (Reading, 1986) concern (1) the magnitude and frequency of the event, (2) the timescales involved, (3) the nature of the drainage environment, (4) the geomorphic and sedimentological impact of the event and (5) the preservation potential of different components of the sedimentary record.

### Issues arising from recent literature

The need for a clear definition of 'catastrophic' flood events (and of the deposits and landforms arising from these events), based on the criteria previously cited, is best illustrated by reference to some specific examples. Within a sub- or englacial environment, sediment transport and channel processes may favour chaotic or 'catastrophic' sedimentation even under 'normal' conditions. High water pressures, smooth tunnel walls, and large amounts of readily available sediment will result in 'flood' flow conditions representing the 'normal' meltwater regime. A recent paper (Shulmeister, 1989) concerning esker sedimentation came to a 'catastrophic' conclusion without further definition. The large number of Late Devensian eskers in Scotland, for example, which exhibit coarse cobble-boulder cores (Sissons, 1967; Garbutt and Russell, in prep), suggests that 'catastrophic' drainage may well have been the 'norm' during deglaciation. What, therefore, is meant by 'catastrophic' in this context? Although the flow events were of 'high magnitude' they do not appear to have been exceptional or rare.

Similarly, jökulhlaups produced by the drainage of ice-dammed lakes, are often regarded as 'catastrophic' events. Such jökulhlaups can occur as one-off events or as a series of events related to repeated filling-and-draining cycles of the lake. What controls whether the flood events are indeed 'catastrophic' or are not? For example, there appear to have been up to 80 huge flood events draining from Lake Missoula during its lifetime, with peak discharges reaching  $10\text{--}15 \times 10^6 \text{ m}^3 \text{ s}^{-1}$  and with recurrence intervals of 40–60 years (e.g. Waitt, 1980, 1984; Craig, 1987). Were these events therefore 'exceptional'? Should the degree to which events (or populations of events) are considered to be 'catastrophic' depend only on magnitude and frequency of these events, or also on the impact of these events? Regular sudden drainage from ice-dammed lakes along the margin of the Greenland ice-sheet (Russell, 1989a, b, c), and in front of some Alaskan glaciers (Fahnestock and Bradley, 1973), for example, has had little geomorphic impact on the flood routeway since the first flood occurred (Russell, 1989b, c). The Lake Missoula flood routeways may also have been modified only by the first few floods, following which the drainage system became relatively stable and achieved a state of equilibrium with the flood drainage regime. By what criteria should we therefore classify such floods as 'catastrophic', if the geomorphic impact of the majority of the events was negligible?

The timescale of the drainage events is clearly relevant in this context. Long-term patterns of ice-marginal lake drainage, for example, largely depend on the stability of the ice-dam. Ice-dammed lake drainage along a relatively stable section of the Greenland ice sheet occurs regularly with almost constant magnitude, suggesting that the WHOLE PHASE (here, lasting for 10–10<sup>2</sup> years) of lake drainage (rather than individual events) should be considered as 'catastrophic'. Similarly, (Shaw, 1983, 1988; Shaw and Sharpe, 1987; Sharpe and Shaw, 1989; and Shaw et al., 1989) attribute the development of certain drumlin types and small-scale bedrock scour marks (flutes, scallops, potholes, etc.) in Canada to 'catastrophic' drainage beneath the Laurentide ice-sheet. However, the development of the latter features in particular, may require relatively stable or steady 'high magnitude' flows over a long period of time (Maizels and Russell, submitted). Otherwise, fractured bedrock is likely to be removed by hydraulic plucking, rather than sculpted into 'rock bedforms'. Relatively prolonged, stable, high magnitude flow conditions are most likely to be achieved during large-scale and rapid deglaciation, rather than by individual flood events spanning a few days. Hence, should we consider rapid deglaciation of the ice-sheets as catastrophic, rather than the individual events that were generated during this period of melting?

The preservation potential of the evidence of a former 'catastrophic' event will also govern its interpretation. If all earlier sedimentary or morphological evidence is removed by the last major flood to drain an area, then we have no measure of the relative importance of that event in relation to the longer term flow regime. Since most depositional records are largely incomplete, either as a result of periods of nondeposition or of subsequent removal, we will rarely be in a position to judge the relative significance of different drainage events during the Quaternary. Unless the flow regime (including flood and non-flood events) can be established (e.g. from lake sediment sequences; see Waitt, 1980), we are therefore not in a position to be able to determine, in terms of the normal flow regime, whether events recorded in the Quaternary sedimentary record were indeed 'catastrophic' or not.

## **Criteria for identification of 'catastrophic' flood events and associated deposits in the Quaternary record**

We consider that any classification of Quaternary deposits or landforms as being of 'catastrophic' flood origin should: (1) define the criteria on which this interpretation is based, and (2) evaluate the extent to which other factors might affect the interpretation. We suggest that the following criteria should be used to define 'catastrophic' events.

### **1 Hydrologic criteria: magnitude/frequency of the flow event**

The relative importance of the identified event in relation to the complete population of flow events needs to be evaluated. A 'catastrophic' event can then be defined in terms of one or more of the following criteria:

- (A) the likely RECURRENCE INTERVAL of the flood event (e.g. a recurrence interval of 10, 10<sup>2</sup>, 10<sup>3</sup> or 10<sup>4</sup> years);
- (B) the RATIO OF PALEOFLOOD MAGNITUDE TO PRESENT-DAY PEAK FLOWS in the same river system or catchment (e.g. order of magnitude difference in peak flows). However, comparison of Quaternary flows with those of the present-day can be misleading, since former 'catastrophic' flows may have represented 'normal' drainage conditions during deglaciation;
- (C) the extent of which the identified event represents DISTINCT POPULATION of exceptional events.

While there are a variety of techniques available for estimating former flow magnitudes and stream powers to at least one order of magnitude (e.g. Baker, 1973; Baker and Nummedal, 1978; Maizels, 1983, 1987, 1989a, b), the difficulty of obtaining a precise chronology for selected flow events and of determining flood frequency for events recorded in Quaternary sediments remains a major obstacle to achieving a convincing interpretation on the basis of hydrologic criteria alone.

### **2 Impact criteria: geomorphic and sedimentologic evidence**

The extent to which a flow event is described as 'catastrophic' can depend on evaluation of its geomorphic impact on the flood routeway. The impact may be assessed in terms of both erosional and depositional forms, although the composite nature of many landforms, and the relation of geomorphic features to individual rather than to series of flow events, may remain uncertain.

#### **(A) GLACIOFLUVIAL DEPOSITS**

Glaciofluvial sediments of many types have now been interpreted as 'catastrophic' flood deposits. However, only rarely have the criteria for making this classification been discussed, while interpretations have normally been based on the estimated paleoflow magnitudes and depositional features compared either with those of present-day rivers in the same area, or with those described as 'catastrophic' in other areas.

The types of glaciofluvial sediments interpreted as 'catastrophic' flood deposits range from boulder deltas and boulder beds (e.g. Elfstrom, 1983, 1987; Elfstrom and Rossbacher, 1985; Shakesby, 1985; Williams, 1983); coarse openwork and poorly imbricated cobble beds (e.g. Church and Gilbert, 1975; Clague, 1975; amongst many other studies); upward coarsening gravel sequences (Maizels, 1989b; Russell, b, c); thick units of structureless, massive sands and fine gravels (Maizels, 1989b); and coarse sand horizons within laminated silt + clay deposits (e.g. Waitt, 1980, 1984, 1985). In addition, large scale bedforms ('megaripples') and obstacle marks round boulders or former transported ice blocks (e.g. Baker, 1973, Maizels, 1989a, b; Russell, a, b, c, in prep) have been used as indicators of 'catastrophic' glacial floods.

#### **(B) EROSIONAL FEATURES**

The erosional features attributed to such flood events range from mega-scale landscape modification (e.g. the channelled scablands of the Missoula floods, Baker, 1973, Baker and Nummedal, 1978, etc.); to the innumerable drainage channels crossing the former ice-marginal terrains bounding the Laurentide ice-sheet (e.g. Kehew and Lord, 1987; Lord and Kehew, 1987); major spillway

routes between glacial lakes (e.g. Teller and Thorliefson, 1987); streamlined residual landforms (Fraser and Bleuer, 1988) and deep scour channels (e.g. the North German tunnel valleys, Ehlers, 1981; Ehlers and Linke, 1989).

### 3 *Environmental criteria: Quasi-Steady State V. Unsteady conditions*

One of the major controls on jökulhlaup generation during deglaciation of the last ice-sheets is likely to have been the rate of ice thinning i.e. the rate of ice-sheet ablation and marginal recession or wastage. The rate of ice decay would have controlled both the volume of meltwater production and the location and periodicity of ice-dammed lake drainage. Under stable ice-sheet conditions (forming the basis of most numerical models) jökulhlaup drainage is likely to be regular and of constant magnitude, allowing the proglacial drainage systems to reach a quasi-equilibrium state (as in the Alaskan and Greenland examples cited above). Hence, one cannot automatically assume that all jökulhlaup events are 'catastrophic' events in terms of their geomorphic impact, particularly when representing a 'non-catastrophic' or steady state of the ice-sheet. By contrast, where the ice-sheet itself is undergoing rapid, large-scale melting, generating consistently high magnitude runoff throughout each meltseason, these flows cannot be considered 'catastrophic' in hydrological terms (i.e. in relation to the 'normal' runoff regime, since high flows are now the 'norm'). Instead, we can consider the controlling environment (i.e. the ice-sheet) to be in an unsteady state: it is the ice-sheet which is undergoing 'catastrophic' decay.

## *Limitations of this approach*

### 1 *Interpretative framework*

The prevailing approach to the interpretation of Quaternary glaciofluvial deposits as representing 'catastrophic' events is based either on comparison with possible modern analogues or with apparently similar deposits elsewhere. This approach lacks a sound deductive base, and must at some stage be replaced by a formal or systematic analysis of the mechanics of major floods and the depositional sequences likely to be generated by such floods. Any rational interpretation of Quaternary flood deposits as 'catastrophic' or 'non-catastrophic' first requires a more theoretical, systematic, process-based framework. Such a framework would provide a theoretical link between the type of flood deposit and the associated hydrologic and hydraulic conditions (magnitude, frequency, sediment concentration, and hydrograph characteristics) of floods operating in different kinds of terrain and glacial environment. Similarly, we still require a systematic, hydraulics-based analysis of scour processes during high magnitude events in order to provide a sound framework for the interpretation of Quaternary erosional landforms. Until such frameworks are established, interpretation of Quaternary deposits as representing 'catastrophic' flood events will retain its somewhat subjective status.

### 2 *Timescales*

The degree to which events are regarded as 'catastrophic' will clearly depend on the timescale represented by that part of the Quaternary record that is under investigation. While a single event may appear 'catastrophic' over a short timescale (10<sup>2</sup> years), over the longer timescale it may represent only one of many similar events and hence become, in relative terms, 'non-catastrophic'. Any interpretation of such deposits therefore, must also indicate the timescale over which the event is being considered.

### 3 *Preservation potential*

The degree to which the full sedimentary record is preserved will also affect assessment of the longer term significance of the flow event being considered. Any interpretation of possible flood deposits must, therefore, consider both the evidence for other flood and non-flood events, and the likelihood that most of the depositional record and earlier geomorphic evidence has been removed.

### 4 *Nature of drainage routeway*

The geology and topography of the drainage routeway have a major role in controlling local variations in sediment supply and flood power (e.g. Baker and Costa, 1987; Russell, 1989b, c). This means that the dynamics of any particular flood event may vary significantly along the flood routeway, and in

response to any channel modifications achieved during earlier flood events. Hence, a flood event may be classified as 'catastrophic' on the basis of evidence from one part of the flood routeway, but as 'normal' in other reaches.

## Conclusions

Current interpretations of Quaternary deposits and landforms as 'catastrophic' are largely based on an empirical framework rather than a physically-based, deductive, theoretical framework. Until such a process-based framework has been established (see Part II of this paper), it is recommended that identification of 'catastrophic' events should be based on at least one of the following criteria:

- (1) **Hydrologic criteria:** (A) Magnitude/frequency relations or recurrence interval; (B) Ratio of former to present-day peak flow conditions; and (C) extent to which former flow event represented a distinct population of events;
- (2) **Geomorphic impact criteria:** (A) Sedimentary sequences; (B) Depositional landforms; and (C) Erosional features;
- (3) **Environmental equilibrium criteria:** Equilibrium status of controlling conditions (e.g. ice-sheet or glacier).

Finally, the Quaternary scientist also needs to be aware of the extent to which the identification of an event as 'catastrophic' has been affected by (1) the timescale represented by the period of drainage, (2) the degree of preservation of the sedimentary record and (3) the nature of the drainage routeway.

