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THE "LATE-GLACIAL" IN THE TROPICS

By Neil Roberts, Alayne Street-Perrott and Alan Perrott

Late-glacial climatic oscillations in northwest Europe, North America and northern China are well documented from pollen and glaciological evidence (Moore, 1981). On the other hand, despite the fact that the associated vegetational changes are widely recorded in temperate latitudes between 14,000 and 10,000 BP, there is a notable lack of confirmation from some areas, implying that the underlying climatic events may not have been truly global in scale. There is also debate as to whether the generally rising temperature curve during the period of interest was interrupted by one cold episode or two. The purpose of this short note is to show that the emerging palaeoclimatic record from the tropics can throw considerable light on this issue. Evidence for fluctuations in both temperature and precipitation during the terminal Pleistocene (probably a more appropriate term than "late-glacial" for this largely unglaciated zone) comes not only from variations in pollen and the extent of alpine glaciation, as in higher-latitude regions, but also from water-level changes in closed-basin lakes.

In the northern Andes, van der Hammen and his co-workers have identified a number of late-glacial climatic oscillations between 14,000 and 10,000 BP from pollen, glacial and lake-sediment stratigraphies (Van Geel and van der Hammen, 1973). At high elevations in the eastern Cordillera (ca. 3500m), a cold but arid glacial maximum was followed by warmer, moister conditions between 14,000 and 13,000 BP (Susacá interstadial) and, after an intervening cold phase, again between 12,400 and 11,000 BP (Guantiva interstadial). The Guantiva interstadial itself was broken by a short, cold snap at some time after 12,000 BP (van der Hammen, Barelds, de Jong and de Veer, 1981; Salgado-Labouriau, Schubert and Valastro, 1977). Pollen diagrams from 1,000m lower down in central Colombia include only the second (Guantiva) interstadial, which furthermore lacks the double peak of

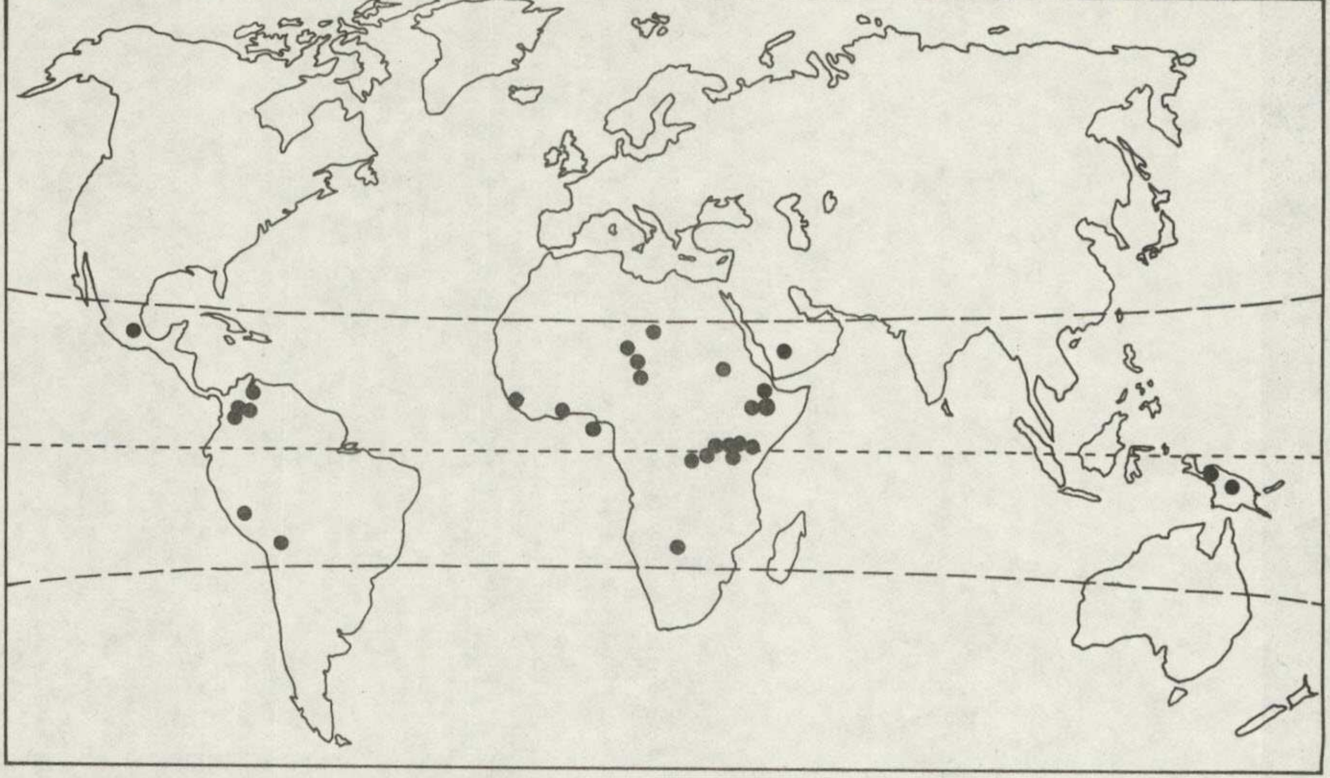

Fig.1. Intertropical sites recording terminal Pleistocene climatic oscillation.