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## **'CATASTROPHIC' DRAINAGE AND THE QUATERNARY RECORD II. ENVIRONMENTAL SIGNIFICANCE OF 'CATASTROPHIC' FLOODS: POSSIBLE APPLICATIONS IN THE UK AND DEVELOPMENT OF A DATA BASE**

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### **Introduction**

In Part I of this paper, we demonstrated that despite the burgeoning literature on 'catastrophic' floods in the Quaternary record, there is still no systematic framework for defining 'catastrophic' events nor a rational or theoretical basis for such interpretations. We recommended the introduction of three empirical criteria to form the basis of future interpretations of 'catastrophic' deposits and landforms, at least until a process-based framework is available. This part of the paper considers the possible environmental significance of the increasing number of 'catastrophic' floods being identified in the Quaternary record, and particularly within the Late Devensian and Lateglacial periods in Britain.

### **'Catastrophic' drainage and ice-sheet decay**

'Catastrophic' outburst flooding of meltwaters is increasingly being recognised as the main form of drainage during deglaciation of the Pleistocene ice-sheets in North America, northern Europe and Iceland. Kehew and Lord (1987), working on the margins of the Laurentide ice-sheet, for example, argue that "catastrophic drainage for glacial lakes was the primary mechanism for transfer of glacial meltwater to the ocean", and that "every major valley contains evidence of catastrophic glacial-lake outbursts". There are now numerous examples in the North American literature of 'catastrophic floods' derived from sudden drainage of glacial lakes, ranging from the Missoula floods in the west (e.g. Baker,

1973; Waitt, 1980, 1984, 1985; Clarke et al., 1984; Baker and Bunker, 1985; Craig, 1987), to floods generated from drainage of Lake Agassiz, and the Huron-Ottawa-St Lawrence systems in the east (e.g. Fenton et al., 1983; Clayton and Attig, 1987; Teller and Thorleifson, 1987).

The evidence also indicates that 'catastrophic flooding' of glacial meltwaters is not confined to areas of impoundment of glacial lakes. Shaw (1983) and Sharpe and Shaw (1989) have argued for a 'catastrophic' flood origin for drumlins and small-scale bedrock erosional features in subglacial environments of the Laurentide ice-sheet. In Iceland, deglaciation during the Lateglacial and early Holocene was so rapid that 'catastrophic' drainage is likely to have dominated meltwater regimes for at least 1000 years (Ingolfsson pers. comm.). Indeed, recent analysis of the sedimentology and stratigraphy of the huge outwash sandur plains forming the south coast of Iceland indicate that they are composed of at least 85% 'catastrophic' flood deposits (Maizels, 1989a, b). While some of these may have originated from subglacial geothermal or volcanic activity, the earliest sandur deposits are believed to reflect flooding in response to 'catastrophic' rates of ablation and ice sheet retreat at the close of the Lateglacial.

These few examples alone suggest that 'catastrophic' meltwater drainage may have been a more universal characteristic of rapid deglaciation during the Late Devensian, or Lateglacial, than has hitherto been recognised. Indeed, there is now growing evidence from the UK of (1) a large number of ice-dammed/ice-contact lakes, particularly in upland Britain (e.g. Ballantyne, 1979; Benn, 1989; Firth, 1984; Sissons, 1977, 1978, 1982) and (2) an increasing number of deposits and landforms interpreted as representing 'catastrophic' flood events (e.g. Sissons, 1979, 1981; Dawson, 1989). This recent development, involving the interpretation of increasing numbers of UK deposits as representing 'catastrophic' drainage during deglaciation, raises a number of important questions which Quaternary scientists should be addressing now. In addition to questions concerning identification and classification of 'catastrophic' flood deposits, three other major questions are pertinent:

### 1 *What were the conditions that allowed 'catastrophic' drainage to occur?*

We need to identify the conditions that allowed 'catastrophic' drainage to occur, as a means of linking different patterns of meltwater drainage to different forms of ice-sheet behaviour during deglaciation in different kinds of terrain. For example, if field evidence suggests extensive and repeated catastrophic floods draining subglacially beneath the ice-sheet (e.g. Shaw, 1983; Shaw et al., 1989; Sharpe and Shaw, 1989), we need to know the physical and glaciological conditions which would have given rise to such floods. Could they have arisen from rapid rates of basal melting, or would most floods have resulted from sudden drainage of sub-glacial or ice-marginal lakes? The repeated drainage of ice-dammed, marginal lakes indicates something about the long-term stability of the ice-margin, of glacio-hydrologic conditions within the ice, and of melting rates. Once the requirements for 'catastrophic' drainage during ice-sheet decay have been identified, then the likelihood of these events occurring in particular areas during deglaciation can be better predicted.

### 2 *How widespread was 'catastrophic' drainage during deglaciation of the European and British ice sheets? How significant was 'catastrophic' drainage, rather than 'normal' meltwater regimes, during decay of the different ice-sheets/ice-caps?*

We need to determine whether 'catastrophic' drainage represented the 'normal' or dominant form of drainage during wastage of the major Pleistocene ice-sheets/ice-caps. If 'catastrophic' drainage was indeed the normal means of removing large volumes of rapidly ablating ice in a given meltseason, then we need to review current views on the formation of outwash gravels in many parts of the country. This means that we will need to subject many of these deposits to a re-interpretation, and to re-consider the role of drainage events in providing sediments to proglacial environments, in modifying proglacial landscapes, and in controlling postglacial drainage routes.

*3 If 'catastrophic' drainage was significant during deglaciation, what role did these events play in affecting patterns and rates of deglaciation?*

We need to establish whether any 'catastrophic' flood events represented only a response to a drainage-triggering mechanism, or whether they also operated some feedback or interactive effect in relation to such factors as subglacial ice motion; acceleration of ice ablation rates; rates and amounts of glacial debris entrainment (if most sediment was removed by meltwaters, for example); rates of marginal ice retreat or calving (the latter into ice-marginal lakes) and subglacial topography. If repeated 'catastrophic' events are indeed found to have significantly affected certain aspects of ice-sheet behaviour during deglaciation, then models of ice-sheet drainage will also need to be revised.

## **Conclusions**

Interpretation of flood deposits in the Quaternary record remains weakened by the lack of a sound, theoretically-based, interpretative framework. A primary research requirement is therefore to construct such a framework. The first stage of construction of this framework could be through investigation of the issues outlined above, in both Parts I and II of this paper, namely through identification of the following relationships (for both present-day and Pleistocene flood records):

- (1) The magnitude, frequency and recurrence intervals of different populations of meltwater flood events;
- (2) The geomorphic impact of flood both in erosional and depositional terms, and in relation to (a) different spatial scales; (b) different kinds of terrain; (c) different kinds of flood events (magnitude/frequency; sediment concentration; hydrograph form); (d) different drainage mechanisms;
- (3) The glaciological, hydrological, topographic, and geologic controls on drainage occurrence;
- (4) The significance of 'catastrophic' events in the deglaciation record from the Quaternary;
- (5) The significance of 'catastrophic' events in the mechanics of ice-sheet drainage and behaviour.

## **FUTURE RESEARCH REQUIREMENTS**

### **1 Hydraulics and sediments of large glacial flood events**

Future research should be directed particularly toward a better understanding of:

- (a) The hydraulics of glacial floods;
- (b) The geomorphic impact of such floods in different terrains, and during events of different magnitude/frequency/sediment concentration and hydrograph characteristics;
- (c) The sedimentary and landform sequences likely to be produced by different types of flood flows; and
- (d) The likely environments and mechanisms of ice-sheet drainage (e.g. in relation to the last ice-sheet in the UK).

### **2 Establishment of a data base for Quaternary flood deposits in the UK**

A valuable first step in testing models of 'catastrophic' flooding in relation to sediments and landforms is to assemble a comprehensive and reliable data base. A data base of this kind will need to cover:

- (a) the hydraulic characteristics of glacier burst events;
- (b) the erosional and depositional features associated with such events; and
- (c) the deposits and landforms in the UK which are believed to have resulted from 'catastrophic' flood events during the Late Devensian and Lateglacial.

## CALL FOR COORDINATION OF NATIONAL DATA BASE

Some of the work on flood hydraulics and sediment sequences has been underway for several years at Aberdeen University, but we now need a more concerted, nationally coordinated base for advancing our understanding of Quaternary flood events, and the criteria for interpretation of such events within the Quaternary record, applied particularly to the UK. The research group at Aberdeen would welcome contributions to, and collaborators on, the assembly of the data base for the UK. All interested are invited to contact the authors.

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## HOXNIAN VERSUS FERDYNANDOVIAN: ARE THESE THE SAME OR DIFFERENT INTERGLACIALS?

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### Introduction

The stratigraphy of the Middle Pleistocene in NW Europe has been established satisfactorily in principle. Several warm and cold episodes, namely Cromerian, Elsterian (= Anglian) glaciation, Holsteinian (= Hoxnian) interglacial and Saalian (= Wolstonian) glaciation have been recognized (West, 1977; Zagwijn, 1985). However, in central Europe, additional warm and cold episodes have been suggested, occurring between the Elsterian and Saalian glacial stages. Cepek (1967) and Menke (1968) described the Domnitz (Wacken) Interglacial as younger than the Holsteinian and older than the Saalian. However, Zagwijn (1986) has suggested that the Domnitz (Wacken) Interglacial corresponds with the lowermost Saalian temperate Hoozeveen Interstadial. In Poland, numerous organic beds have been found between Elsterian and Saalian tills. They often indicate quite different pollen successions suggesting the occurrence of several distinct warm episodes (Mojski, 1985; Krzyszkowski, 1990a). At least four warm periods have now been defined between the Elsterian and the Saalian in central Poland (Fig. 1). Unfortunately, the organic sediments of these new interglacials usually occur individually at separate sites and they are not superimposed one upon another.

The Ferdynandovian Interglacial is the best palaeobotanically and geologically documented new interglacial in Poland (Janczyk-Kopikowa, 1976; Janczyk-Kopikowa et al., 1981; Mojski, 1982, 1985; Krzyszkowski, 1990b). The first description of Ferdynandovian strata was from sixties. These sediments were first interpreted as Cromerian (Sobolewska, 1969) or a temperate interstadial of the Saalian (Rühle, 1969; Lyczewska, 1977) or Holsteinian (Janczyk-Kopikowa, 1975). Finally they were recognized in the Ferdynandów section as a new interglacial (Janczyk-Kopikowa et al., 1981). These latter authors have suggested that the Ferdynandovian is older than the Holsteinian and younger than the Elsterian. In the Soviet Union, many organic beds with pollen successions similar to the Ferdynandovian have been described (Elovicheva, 1979). They exist under different names: Odintzovo, Byelovezhsky, Roslavl and Shklov Interglacials and were correlated with different warm episodes from Early Pleistocene up to the Dnieper (Moscow stage Drenthe/Warthe) despite their identical pollen record (Elovicheva, 1979; Makhnach and Rylova, 1986). Lately they have been recognized as representing one interglacial stage older than the Lichvin (= Holsteinian) Interglacial. This is indicated from the geological record in Byelorussia as well as from the abundant relicts of Pliocene diatoms within the Shklov sediments which do not occur in the Lichvin Interglacial. On the other hand, the Ferdynandovian-Shklov type floras have not been described from NW Europe, yet.

These considerations generate three questions:

- (1) Are the Ferdynandovian and Holsteinian really different interglacial stages?
- (2) Is the Ferdynandovian really younger than the Elsterian? If so, what is the stratigraphic interrelation between the Ferdynandovian and the Holsteinian?
- (3) Do Ferdynandovian-type floras exist in North-west Europe? If so, which profiles correlate with the Ferdynandovian?

### (i) Comparison of pollen successions between Ferdynandovian and Holsteinian

Janczyk-Kopikowa (1975) described the following pollen succession in the Ferdynandów profile (Fig. 2):

VII *Pinus*, *Betula* with some admixtures of *Picea*. NAP up to 50%.

VI *Carpinus*, *Alnus*, *Quercus*, *Ulmus* and *Corylus*.

V *Pinus*, *Betula* and *Picea*. NAP up to 40%.

EAST ANGLIA WEST 1977	THE NETHERLANDS ZAGWIJN 1985	WEST GERMANY MENKE & BEHRE 1973	CENTRAL POLAND KRZYSZKOWSKI 1990 a
WOLSTONIAN	SAALIAN	GLACIAL PERIODS SAALE	WARTANIAN II glacial T9 II glacial T6 I glacial T5 Pilica interstadial ODRANIAN II glacial NO TILL I glacial T4 maximum extent PRE-ODRANIAN T3
HOXNIAN	HOLSTEINIAN	WARTE GLACIAL PERIOD TREERE THERMOMER LIPPE GLACIAL PERIOD DOMNITZ /WACKEN/ INTERGLACIAL MELBECK/FUHNE KRYOMER HOLSTEIN INTERGLACIAL	CZYŻÓW COMPLEX ZBÓJNO INTERGLACIAL LIWIEC COLD PERIOD POLESIE INTERSTADIAL ? CZYŻÓW INTERSTADIAL FUHNE COLD PERIOD MAZOVIAN INTERGLACIAL WILGA COLD PERIOD FERDYNANDOVIAN INTERGLACIAL Upper optimum Lower optimum optimum
ANGLIAN	ELSTERIAN	ELSTER GLACIAL PERIOD	ELSTERIAN COMPLEX SANIAN II T2 ? SANIAN I T2A ? NIDANIAN T1
CROMERIAN BEESTONIAN PASTONIAN HIATUS	CROMERIAN	HARRESKOV INTERGLACIAL ? GLACIAL C ROMSMALEN INTERGLACIAL GLACIAL B ?COLD PERIOD "B" RHUME INTERGLACIAL GLACIAL A COLD PERIOD "A" OSTERHOLZ INTERGLACIAL	CROMERIAN COMPLEX THREE ORGANIC HORIZONS DEPOSITIONARY SUITES WITHIN THE KLESZCZÓW GRABEN T5 TILL HORIZONS WITHIN THE KLESZCZÓW GRABEN

Fig. 1 Comparison between Middle Pleistocene stratigraphies in North-West and Central Europe

- IV **Abies, Picea, Alnus** and **Tilia**. Also **Taxus, Vitis** and **Celtis**.  
**Quercus, Ulmus** and **Corylus** much decreased.
- III **Quercus, Ulmus, Corylus** and **Alnus** (each of about 20–30%) with a significant admixture of **Tilia**. Also **Pterocarya, Celtis** and **Vitis**.
- II **Pinus** and **Betula** with an admixture of deciduous trees.
- I **Betula** and **Pinus** with a significant admixture of **Larix**. NAP up to 40%.

The most characteristic feature of the Ferdynandovian profile is the occurrence of two optimal phases with deciduous forest (III and VI) separated by a period with only coniferous forest (phase V). These two optimal phases may also be interpreted as two separate interglacial stages. **Carpinus** does not exist in the lower optimum phase whereas it is abundant in the upper optimum phase. A significant feature of the lower optimum is the simultaneous and early appearance of **Quercus, Ulmus** and **Corylus**. Moreover, the lower part of phase III reflects a short period characterised by failure of the deciduous forest. A rapid decrease of deciduous trees and simultaneous increase of **Pinus, Betula** and NAP is observed here (Fig. 2).

The Holsteinian (=Mazovian) pollen succession is represented by the Krepiec profile, the new type section of the Mazovian in Poland (Janczyk-Kopikowa, 1981, Fig. 2):

- IV **Pinus** and **Betula**, NAP up to 20%.
- IIIb **Abies, Carpinus, Picea** and **Alnus**. Also **Vitis**.
- IIIa **Pinus, Picea, Alnus** and **Taxus**. Admixtures as in phase II.
- II **Pinus, Picea, Alnus** and a significant admixture of deciduous trees, mostly **Quercus, Ulmus** and **Tilia** (each of about 5–10%). Also **Pterocarya** and **Azolla filiculoides**.
- I **Betula** and **Pinus** with admixture of **Picea** and **Alnus**. NAP up to 20%.

The most characteristic difference in comparison with the Ferdynandovian is the predominance of **Pinus, Picea** and **Alnus** with less abundant deciduous trees in the optimum phase and common occurrence of **Carpinus**.

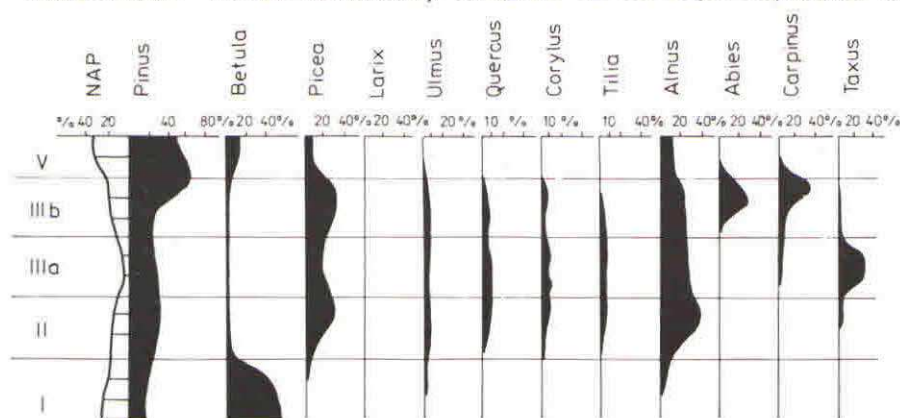
From the above, it follows that both profiles represent quite different pollen successions taking into account two optimal phases of Ferdynandovian as well as only the lowermost one. These differences cannot be explained by differing geographical distribution as the profiles are all located in the same region of Eastern Poland nor can they be ascribed specific edaphic conditions. Hence, the Ferdynandovian and Mazovian (=Holsteinian) must be recognized as separate interglacial stages (Janczyk-Kopikowa et al., 1981).

## (ii) Position of the Ferdynandovian Interglacial

Janczyk-Kopikowa et al. (1981) recognized that Ferdynandovian lacustrine sediments in the Ferdynandów profile lie between two glacial series. The lower glacial series consists of a lower glacial till and/or gravel lag lying on Cretaceous rocks; middle fluvial sediments and loess and upper glacial till. The latter was correlated with the middle Elsterian till according to the threefold division of the Elsterian by Mojski (1982; 1985). The upper glacial series consists of two glacial tills separated by glaciofluvial and glaciolacustrine sediments. Previously, they both were interpreted as Saalian: pre-Odranian and Odranian = Drenthe stages (see also Ehlers et al., 1984 and Mojski, 1985). Recently, the lower till of the upper glacial series has been suggested to represent a new glacial stage: the Wilga glaciation. Janczyk-Kopikowa et al. (1981) believe that the Wilga till represents the same till horizon as is found in the Śledzianów profile (East Poland) below both the Holsteinian (=Mazovian) and the Saalian (Odranian and Wartanian). However, this is not a direct correlation and misinterpretation is possible.

The sections of the open-pit mine at Belchatów (Central Poland) give some new data on the problem discussed. There is an unusual complete profile of the Quaternary in Poland containing deposits from the Cromerian up to the Holocene (Fig. 3). The Quaternary sediments infill the narrow tectonic Kleszczów Graben and are about 200 m thick. All sections described were observed within the open-pit

MAZOVIAN (HOLSTEINIAN), Krępiec (Z.Janczyk-Kopikowa 1981)



FERDYNANDOVIAN, Ferdynandów (Z.Janczyk-Kopikowa 1975)

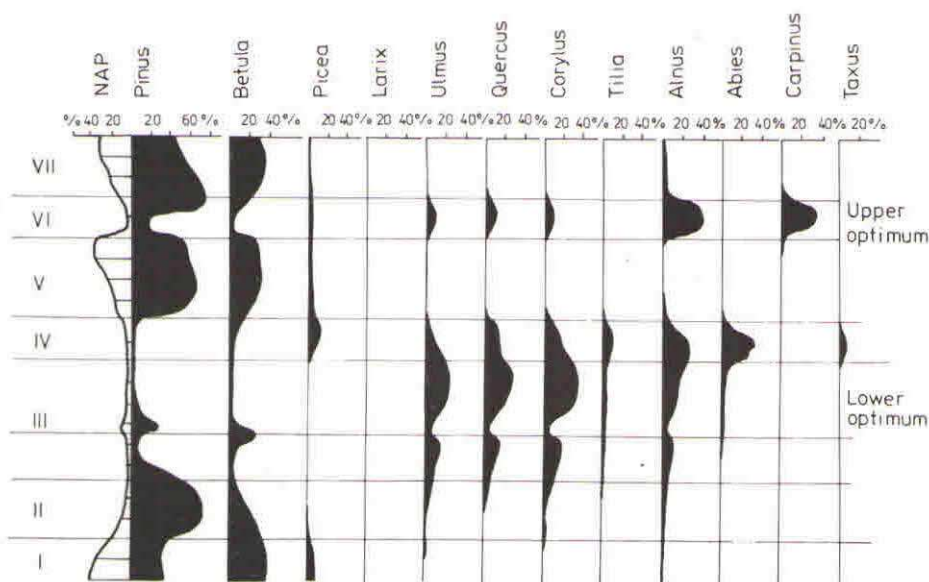
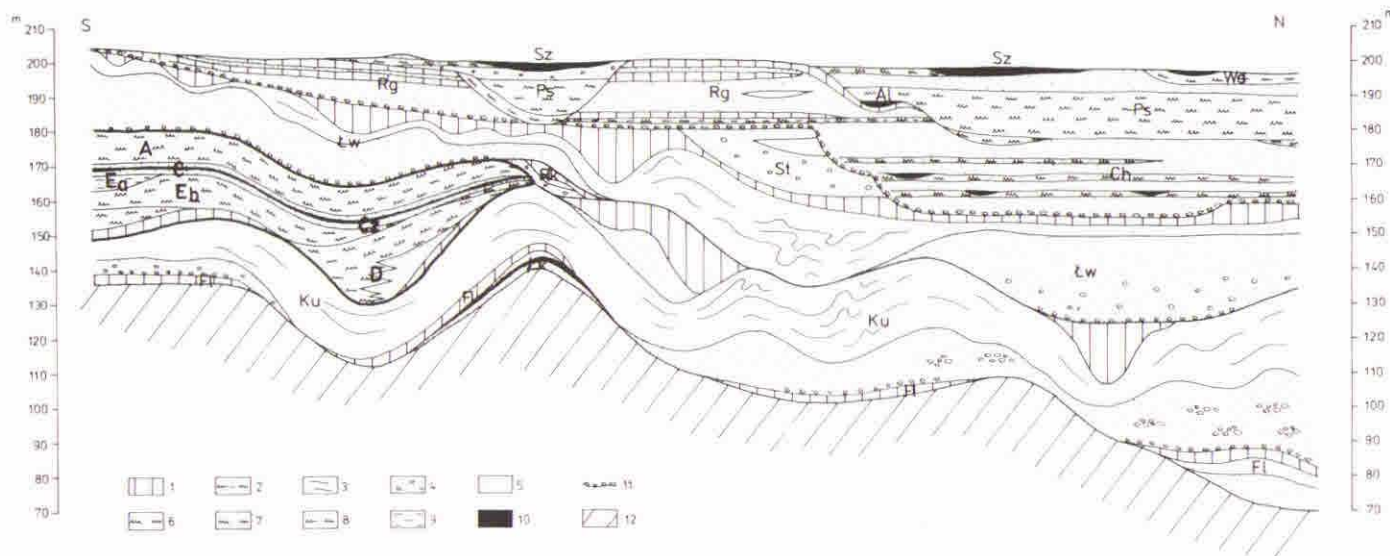


Fig. 2 Simplified pollen diagrams of Ferdynandovian and Holsteinian Interglacials in Poland





**Fig. 3** Quaternary of the Kleszczów Graben, central Poland (the Belchatów outcrop record)

1 glacial tills, 2 varved clays, 3 glaciolacustrine sediments, in general, 4 sands and gravels, 5 sands, 6 massive silts, 7 laminated silts, 8 alluvial silty-sandy cyclothem, 9 diatomites and lacustrine marls, 10 peat, 11 residual gravels, 12 Tertiary bedrock

Stratigraphy: **Cromerian**: Lk - Lekko Formation; **Elsterian**: Fl - Folwark Formation, Ku - Kuców Formation; **Cz - Czyżów Formation**: D - lower lacustrine member, Eb - lower fluviatile member, Ea - Ferdynandonvian lacustrine member, C - middle fluviatile member (Czyżów Interstadial), A - upper fluviatile member (Podlesie Interstadial); **Saalian**: Rk - Rokity Formation, Lw - Ławki Formation, St - Stawek Formation, Ch - Chojny fluviatile Formation, Rg - Rogowiec Formation; **Eemian**: Al - Aleksandrów Formation; **Middle Weichselian**: Ps - Piaski Formation; **Late Weichselian and Holocene**: Sz - Szerokie Formation, Wd - Widawka Formation



outcrop. Hence, the stratigraphical position of the sediments is unambiguous (Krzyszowski, 1987). Special attention should be paid to the Czyżów Formation. This occurs between Elsterian suites containing all three tills (Folwark and Kuców Formations, Fig. 3), and a complex Saalian suite (pre-Odranian–Rokity Formation, Odranian–Lawki Formation, and younger deposits, Fig. 3). The Czyżów Formation contains five members of lacustrine and fluvial sediments separated from one another by erosional surfaces. They are, from bottom to top, (Fig. 4):

- D — a lower lacustrine member containing rhythmites and deltaic sands, representing cold steppe lake sedimentation (Krzyszowski, 1990a).
- Eb — a lower fluvial member containing silts and sands deposited by mixed proglacial and extraglacial streams during cold steppe and/or tundra conditions (Krzyszowski, 1990a).
- Ea — a Ferdynandovian lacustrine member which contains diatomites, lacustrine marl and peat of the lower optimum phase of the Ferdynandovian Interglacial. The upper part of the lacustrine suite is strongly weathered (Krzyszowski, 1990a, 1990b; Kuszell, 1990a).
- C — a middle fluvial member containing the large amount of organic sediments and representing the temperate Czyżów Interstadial with a Holstein-type pollen succession (Krzyszowski, 1990a; Kuszell, 1990b).
- A — an upper fluvial member containing silts, sands and peat deposited during the cold Podlesie Interstadial by an anastomosing river (Krzyszowski, 1990a).

Moreover, three palaeosol horizons were recognized within the Czyżów Formation, two of them representing warm episodes (Fig. 4). No glacial deposits have been found within the formation although some glacially derived heavy minerals occur in the sedimentary suites.

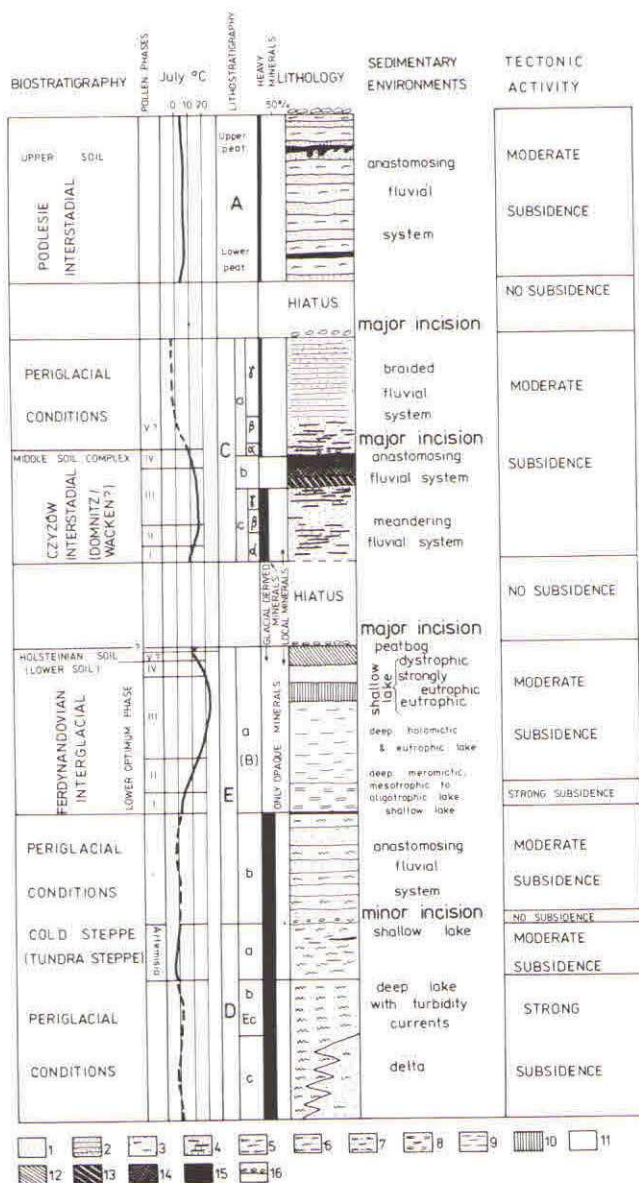
The stratigraphic interpretation of the profile described is as follows (Fig. 4):

Lower lacustrine and fluvial members represent the period of the decay of the Elsterian ice sheet and are succeeded by Ferdynandovian deposits. The latter undoubtedly represents only the lower optimum phases (I, II, III and IV) of the interglacial. The peat lying above is strongly weathered (fossil soil horizon) and no pollen have been found, though the rapid increase of chlorophylls and carotenoids in the upper part of the peat layer may suggest the occurrence of phases V and VI (upper optimum) of the Ferdynandovian (Krzyszowski, 1990b). The middle fluvial member indicates the Hosten-type pollen succession with predominance of *Pinus*, *Picea*, *Alnus* and *Quercus* in the optimum phase but without *Carpinus* and *Abies*. It cannot be directly correlated with Mazovian (= Holsteinian) (Kuszell, 1990b). Krzyszowski (1990a) has suggested it can be correlated with Domnitz (Wacken) Interglacial in Germany due to a similar pollen succession and stratigraphic position. Hence, the hiatus between the lower Ferdynandovian sediments and the fluvial sediments of the Czyżów Interstadial contains a part of the upper optimum phase of the Ferdynandovian, Holsteinian and the cold (glacial?) episodes occurring between them. The soil horizon developed on the Ferdynandovian peat has, however, been recognized as representing the Holsteinian (Krzyszowski, 1990a). From the above, it follows that the Ferdynandovian occurs unquestionably above the Elsterian and below the Saalian in the Belchatów outcrop. Moreover, Ferdynandovian sediments are older than the fluvial sediments representing the Holstein-type (Domnitz/Wacken?) pollen succession and the Hostenian soil developed on Ferdynandovian strata.

In summary, the Belchatów outcrop contains the most complex Middle Pleistocene suite in Poland, recording in one section three warm episodes between the Elsterian and Saalian (Fig. 1). The geological record of the Czyżów Formation does not confirm the existence of the Wilga and Fuhne glacial stages, although it does not contradict the possibility that cold stages occurred between the warm episodes described.

### (iii) Hoxnian versus Ferdynandovian: the same or different interglacials?

Pollen diagrams from the Hoxnian interglacial look strikingly different from Holsteinian ones on the Continent (Turner, 1970; 1975). These differences consist of the expansion to predominance of mixed-oak and the failure of *Picea* and *Pinus* during the optimum phase of the Hoxnian. The other features are similar i.e. the occurrence of *Pterocarya* and *Azolla filiculoides* as well as abundant *Abies* in



**Fig. 4** Internal stratigraphy and palaeogeographic interpretation of sediments of Czyżów Formation of Belchatów outcrop

1 cross bedded sands, 2 horizontally bedded sands, 3 sands with silty lamina, 4 sands with organic lamina, 5 massive silts, 6 laminated silts (rhythmites), 7 alluvial silty-sandy cyclothem, 8 annually laminated diatomites, 9 homogeneous diatomites, 10 brown lacustrine marl, 11 white lacustrine marl, 12 weathered peat, 13 telmatic mud, sandy, 14 telmatic mud, clayey, 15 peat, 16 residual gravels

the post-optimal phase in contrast to the Eemian. The Hoxnian pollen succession in turn, is very similar to the lower optimum phase (II-III-IV) of Ferdynandovian apart from only small admixtures of *Carpinus* in the Hoxnian. Janczyk-Kopikowa (1975) has suggested that they both represent the same interglacial period as indicated from the similar succession and almost identical percentages of taxa within the optimum phases. The occurrence of *Pterocarya* and *Azolla filiculoides* is significant also in the Hoxnian as a correlative with the Ferdynandovian (=older than Holsteinian). A secondary feature of the diagram also suggests a direct correlation between the Hoxnian and Ferdynandovian (lower optimum phase). The Hoxnian pollen diagrams from East Anglia record a short period of deforestation towards the end of zone Ho II (Turner, 1970; West, 1977) similar to the failure of deciduous forest at the beginning of the lower optimum phase (III) of the Ferdynandovian in Poland. Palaeolithic artefacts are associated with this horizon in East Anglia (West, 1977). It is possible that the Ferdynandovian reflects similar man-induced change. Is this a hazard of the pollen recording or direct correlation?

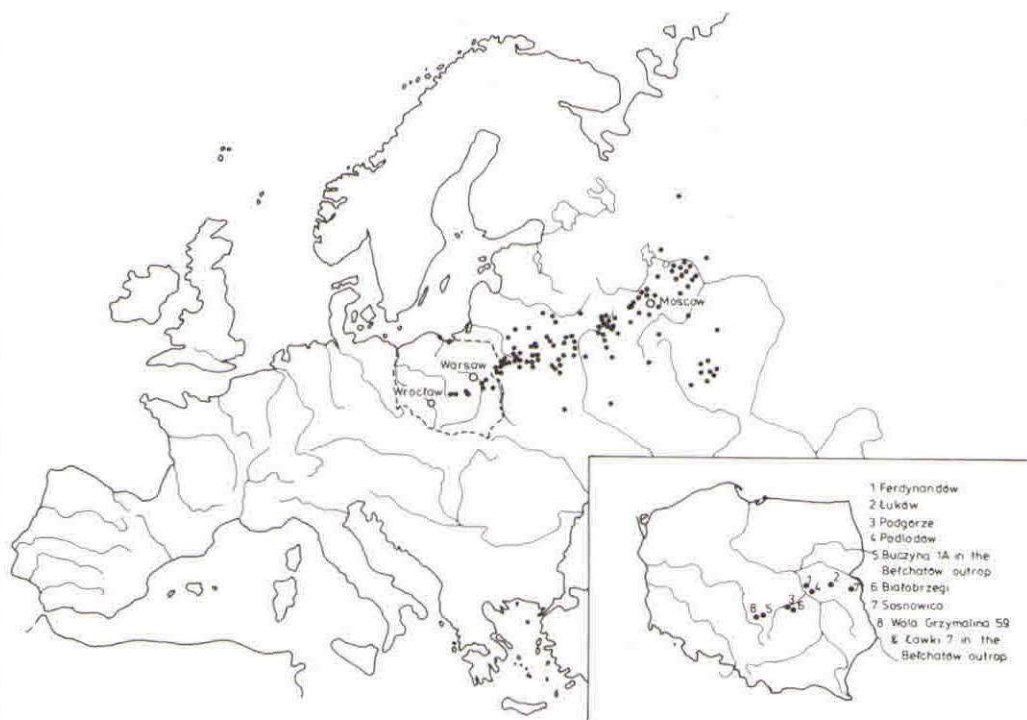


Fig. 5 Distribution of the Ferdynandovian-Shklov-type floras in Europe (IN Soviet Union after Elovicheva, 1979)



Moreover, Turner (1970, 1975) approximated the duration of the Hoxnian to 20 000 to 25 000 years, whereas the Holsteinian in northern West Germany was shorter, only 16 000–17 000 years long (or 12 500–13 500 years for the optimum phase) (Meyer, 1974). The lacustrine suite of the lower optimum phase of the Ferdynandian contains annually laminated sediments (Krzyszowski, 1990b) indicating that approximate duration of this warm episode was about 20 000 years with the optimum, deciduous forest phase being 14 000–16 000 years in duration.

It is appreciated that the correlation presented in this short paper is bold and questions a long existing feature of British Middle Pleistocene stratigraphy. But, why not?

Lately, many revisions of Pleistocene stratigraphy have been suggested based on the oceanic record. The Ferdynandian may be a harbinger from the Continent of a new Pleistocene framework. Obviously, the revision or rejection of the chronostratigraphic position of the Hoxnian must be the prerogative of British Quaternary geologists, but a broad European discussion is necessary. It is emphasised that the general stratigraphic position of Ferdynandian and Holsteinian is similar. They both are younger than the Elsterian (Anglian?) and older than the Saalian (Wolstonian?). If the correlation between Ferdynandian and Hoxnian is rejected, the restricted occurrence of Ferdynandian sites would need to be explained. The Ferdynandian-type floras are common in the Soviet Union and Central and Eastern Poland, whereas they have not been described in NW Europe yet (Fig. 5). One would anticipate that they should also be capable of recognition in North-west Europe.

## Acknowledgement

I would like to thank P Allen, R Bryant and A Haggart for improving the English and useful comments.

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## REPORTS

### APPLICATIONS OF QUATERNARY RESEARCH

#### Quaternary Research Association Discussion Meeting, Manchester Polytechnic, 3 and 4 January 1990

Quaternary studies, by their very nature, deal with processes and sediments that affect the Earth's surface and it is critical that a realisation of the importance of Quaternary research amongst scientists and others not familiar with the subject is actively promoted. We can no longer afford to sit back content with the knowledge that our subject is one of considerable importance because we now have to influence the decision makers, grant awarding bodies, politicians and the public in order to increase awareness of the subject and its relevance. If we do not promote and utilise applied Quaternary studies then others will fill our places, even if they are not suitably trained, and the subject will be the worse for our absence.

Against a background of a dramatic increase of environmental awareness in Europe, concern about Global climatic change, a need for sensitive and informed planning (in all spheres e.g. urban, regional, natural resource . . .) and increasing levels of funding in our research area, the QRA decided to hold its Annual Discussion Meeting on the topic of applied Quaternary research. One difficulty facing the convenor (**Murray Gray**) was the very broad range of applications that are confronted by Quaternary researchers and it is much to his credit that he found speakers to cover aspects ranging from the down to earth topics of aggregate resource evaluation and civil engineering to the record of global climate models using sophisticated palaeoecological techniques. The programme managed to cover many facets of Quaternary research in three main sessions: *Resources, Civil Engineering and Environmental Issues and Problems*. The range of themes covered could usefully have filled a longer conference but given the time available for this meeting the programme was a good one and proved to be well worth attending. Over 50 people had registered up to the beginning of the meeting but others arrived and the audience (although fluctuating) was a good one (especially considering flu epidemics and alternative conferences) of 70+ at times.

The meeting began with a trip to Manchester Museum but unfortunately as a committee member I missed this so I can't comment other than to thank **Dr John Nudds** for his trouble.

**Murray Gray** introduced the programme showing how the various speakers covered the range of processes, environments and sediments that Quaternary scientists deal with and the methods that they used. In doing so he both outlined the aims of the meeting and the reasons that the speakers had been asked to contribute.

The first session on *Resources* included 5 speakers covering placer deposits, mineral exploration, sand and gravel resources and agriculture.

These lectures produced an interesting assortment of themes and approaches. **Don Sutherland** spoke of the Quaternary scientist's role in applied research and their need to remember that they are frequently solving externally derived problems. He was clearly speaking from personal knowledge when he referred to the planning of projects, resisting the urge to be sidetracked, and the challenge of applied research. **Dr Sutherland** went on to discuss the identification and location of major placer deposits and gave a well-chosen account of an African example of diamond exploration where a knowledge of geomorphology, stratigraphy and sedimentology were crucial and regularly used techniques in Quaternary geology were applied. **Malcolm Brown** continued the theme with an account of mineral exploration in a glaciated terrain. Again techniques commonly used by many of us were shown in an applied context being used to trace gold veins through till cover in the north of Ireland. The sampling methodology was described and the results showed how consistent 3D plotting of gold anomalies in till could assist in locating gold mineralisation in hidden bedrock. The next two presentations involved the sand and gravel industry. The first by **David Chester** discussed straightforward reconnaissance for sand and gravel giving three case studies and the second by **Ian Selby** introduced the growing marine aggregate industry. The scale of extraction of marine aggregates, especially in waters around southern Britain was staggering with  $25 \times 10^6$  tonnes being extracted in 1988. **Dr Selby** outlined the techniques

involved in the locating, extraction and utilisation of this resource as well as explaining the controls and licensing of this activity. The detailed mapping of the sea floor by extraction companies has provided much information regarding Quaternary deposits and hopefully these data will eventually find an academic outlet as well as providing maps of a resource for major construction projects. The final lecture of the session by **John Catt** covered some aspects of soils and agriculture including a case study that demonstrated aspects of crucial soil properties and agricultural yield—the link between the Quaternary and beneficial applications cannot be stronger than in food resource management.

In the evening an excellent dinner had been organised and was enjoyed in convivial company. The only event marring the occasion was the fact that Bob Hageman, due to give the after dinner lecture, was unable to attend the meeting due to illness.

The following day started with a morning of *civil engineering* applications. **Ed Derbyshire** started off the session outlining the problems of dealing with Quaternary sediments and the role of the geomorphologist as a 'troubleshooter' in civil engineering projects. His case studies (including different types of applications e.g. geotechnical, supply of suitable local fill, oil rig location . . .) were clear examples of the value of a geomorphological training and the importance of a knowledge of Quaternary sediments. Each of **Professor Derbyshire's** examples had unquestionably saved substantial amounts of money. Later in the morning **Jonathan Raper** went on to analyse how Quaternary research may allow the identification of sedimentary architecture in glaciated valleys—an approach that may enable prediction of likely civil engineering problems. **Paul Gostelow** of the BGS explained how they had mapped sediments in the Cromarty Firth and the Firth of Forth, in the latter case using a massive data set, according to their lithologies (i.e. cohesive, consolidated, non-consolidated, cohesionless . . .) producing maps of great value to those interested in geotechnical properties. It would have been interesting to have seen some of the applications (planning, construction, waste hazard potential . . .) that must have been made using these maps.

After coffee the broad interests of QRA members was proved when two papers on periglacial matters were presented. The first by **Peter Worsley** looked at simple examples of engineering problems in permafrost regions including construction of runways, water supply and sewerage collection and disposal. The second by **John Hutchinson** looked at relict periglacial features in Britain (solifluction, pingos and cambering) and assessed their potential as hazards to the civil engineer. Marvellous examples of reactivated slope failure showed remnant areas of solifluction and also former shear planes to be a considerable problem if they were disturbed. Pingos did not seem to be a problem (if avoided) while **Prof. Hutchinson's** attempts to estimate the depth of former permafrost using valley bulges and cambering should provide a basis for discussion for some time to come.

The afternoon session on *Environmental Issues and Problems* was a fascinating one and it began with a resource that many take totally for granted in Britain and Ireland—fresh, clean drinking water. **Donal Daly** of the Geological Survey of Ireland showed the vital nature of Quaternary sediments in determining water quality and he also pointed out that Quaternary geologists have got to produce good surveys and maps based on lithological criteria if this critical resource is to be managed and protected in a sensible manner. It was clear that information of the type required by hydrogeologists is not widely being produced by trained Quaternary geologists. **Rick Batterbee** spoke about the 'Pollution Period' (Holocene post-1800) and described the precise dating and palaeoenvironmental techniques used by Quaternary scientists in the analysis of lake acidification. He showed how careful site selection (lakes with small catchments, lakes with no surrounding land-use and long (i.e. thousands of years) records could determine that rapid and recent acidification was caused by acid deposition since 1800 rather than by long-term trends and land-use changes including afforestation. **Brian Huntley** gave a lucid and fascinating account of the role of palaeoecological data in determining past and possibly future rates of environmental change. Pollen data bases provide multivariate information and he explained methods that have been used by COHMAP (e.g. Huntley and Webb, 1989) to calibrate pollen data and palaeoclimate. Once the present geographic distribution of taxa has been mapped climatically and this compared with surface pollen samples then it is possible to infer past climate from complex data sets of pollen assemblages in which each taxon has an individual response to climate. Such techniques not only allow the reconstruction of past climates from pollen data but also allow results of GCMs to be evaluated by reconstructing expected vegetation patterns using data from the GCMs over time and verifying these against the established pollen record. These powerful procedures will undoubtedly realise great importance in our understanding of global climatic change.



Again on a global scale **Bill Carter** described another important and controversial topic that has been in the public eye for some time—sea-level change. He discussed the successes and failures in sea-level research and concluded that although we have determined broad patterns of Quaternary sea-level change, refined and defined the limitations of sea-level index points and established an international framework for palaeo sea-level research there is still a lack of reference datums, there is a lack of appreciation of coastal processes (in interpreting low and high frequency events) and the assumptions concerning coastal response to sea-level change are poor. Thus, at whatever rate the sea-level changes, it is not clear how individual coasts will respond because they are complex systems. A beautifully illustrated case-study from Nova Scotia made the point.

The final lecture of the day was also splendidly illustrated and **Judith Maizels** gave a marvellous account of attempts to predict large scale meltwater releases (jökulhlaups) from Icelandic glaciers. The description of these high magnitude floods was supported with pictures of pre- and post-flood geomorphology and sediment descriptions hopefully allowing the deposits to be identified in the sedimentary record. It was shown that although it was sometimes possible to predict a flood it was harder to predict within flood fluctuation in discharge.

The conference programme was stimulating and showed the range of applications and importance of Quaternary studies as the organisers had hoped it would. The mixture of approaches and the scale and diversity of applications made the conference one that the QRA can be proud of. It is a pity that we were 'preaching to the converted' though and the message needs to go further afield. I would think that the best way to get this message across is to carry out applied research!

The organisers of the meeting (**Murray Gray and David Case**) are to be congratulated on both the programme of speakers and the 'domestic' arrangements—all seemed to run very smoothly and efficiently.

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**Huntley, B. and Webb, T. III.** 1989. Migration: species response to climatic variations caused by changes in the earth's orbit. *Journal of Biogeography*, 16, 5–19.

## **RADIOCARBON DATING: RECENT APPLICATIONS AND FUTURE POTENTIAL**

### **A Discussion Meeting organised by the Joint Association for Quaternary Research of the QRA and the Geological Society**

This was a very popular and useful meeting, timed for the day before the Community Meeting on the NERC Palaeoclimate Special Topic and preceded by two London Quaternary lectures (by Mike Walker and Svante Björck), at RHBNC the day before — a varied and nourishing menu for any Quaternary scientist! Since the abstracts of the papers presented are published here, and since a full publication is in preparation, what follows is a personal view which I hope will convey something of the atmosphere of the first JAQR meeting.

Jim Rose, chairing the morning session, first explained that the meeting had come about as a result of a NERC/RCL Steering Committee discussion of various technical matters following the recent second International Inter-Comparison exercise by over 50 radiocarbon laboratories, and that John Lowe had been asked to organise it on behalf of the QRA/JAQR. Describing himself as the 'warm-up' speaker John Lowe then fulfilled his task well with the aid of some nice coloured OHTs, stressing the problems of stratigraphic resolution, especially when radiocarbon-dating Lateglacial sediments of low organic content. Sites such as Llyn Gwernan, with 238 cms of Lateglacial Interstadial sediment accumulated at about 10 yrs/cm, deserve to have lots of dates allocated to them, but any stratigraphic problems with a site must be sorted out first. Not for the first time during the day's proceedings I found myself thinking of the average Ph.D. student with, say, six sites and an expectation of perhaps only 2–3 dates per site — are their conclusions based on dodgy data?

Marion Scott followed with a blockbuster of a joint paper summarising the international collaborative study finished in September 1989 and to be published in a special issue of Radiocarbon. Buzz-words abounded — quality assurance, user-confidence, error-multipliers — in a paper which had us all guessing which numbers on the slides showing lab. comparisons represented which labs. Shouldn't we be told? In answer to a question by John Lowe regarding the identification of any common denominators of good labs versus bad labs, Marion seemed to be saying that the very best 5–6 labs used gas counting, and that liquid scintillation may be more variable, but understandably in a project based upon confidentiality she added that all labs had the potential to provide reliable dates.

Accelerator dating was then reviewed by Rob Hedges who outlined the history of the Oxford unit from being primarily an archaeological set-up through to its increasing commitment to environmental samples — and to commercial applications such as dating silk for the art market. To quote... "direct payment works wonders!" You can however apply for AMS dates through NERC/RCL Steering Committee if you have a good case for dating 500 midges or Lateglacial birch seeds, and the Oxford lab has done over 100 environmental samples since 1987. In the early days, 5 mg of carbon were needed but the preferred range is now 1–3 mg but if you can't manage such heavyweight samples, then they have recently dealt with a 0.1 mg sample (yes, one-tenth of a milligramme — after all C atoms don't weigh much!).

In his own words, we then went "from the sublime to the ridiculous" with Claudio Vita-Finzi's account of how to get dates from shells in 40 minutes using 50% HCl to generate CO<sub>2</sub> for liquid scintillation "first order" counting. Such dates are cheap (3 for the price of a pint of beer as Mike Walker summed it up) but are they cheerful or nasty? Decidedly nasty, thought Doug Harkness, having spent 25 years on improving precision and refining lab techniques, but that attitude comes from "hobnobbing with physicists" according to Claudio. In a very lively talk and discussion, I was irresistibly reminded of the way that Geoffrey Kellaway had shaken up the Quaternary world in the early 70's — time will tell who's right.

Post-lunch napping was discouraged by the "harsh reality" of Jon Pilcher's paper. This certainly shook me into realising the real significance of the "Suess wiggles" and the high-precision curve published by Pearson et al. a few years ago, and Jon confirmed it in answer to my question. Apparently, wood samples dating from 400 to 800 BC all have the same 14C activity, so all those attempts by peat stratigraphers to marry up or explain away the differing dates of the Grenzhorizont or RYIII, c.600 BC, were a waste of time — those 400 years are the worst in the whole postglacial! This is not a problem to

be solved by Jon's preferred solutions for other time-periods (high-precision counting and "wiggles-matching") so all those working on the Late Holocene sediments must be aware of this. Peter Worsley, who chaired the afternoon sessions, remarked in his summing-up on the look on my face as this thought struck home. On reflection, of course, I'm much happier — we'll just have to go back to "pollen-dating"! I predict a wide readership of Jon's paper — a most important and timely contribution.

Eduard Bard then delivered the joint French paper on AMS dating of planktonic forams, concluding that the Younger Dryas was as cold as the full glacial off Ireland and, rather interestingly, presenting evidence for early Holocene cooling c.8800 BP. Also of interest was his estimate that of the changes recorded, 1.5 per mille was due to temperature change, and that 1.1 per mille was due to the glacial/interglacial change in ice volume.

Ken Creer's paper (taken out of order) concerned deep lake sediments cored with huge Mackereth corers and from a Rolls Royce of a raft at Velay, France. This lake is comparable to the Grand Pile site in extending back to the Eemian and therefore provides an opportunity to date older sediments by various means and to "tune the timescale" to reveal Milankovitch and geomagnetic periodicities. It was, I thought, a pretty enough tune but not everyone appeared to want to dance to it.

Svante Björck's paper was a nice example of the logical Swedish approach — if you've got a problem with Devensian Lateglacial dates, try to solve it by going to a present-day "Lateglacial" environment and see what the lakes are up to. It has often seemed to me that Quaternarists reject this process approach at their peril and that some of the arguments we have on field meetings are confounded by this dichotomy of view and experience — those who study sediments must understand present-day sedimentation. This Svante had done by looking at Antarctic lakes, some of whose sediments had a rather exotic origin from the rear-ends of penguins! Through ingesting krill and depositing it into one lake, these penguins caused the date of a surface sediment sample to come out at 2275 BP. Such factors could hardly have affected the Swedish lateglacial but no-one had a convincing explanation as to why some of the dates were 5000 years too old, though Doug Harkness had a go with volcanic carbon dioxide.

The last two papers were excellent examples of opportunism at work in Quaternary research. Mike Walker and Doug Harkness did a double act on the opportunity afforded by British Coal at Llanilid, South Wales, where opencast working had exposed a section through kettle hole deposits. Sections, rather than boreholes, always do open up a whole world of sampling strategies, as we peat stratigraphers are the first to acknowledge. Here it was taken full advantage of, as the abstract indicates, and what sticks in my mind is Doug's comparison of Scotch whisky and date samples — the normal sample equates to a blend; a high-integrity sample is like a malt! — and Mike's lovely pollen diagram wherein the Bolling rides again. Interestingly the juniper pollen peak of Llanilid is contemporaneous, at 12 450 BP, with the birch pollen peak I have dated at Church Moor, New Forest — a nice bit of palaeobiogeography.

If you haven't got a section try getting funding from Eurotunnel for a grid of 180 cores over your site. That's what Richard Preece managed to do at Holywell Coombe, Folkestone, as well as some impressive sections dug by machines, and from these he has reconstructed a unique record for the area covering the last 13 000 years and many fossil groups, including a birch log dated to 12 100 BP. The dating interest from the site lies in the range of types of sediment and fossil and in the fact that both AMS and conventional dates were applied to the material. Richard's paper will be very appropriate reading on any French holiday via the Chunnel.

The final discussion, led by Don Sutherland, had to some extent been pre-empted by earlier contributions after each paper, but was nevertheless a satisfying round-up of the major points, with Don stressing that 'sample integrity' needs to be taken more seriously by 14C users, and commenting on the muted response to Marion Scott's paper. This was topped off by a well-deserved vote of thanks by Peter Worsley to John Lowe and his helpers. To read this day's work in the publication will take days — those who were there were privileged to hear such a wide range of stimulating papers.

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## ABSTRACTS



### **RADIOCARBON DATING — RECENT APPLICATIONS AND FUTURE POTENTIAL ABSTRACTS OF A JOINT QRA AND GEOLOGICAL SOCIETY DISCUSSION MEETING HELD ON 7 FEBRUARY 1990, AT THE GEOLOGICAL SOCIETY, LONDON**

#### **STRATIGRAPHIC RESOLUTION AND RADIOCARBON DATING**

**J J Lowe**

**Department of Geography, Royal Holloway & Bedford New College,  
University of London**

Following a brief introduction to some of the major problems that have a bearing on the interpretation of radiocarbon dates, the importance of a consideration of the stratigraphic resolution of samples will be examined. Comparisons will be made between suites of dates obtained from several Lateglacial stratigraphic successions. Implications will be drawn as to the effects of varying stratigraphic resolution between the different suites. The problems of establishing an improved geochronology for Lateglacial sediment successions will be introduced.

#### **QUALITY ASSURANCE IN $^{14}\text{C}$ DATING**

**E M Scott, D D Harkness<sup>1</sup>, G T Cook<sup>2</sup> and M S Baxter<sup>2</sup>**

**Department of Statistics, University of Glasgow**

**<sup>1</sup>NERC  $^{14}\text{C}$  Laboratory, East Kilbride**

**<sup>2</sup>SURRC, East Kilbride**

The  $^{14}\text{C}$  community has recently voluntarily agreed to undertake a quality assurance scheme designed to ensure reliability and comparability of results across laboratories.

Historically,  $^{14}\text{C}$  laboratories have inter-calibrated irregularly with restricted numbers of samples to help ensure satisfactory performance. Large scale organised interlab comparisons have in the past revealed significant discrepancies amongst  $^{14}\text{C}$  laboratories. Recently, the second International Inter-Comparison (Scott et al., 1989) further demonstrated the existence of discrepancies. Over 50 laboratories worldwide (including representatives of gas counting, liquid scintillation and accelerator laboratories) participated in the three-year project which involved 3 stages, each stage being roughly associated with the processes of pretreatment, synthesis and counting. Realistic samples whose results were not known in advance were used throughout and in addition, several known age wood samples were included. Analysis of the results demonstrated the existence of systematic laboratory biases and additional sources of variability not accounted for by the quoted errors.

As a result of the study and following discussions of its findings, a proposal for quality control and assurance has been devised. The approach is as follows:

(a) A recommended protocol for internal laboratory procedures will be published. An essential part of the protocol will be the analysis of certain standards at regular intervals. The additional reference standards are being prepared by, and will be made available through, the auspices of the IAEA. The new reference standards will include cellulose, charcoal and marble, and will require no further pretreatment by laboratories. The age range of such new standards will be from 15 000 BP to modern.

(b) Regular inter-comparisons will be arranged involving realistic samples of different materials. An important element of this work will be the lack of prior knowledge of the results and its use of natural samples.

This final procedure will allow the effectiveness of the proposals in (a) in ensuring comparability of results to be assessed and will provide conclusive evidence to users of the continuing commitment of the  $^{14}\text{C}$  community to ensuring the quality of their routine results.

## **AMS DATING: PRESENT STATUS AND POTENTIAL APPLICATIONS**

**R E M Hedges**

**Radiocarbon Accelerator Unit, Research Laboratory for Archaeology  
and the History of Art, University of Oxford**

The current performance of the Oxford AMS system (including reference to other AMS systems) is reviewed. This covers sample size, age range, accuracy and questions of cost, sample submission procedure, throughput and intercomparability.

An account of how AMS might best be applied to the 'dating' of Quaternary sediments is given. This includes consideration of the different sources of carbon being dated, and outlines the possibilities for recognising and isolating a single source for measurement. Results from work at Oxford which aims to do this will be used to illustrate the problems.

I hope to consider the topic at a fairly general level, and that subsequent discussion might focus on more specific questions e.g. concerning specific sites.

## **FIRST ORDER DATING IN NEOTECTONICS**

**C Vita-Finzi**

**Department of Geological Sciences, University College London**

First-order radiocarbon dating by liquid scintillation counting of absorbed  $\text{CO}_2$  usefully complements conventional methods in the study of coastal neotectonics in two key ways: by permitting regional patterns to be identified and by facilitating sample selection. Both will be illustrated by reference to recent work in SE Asia, where the technique has been applied to Holocene molluscs, barnacles and coral. Brief mention will also be made of recent improvements in sample preparation and data analysis, and the traditional modes of expressing age precision will be examined.

## **AMS DATING OF CLIMATIC VARIATIONS IN THE NORTH ATLANTIC OCEAN AND ADJACENT AREAS**

**M Arnold, E Bard & J C Duplessy**

**Centre des Faibles Radioactivités, Laboratoire Mixte CNRS-CEA, Gif-sur-Yvette**

The last glacial to interglacial transition, which occurred between about 15 000 to 7000 years BP, has been characterised by a two-step deglaciation, with maximum melting rates between 14 000 and 12 000 years BP, and from 10 000 to 7000 years BP separated by a midglacial pause with little ice volume. During the same period, the sea surface temperature increased in the North Atlantic Ocean and reached values similar to the modern one by the end of each melting step. However, during the pause in the ice melting phase, a major cooling occurred during the Younger Dryas event, characterised by temperatures similar to those prevailing during the last glacial maximum.

We used AMS C-14 dating on planktonic foraminifera in order to determine a precise time scale for the sea surface temperature (SST) variations and to estimate the rate of temperature change in the North Atlantic. We also analysed continental deposits with pollen records in order to assess the impact of Atlantic surface temperature variations on the nearby European continent.

Analysis of three sediment cores from the North Atlantic show that sea surface temperature changes have been rather abrupt, with a rate of change close to 2.5°C per century around 12 500 years BP. The comparison of the marine isotopic records of the North Atlantic Ocean with pollen records from western Europe show that the response of the European continent to marine changes occurred almost instantaneously, within the experimental errors of the C-14 dating method.

## **EXPERIENCE OF RADIOCARBON DATES FROM ANTARCTICAN LAKE SEDIMENTS**

**S Björck**

**Department of Quaternary Geology, Lund University**

Radiocarbon dates on bulk sediment samples of Lateglacial lake sediments have in many studies proved to be too old, often due to contamination by older redeposited organic material. Radiocarbon dates from lake sediments around the Antarctic Peninsula suggest similar problems. The reasons behind these 'too old' dates seem to be of a complex nature, where older redeposited organic material probably has played a much less important role than in Lateglacial sediments of temperate-boreal regions. Other, more important, factors will be discussed, but it will also be shown that these dating problems may be solved by creating a regional tephrochronology.

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## **RADIOCARBON CALIBRATION AND RADIOCARBON ACCURACY: WHY THEY MATTER TO QUATERNARY SCIENTISTS**

**J R Pilcher**

**Palaeoecology Centre, Queen's University, Belfast**

There has been a tendency amongst Quaternary workers to ignore radiocarbon calibration as an unnecessary sophistication that anyway is only applicable to a part of the Holocene. There has also been a consistent trend among pollen analysts to overestimate the accuracy of routine radiocarbon dates. The harsh reality of routine radiocarbon dating is that it will not normally specify the calendar date to better than the nearest half millennium. In contrast to this, high precision radiocarbon dating and the possibility of wiggle-match dating open up exciting new dating possibilities for the Holocene.

## **RADIOCARBON DATING THE LATE DEVENSIAN LATEGLACIAL IN BRITAIN: NEW EVIDENCE FROM LLANILID, SOUTH WALES**

**M J C Walker<sup>1</sup> & D D Harkness<sup>2</sup>**

**1 St. David's University College, Lampeter**

**2 NERC Radiocarbon Laboratory, East Kilbride**

The recovery of large quantities of limnic sediment from an open section through kettle hole deposits at Llanilid, South Wales, provided a unique opportunity for radiocarbon dating materials of Late Devensian Lateglacial and early Flandrian age. The availability of such large amounts of sample material enabled stringent pretreatment in order to avoid the more natural forms of contamination. Twelve horizons were selected for dating purposes on the basis of pollen stratigraphy and three chemically-defined organic fractions were isolated in each sample, i.e. the acid-insoluble (fulvic), the acid insoluble/alkali soluble (humic) and the acid insoluble/alkali insoluble components. Comparisons between age determinations on the humic and humin organic fractions reveal the extent of contamination by both older and younger carbon residues. The Llanilid timescale for the Lateglacial suggests that the earliest organic sediments date from around 13 200 BP, the early Interstadial *Juniperus maximum* occurred at c.12 400 to 12 500 BP, with a marked decline some 200 years later; the main *Betula* phase

lasted only from c.11 700 to 11 400 BP, and the end of the Interstadial occurred around 11 100 BP. The beginning of the Flandrian dates from c.10 000 BP, the *Juniperus* maximum occurred approximately 200 years later, the expansion of birch woodland began around 9600 BP while the first hazel arrived in the area at c.9300 BP.

## **ACCELERATOR AND RADIOMETRIC DATES FROM A RANGE OF MATERIALS WITHIN COLLUVIAL DEPOSITS AT HOLYWELL COOMBE, FOLKESTONE**

**R C Preece**

**Department of Zoology, University of Cambridge**

Holywell Coombe, Folkestone, is filled with a tripartite sequence of colluvial deposits comprising (i) Lateglacial solifluction and associated sediments, (ii) early-mid Flandrian tufa, and (iii) hillwash, resulting from Neolithic and later forest clearance. Waterlogging of the basal sediments has resulted not only in the preservation of an array of fossils not normally found in colluvial sediments (e.g. pollen, insects) but has also provided organic material for radiocarbon dating. The deposits are laterally extremely variable both in terms of their occurrence and relative thickness. A complete stratigraphical record has therefore had to be assembled from composite profiles using biostratigraphy and radiocarbon dating. A detailed chronology has been established based on a combination of conventional dates on wood and charcoal and accelerator dates on fruits, seeds and charcoal. Additional determinations have been obtained from conventional dating of tufa and accelerator dating of shell carbonate. This talk will examine how the dates compare and the lessons to be learned from such a study.

## **DATING OF 'OLD' SEDIMENTS: COMPARISON OF RADIOCARBON AGES WITH OTHER AVAILABLE AGE CONTROLS**

**K M Creer**

**Department of Geology & Geophysics, University of Edinburgh**

Sediment cores taken from Lac du Bouchet (Velay, France) provide quasi-continuous sequences covering the last glacial cycle. The longest cores penetrate to 20 m and extend into the Bémian, about 120 000 years before the present. A wide variety of studies has been carried out on these cores under the EEC funded 'Geomaars' programme, including extensive and detailed palynology (Lab. de Botanique historique, St. Jérôme, Marseille), which provides dating control not only through the Holocene and Lateglacial but also by correlation of warm interstadials with oxygen isotope stages as defined in marine cores.

An extensive set of radiocarbon ages has been made on samples from the Bouchet cores, starting with 5 measurements using the conventional method at Gif-sur-Yvette, then 8 accelerator measurements at Oxford in 1984, 6 accelerator measurements at Tucson in 1986, and finally in 1989 a further 11 accelerator measurements at Oxford. The oldest of these dates is around 40 000 years.

The sets of radiocarbon ages will be critically discussed in the light of the other independent age controls. Spectral analysis of the geomagnetic secular variation record derived from these cores and transformed to a timescale using the available age controls of which the accelerator radiocarbon dates constitute an important part, reveal the Milankovitch precessional and obliquity periodicities.





**ABSTRACTS OF PRESENTATIONS AT THE POSTGRADUATE  
PALAEOECOLOGY CONFERENCE, DEPARTMENT OF GEOGRAPHY,  
UNIVERSITY OF KEELE, JANUARY 6TH AND 7TH 1990**

The following talks were given by postgraduates at all stages of research. The organisers would like to thank all participants for the excellent standard of presentations and the stimulating discussions afterwards.

The abstracts are presented in groups based on the general field of research and it is hoped that by publishing them, researchers elsewhere will be made aware of these projects.

A similar conference in January, 1991, was proposed, possibly at Keele again, but further information will be available later in the year. Any recommendations or suggestions regarding future meetings would be gratefully received by Jeff Blackford/Tim Mighall at Keele.

**Palaeolimnology**

**Tim Allott (UCL)** *Recent lake acidification: Reversibility studies using lake sediments.*

Levels of acid precipitation in the UK have fallen since the peak in the early 1970's. Work in progress is assessing the effect of declining pollution loadings on acidified lakes in Galloway, SW Scotland. A multi-core approach has been employed to allow recent trends of lakewater pH to be reconstructed using diatom remains within the lake sediment.

**Basil Davies (Newcastle)** *Environmental change in lake and river systems in NE Spain.*

Preliminary analysis of sediments from the saline lakes of the Charsas de Alcaniz, North East Spain, would appear to provide a secure basis for palaeoenvironmental reconstruction. In addition, integration with archaeological and alluvial fill evidence offers a broader approach within and independent of the lake systems. It is hoped this research will throw light upon the role of man in influencing Mediterranean landscapes and climatic change in a previously neglected region.

**Helen Bennion (UCL)** *Assessing the usefulness of sediments from ponds and pools in south-east England.*

Little is known about the impact of atmospheric pollution, surface water acidification or cultural eutrophication in SE England, despite deposited sulphate levels, hydrogen ion concentrations and population densities that are among the highest in the UK. In the absence of natural lakes, it is the aim of the current study to use the diatom assemblages in the surface sediments of 30 ponds and pools and contemporary water chemistry, to generate pH and trophic state transfer functions. These functions can then be applied to fossil assemblages in longer cores from similar water bodies and aid in reconstructing their environmental histories.

**Philip Barker (Loughborough)** *Diatoms, Palaeoecology and Tropical African Lakes.*

In low latitudes, fluctuations of closed basin lakes offer one of the best means of investigating climatic oscillations. The reconstruction of lake water level and lake area is best achieved in the context of multidisciplinary research. Diatom palaeoecology is one of the most important of these methods as the diatom flora sensitively reflects changes in lake water chemistry. Diatom analysis at Lake Magadi, Kenya, has demonstrated major environmental fluctuations during the Late Pleistocene period.

**Archaeology-based Palynology**

**Simon Butler (Sheffield)** *Archaeopalynology of the settlement at Kebister, Shetland.*

Detailed excavation and survey by the Scottish Development Department between 1985 and 1987 revealed evidence for a multiperiod (Neolithic to 18th Century AD) settlement and field system. An integrated pollen sampling strategy has been aimed at understanding the land-use and ecological history of the site. The strategy utilises the varying scales of analysis provided by different depositional contexts, from regionally sensitive lake sediments to blanket peat, mineral soils and interior floors.

**Jackie Hatton (Exeter)** *Fire during the Mesolithic periods on Dartmoor.*

Detailed examination of charcoal and pollen has been undertaken at a site on Northern Dartmoor over a period between 8000 and 6000 bp. Despite the problems of identification, estimation and representation of charcoal data, a period of increased burning has been shown. A number of species whose reproductive mechanism is encouraged by burning or which are tolerant of waterlogged or damp conditions show a marked increase during this period. Human interference in the form of deliberate burning appears to have contributed to irreversible changes in the vegetational history of the area.

**Lisa Dumayne (Southampton)** *Environmental Variability in Northern Britain during Late Prehistory.*

Before the Roman invasion of Britain, prehistoric man had very little permanent impact on the vegetation of Northern Britain. It is thought that the relationship between man and vegetation was significantly altered during the Roman occupation of the area. The degree of environmental variability in Northern Britain at this time can be reconstructed by palynological analysis of lake and peat bog sediments. The results of such an investigation will enable an assessment of the Roman impact on vegetation to be made.

**Tim Mighall (Keele)** *Copa Hill, Cwmystwyth; preliminary palaeoecological observations.*

Palaeoecological techniques are being utilised in order to provide insight into the current debate for prehistoric mineworkings. Results indicate that the area was deforested at some stage in prehistory but radiocarbon dates are required to place events into a chronological context.

### **Climate/Palaeoecology**

**Rob Stoneman (Southampton)** *Climatic change over the Late Holocene in Northern Britain.*

It has been shown that climate plays the dominant role in the development of raised bogs. The macrofossils in a column of peat should, therefore, reveal a record of climatic change. The approach needed to obtain a picture of climatic variation and the theoretical considerations behind the technique were discussed.

**Jeff Blackford (Keele)** *Blanket peat humification as a proxy climatic indicator.*

Humification, pollen and fungal data from blanket peat profiles from the North York Moors, Snowdonia and Connemara, show the occurrence of 'wet shifts' in peat growth. These are characterised by a change to less humified peat and changes in the relative abundance of various pollen and spore types. Radiocarbon dates from these shifts show a coincidence around 1400 radiocarbon years BP, more detailed analysis being hindered by the apparent inaccuracy of radiocarbon dating from blanket peat.

**Dan Charman (Southampton)** *Blanket mire initiation and development in the Flow Country.*

The timing and causes of blanket peat growth are some of the most vexed questions in palaeoecology. Data from the Flow Country, Northern Scotland, suggests that early anthropogenic influence is implicated in ombrotrophic peat growth from c.8000 years BP. It is suggested that some of the terminological problems could be solved by the use of further analyses, in particular the adoption of loss on ignition to define the earliest true peat horizons.

### **Theoretical/Experimental Palaeoecology**

**Carol David (Loughborough)** *Vegetation history and pollen recruitment in a small lowland lake.*

Preliminary results of an investigation of pollen recruitment to a small lowland English lake are presented. The history of woodland and lake-use has been reconstructed for the past c.250 years from documentary and lake pollen records. The downcore response of selected pollen types to vegetation and land-use changes are used to establish the 'effective' pollen catchment area of the lake and to investigate how well this supports predictive models of pollen input to lakes.

**Ros Singer (King's College, London)** *Using palynodebris for palaeoecological interpretations.*

Palynodebris (Sporomorphs and organic debris resistant to mineral acid treatment) assemblages of several Tertiary sites in the Isle of Wight are being studied to produce a new classification of debris that is suitable for palaeoecological analysis. Plant megafossils, mammals, mollusca and ostracods have been studied but these are limited to discrete horizons. Palynodebris is more widely distributed and it is hoped that assemblages diagnostic of particular environments will be established.

**Jon Lageard (Keele)** *Testing R-Values from an early Holocene pine/birch forest, White Moss, South Cheshire.*

Multi-disciplinary techniques (mainly palynology and dendrochronology) are being used to reconstruct a palaeoforest formerly growing on a peat deposit. The aim of the project is to study the fossil tree pollen production vis-a-vis subfossil tree stump layers (*Pinus sylvestris* and *Betula* spp.).

#### **Field Visit**

White Moss was visited after the conference where an impressive quantity of large pine stumps and trunks has been revealed by commercial peat and sand extraction. Excavation of the forest layers has been conducted in great detail despite encroachment by the quarrying operation, a high water table and the interstratified nature of the deposits.

Jeff Blackford

Tim Mighall

January 1990



# Announcements & Meetings



## DEVENSIAN LATEGLACIAL PALAEOCLIMATE — a new collaborative NERC project

This collaborative project has been funded by NERC under the Special Topic 'Palaeoclimate of the last glacial/interglacial cycle'. It is coordinated from the University of Durham by Dr Brian Huntley with Prof. Russell Coope (Geology, University of Birmingham and Geography, Royal Holloway and Bedford New College), Dr David Keen (Geography, Coventry Polytechnic) and Dr John Lowe (Geography, RHBNC) as the other principal investigators. Drs D D Harkness (East Kilbride), R E M Hedges (Oxford) and M J C Walker (Lampeter) are associated investigators. We shall, in the near future, be advertising three full-time posts, each of 2 years duration. These will be one each of post-doctoral research assistant (Durham), post-graduate research assistant (Coventry) and technical assistant (Birmingham).

The overall aim of the program of research is the elucidation of climatic gradients during the lateglacial period, and of the rates of change both of the climate and of these climate gradients. The research strategy will capitalise upon existing data whilst at the same time providing new data that will enable critical assessments of the reconstructed palaeoclimates and climate gradients, and of their rates of change, in critical regions of the British Isles. An important component of the strategy is the employment of combinations of different palaeoclimate proxies, especially in the study of new sites. Not only will this provide valuable information about different aspects of the palaeoclimate, but the parallel use of pollen, coleopteran and molluscan evidence will aid in improving our understanding both of the factors influencing each of these proxy records and the apparent discrepancies between the palaeoclimate inferences that may be made from them. The research will proceed in parallel along two complementary paths that represent two distinct but closely interwoven sub-projects.

### Sub-project A: Synthesis of lateglacial palynological data and palaeoclimate reconstruction for Europe

This sub-project will be coordinated by Dr Brian Huntley in Durham. The work will focus upon the synthesis into database form of European pollen data for the period 15 000 to 9000 BP. The database will be planned and constructed in collaboration with the European Pollen Database project being coordinated by the Université d'Aix Marseilles. Raw pollen count data will be sought from as many sites that span this period as possible, and the success of the project depends heavily upon the collaboration and cooperation of colleagues who have collected suitable data. If you have suitable data that you are willing to make available, then I would be pleased to hear from you and to discuss the mechanisms for incorporating them into the database as well as provisions for limiting the ways in which they may be used. I will be writing within the next few weeks to those of you who have already indicated willingness to make data available.

Once the database has been constructed, pollen-climate response surfaces will be applied in order to make both time-series and mapped palaeoclimate reconstructions. The rates of change of both the pollen time-series and the reconstructed palaeoclimate values will be investigated. The results will be compared with independent palaeoclimate reconstructions made from palynological data and from Coleoptera as part of a wider international collaboration with workers in France, Sweden and the USA.

### Sub-project B: Late-glacial climatic gradients in the British Isles as sensed by a combination of several proxy indicators

This sub-project is coordinated by Dr John Lowe, with work taking place in all of the collaborating centres. New, high quality studies will be performed at a small number of carefully selected sites from various parts of the British Isles. These studies will, as far as possible, combine three complementary palaeoclimate proxies—pollen, Coleoptera and Mollusca—and will be carried out with as fine a temporal resolution as is practicable and as is appropriate to the sedimentary environment. A combination of conventional and AMS determinations of  $^{14}\text{C}$ , the latter performed upon material from terrestrial

plant macrofossils, will be used to provide chronologies for the sediments. The sites studied will be dispersed geographically so as to provide assessments of both the west-east and north-south climate gradients, and will be selected according to a series of criteria including:

- 1 The continuity and temporal extent of the record provided; sites with continuous sedimentation from early in the lateglacial period until 9000 BP will be favoured.
- 2 The depth of sediment accumulated and the sedimentary environment; sites offering the potential for achieving fine temporal resolution will be favoured.
- 3 The presence in the sediments of pollen, Coleoptera, Mollusca and plant macrofossils; sites that contain all of these will be favoured.
- 4 The method of sampling possible; sites that can be sampled from exposures will be favoured over sites that can only be sampled by coring.
- 5 The absence of any evidence of sources of hard-water error or other contaminants that would invalidate the  $^{14}\text{C}$  determinations of sediment age.

We welcome suggestions of suitable sites from any colleagues who may know of sites that meet these criteria; we are also keen to develop collaborative investigations of such sites with colleagues who may already be investigating some aspect of the stratigraphy of a suitable site. Please contact John Lowe if you are able to suggest a suitable site(s).

Palaeoclimate inferences will be made from the independent proxies using appropriate methods; Dr Tim Atkinson (UEA) will collaborate in the inference of palaeoclimate from the Coleoptera. The overall synthesis of the results will be made collaboratively by the whole group.

The research strategy that we have adopted could be expanded to generate new data of high value from Europe as a whole, and it is intended that a workshop meeting will be organised in due course to present and discuss the strategy and to stimulate and encourage parallel studies in other parts of Europe, some of which may be collaborative projects involving members of this group.

Dr Brian Huntley  
Palaeoecology and Ecology Research Group  
Environmental Research Centre  
University of Durham  
Department of Biological Sciences  
South Road  
Durham DH1 3LE.

## EARLY ANNOUNCEMENT OF FORTHCOMING LECTURES

- |                   |   |
|-------------------|---|
| Julian Dowdeswell | Scott Polar Research Institute<br><b>Ice-berg calving: implications for ice-sheets and the marine record.</b> |
| Martin Sharp      | University of Cambridge<br><b>Glacial hydrology and dynamics of Quaternary ice-sheets.</b>                    |

These lectures will be held on *Thursday 13th December* at 3.00 and 6.00 p.m., Room 125, Department of Geography, Queen Mary and Westfield College, Mile End Road, London E1 4NS. For information contact Murray Gray at the above address or phone 071-975 5406.



# LQL

## LONDON QUATERNARY LECTURES

Thursday, 8th November 1990

ROYAL HOLLOWAY & BEDFORD NEW COLLEGE  
UNIVERSITY OF LONDON

1500

**Professor D.Q. Bowen**  
*Director, Institute of Earth Studies,  
University College Wales, Aberystwyth*

'The Last Interglacial/Glacial Cycle in Britain'  
[LQL No.41]

1730

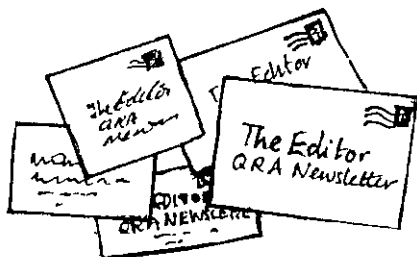
**Dr C. Schlüchter**  
*Secretary-Treasurer of INQUA  
Department of Geology, E.T.H., Zurich*

'The Last Interglacial/Glacial Cycle in Switzerland'  
[LQL No.42]

In: Lecture Theatre, Queen's Building, RHBNC, Egham Hill, Egham, Surrey TW20 0EX

Additional lectures in the series for the 1990/91 academic session, to be presented at the City of London Polytechnic, Queen Mary College, and University College London, are also being arranged

# Post Bag



Dear Sir

## CUMBERLAND GEOLOGICAL SOCIETY

The Cumberland Geological Society is a well established amateur society which covers that glacially-interesting area known as the Lake District and from time to time, our summer programme of outdoor excursions has visits to areas that would be of particular interest to your own members. We extend a warm welcome to any of your members who would like to join us and I enclose a copy of our forthcoming programme.

My main reason for writing is to advise you that we shall shortly be publishing the long-awaited supplement to the "Bibliography of the Geology and Geomorphology of Cumbria" by Dr R A Smith. This was published in 1974 and the new supplement covers the very considerable literature on the area published during the last 15-16 years. The bibliography lists the references alphabetically followed by classified indexes to specialist subjects such as fluvioglaciation, palynology, solifluction and so on. Copies may be obtained from our Publications Secretary, Mr T P Loftus, 9 Jackson Road, Houghton, Carlisle CA3 0NW. The cost is £3.00 including postage. The original bibliography, which is an essential part of the new supplement, is still available and copies of both parts are available at the inclusive price of £3.50 for the two. Please make cheques payable to the Cumberland Geological Society. I would be most grateful if you could find the opportunity in a future newsletter to mention this publication which, I am sure, would be of interest to many of your members.

## EXCURSION PROGRAMME—1990

**Wednesday, June 27**, Volcanic intrusions in Dodd Wood, Skiddaw. MP Layby near Little Crosthwaite MR NY237272 (Sheet 89/90). Leader Mr Derek Allen.

**Saturday, July 7**, 9.30 am, Volcanic intrusions in Dodd Wood, Skiddaw. MP Layby near Little Crosthwaite MR NY237272 (Sheet 89/90). Leader Mr Derek Allen.

**Saturday, July 7**, 9.30 am, Coal Measures around Whitehaven, MP Keekle Opencast Offices MR NZ006179 (Sheet 89). Leaders Dr Paul Guion and Mr Dennis Dickens.

**Saturday, July 14**, Armthwaite Dyke and red rocks of the Eden Valley. MP Dog and Pheasant, Armthwaite MR NY508460 (Sheet 86). Leader Dr Eric Skipsey. Joint meeting with the Open University Geological Society.

**Wednesday, July 18**, Iron Ore Mines, Keltonfell Top. MP 200 yds, north of Croasdale Top junction MR NY087183 (Sheet 89). Leader Mr Mervyn Dodd.

**Sunday, September 16**, Honister/Yew Crag slate quarries. MP Honister car park MR NY225135 (Sheets 89/90). Leaders Mr Alistair Cameron and Mr Ian Matheson. Joint meeting and organised by the Cumbria Amenity Trust and Mining History Society. NB Helmets are essential for visiting underground workings.

Yours sincerely

K W Bond  
Gen. Sec.



Dear Dr Taylor

The February issue of QN has just reached me (7 May!) so I reply in haste in hope that this letter can be printed in the June issue.

I am surprised that some QRA members found my previous letter overly 'political'. It was written in the heat of the aftermath of the Tian Anmen Square massacre. However, the membership should note, as Brian Taylor correctly states, that the letter expressed a *personal* point of view and was very carefully couched in the *conditional* tense. I was merely suggesting certain courses of action for individual consideration. People were perfectly free to disagree with me, as most seem to have done!

I would make two further points. I visited Romania in 1988 as an officially invited guest, the only possible way to meet colleagues before the abominable Ceaucescus were rightly executed, so I am fully aware how desperately scientists in such benighted countries long for contact with the outside world. However, there is a great difference between an individual visit, even under a government-sponsored cultural exchange programme, and attendance at a prestigious international conference, all the costs of which must be paid in US dollars, most of which will never reach the scientists who ought to benefit from them. Any government, especially such a discredited regime as still rules China, will attempt to profit from such a 'newsworthy' occasion. My major concern now and when I first wrote is that the Beijing junta should not bask in the reflected glory the conference will quite rightly bring to Chinese science. I have every sympathy for the plight of individual Chinese scientists, they have been in the wilderness far too long. I should like very much to visit China and study the Zhoukoudian fossils and other Palaeolithic material, but as a politically unimportant individual, not an exploitable international conference delegate.

Other QRA members will undoubtedly do as they see fit.

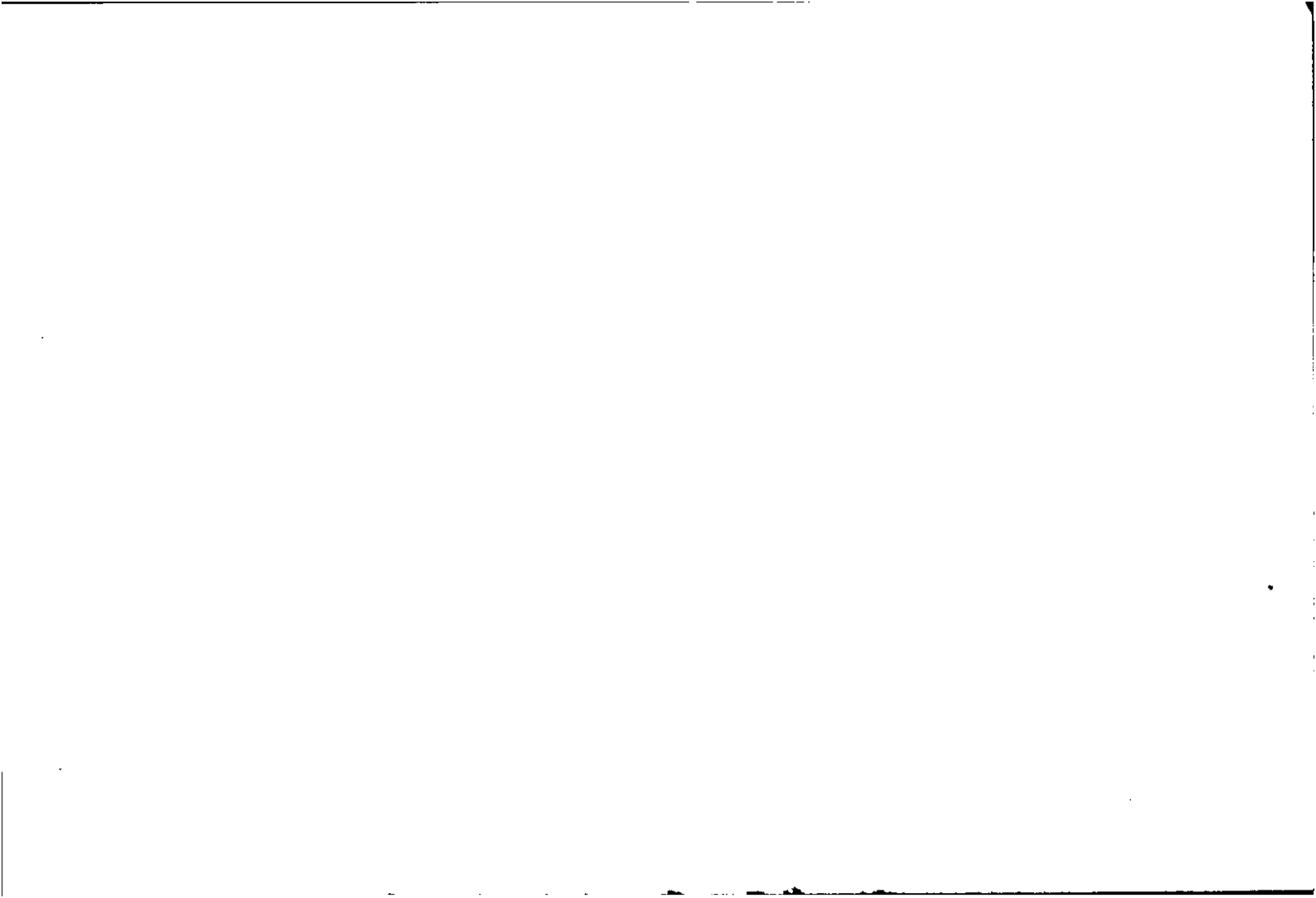
Yours sincerely

Esmée Webb  
Department of Archaeology  
University of Western Australia  
Nedlands WA 6009

PS On a lighter note, I deeply regret the demise of the cover cartoons and hope the amusing editorials will continue.







## QUATERNARY RESEARCH ASSOCIATION

The Quaternary Research Association is an organisation comprising archaeologists, botanists, civil engineers, geographers, geologists, soil scientists, zoologists and others interested in research into the problems of the Quaternary. Most members reside in Great Britain, but membership also extends to most European countries, North America, Africa and Australasia. Current membership stands at c.1000. Membership is open to all interested in the objectives of the Association. The annual subscription for ordinary members is £10.00 and is due on January 1st for each calendar year. Reduced rates apply for students, unwaged and associated members.

The main meetings of the Association are the Annual Field Meeting, usually lasting 3 or 4 days, held in April, and a 1 or 2 day Discussion Meeting held at the beginning of January. Additionally, Short Field Meetings may be held in May or September and occasionally these visit overseas locations. Study Courses on the techniques used in Quaternary work are also occasionally held. The publications of the Association are the *Quaternary Newsletter* issued with the Association's *Circular* in February, June and November, the *Journal of Quaternary Science* published in association with Longmans, and with three issues a year, the Field Guides Series and the Technical Guide Series.

The Association is run by an executive committee elected at an annual general meeting held during the course of the April field meeting. The current officers of the Association are:

President: Professor J Rose, Department of Geography, Royal Holloway and Bedford New College, University of London, Egham Hill, Egham, Surrey TW20 0EX

Vice President Professor W A Watts, Provost's House, Trinity College, Dublin 2, Ireland

Secretary Dr M J C Walker, St David's University College, Lampeter, Dyfed, Wales SA48 7ED

Assistant Secretary (Publications): Dr D R Bridgland, Nature Conservancy Council, Northminster House, Peterborough PE1 1UA

Treasurer: C A Whiteman, Botany School, University of Cambridge, Downing Street, Cambridge CB2 3EA

Editor (*Quaternary Newsletter*): Dr B J Taylor, British Geological Survey, Keyworth, Nottingham NG12 5GG

Editor (*Journal of Quaternary Science*): Dr P L Gibbard, Botany School, University of Cambridge, Downing Street, Cambridge CB2 2EA

All questions regarding membership are dealt with by the Secretary, the Association's publications are sold by the Assistant Secretary (Publications) and all subscription matters are dealt with by the Treasurer.

# QUATERNARY NEWSLETTER

## QN:

June 1990 No. 61

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