warmth found at higher altitude sites. This interstadial saw the re-establishment of forest vegetation, while the succeeding El Abra stadial (11,000 - ca. 10,000 BP) witnessed the replacement of forest by more open subpáramo (sub-alpine shrub) vegetation, suggesting a return to a cooler, drier climate (Schreve-Brinkman, 1978).

Further north, in Mexico, where it appears from present evidence that the most extensive glacial advance within the limits of radiocarbon dating occurred during the terminal Pleistocene, Heine (1973, 1978) has proposed that increased precipitation rather than temperature change was the key factor triggering expansions of the montane glaciers. His suggestion is supported by evidence from South America, which shows that the late-glacial readvance of tropical glaciers was contemporary with an expansion of high altitude lakes. Lake Tauca in the Bolivian Altiplano, for example, reached its greatest extent - some 50,000 km^2 - between 12,500 and 11,000 BP (Servant and Fontes, 1978), at the same time as glaciers in Peru were undergoing their last substantial re-advance (Mercer and Oscar Palacios, 1977).

The most convincing evidence for terminal Pleistocene lake-level fluctuations comes from the African continent (Street and Grove, 1979). Analysis of twelve intertropical lake basins recording significant water-level changes during this period, shows that between 12,500 and 10,000 BP, a single, as opposed to a double, lake maximum occurred in all but two basins. Moreover, the latitudinal distribution of the lakes involved is very wide, ranging from Botswana in the south (20°S) to Tibesti in the north (23°N) (fig. 1). The best-dated lake-level curves which show this oscillation are those from Bosumtwi in Ghana (Talbot and Delibrias, 1980), Chad (Servant and Servant-Vildary, 1980), and Ziway-Shala in southern Ethiopia (Street, 1979). The majority of lakes rose between 12,500 and 11,500 BP and fell again after 10,500 BP, reaching minimum levels around 10,200 BP. It is difficult to determine the relative importance of precipitation and temperature in causing these terminal Pleistocene fluctuations, but it is interesting that taking the period 17,000 - 5,000 BP as a whole in tropical Africa, there is a strong positive correlation between water levels and global temperature, suggesting that rising lakes accompanied rising temperatures, and *vice versa.*

Not surprisingly, many African rivers, including the Nile, experienced a change in régime equivalent to that recorded in the lakes, during the terminal Pleistocene (Thomas and Thorp, 1980; Adamson, Gasse, Street and Williams, 1980). For instance, climatic oscillations are recorded in marine sediments on the outer Niger Delta in West Africa (Pastouret, Chamley, Delibrias, Duplessy and Thiede, 1978), with phases of increased river discharge dated from 13,600 to 11,800 yr BP, and from 11,500 to 11,300 yr BP.

Pollen diagrams from montane sites in eastern Africa also indicate a late Quaternary climatic oscillation, though the shifts are subtle, inadequately dated and therefore difficult to interpret. In the Ruwenzori Mountains (Uganda) post-glacial climatic amelioration began at or around 14,750 BP (Livingstone, 1967). On Mount Satima (Perrott, unpublished) an initial expansion of dry montane forest characterised by *Podocarpus* spp., *Juniperus procera*, *Olea* spp. and *Hagenia abyssinica* gave way to species of open ground and light-demanding colonisers such as *Myrica* sp. and *Acacia* sp., indicating a substantial depression of the forest boundary. This was followed by re-establishment of montane forest.

At Sacred Lake, Mount Kenya, where ameliorating conditions with a rising tree line are recorded from shortly after 14,050 BP (Coetzee, 1967), a sudden and relatively short-lived tree line depression occurred at ca. 11,000 BP. This depression of the upper forest boundary to at least 700m below its present position indicates a minimum temperature decrease of 4.4°C. Two other montane pollen diagrams, from Mount Elgon (Kenya) and Mount Badda (Ethiopia) (Hamilton and Perrot, unpublished), record arid conditions between 11,000 and 10,000 BP. These high altitude (> 4,000m) diagrams have basal dates of 11,012 BP and 11,500 BP respectively. It is therefore possible that the basal sediments at these two sites record the climatic oscillation that interrupted the terminal Pleistocene climatic amelioration elsewhere.

Across the Indian Ocean, the deglacierization sequence in New Guinea provides an example of a double cold oscillation similar to that found in Scandinavia, with glacier readvances occurring between 13,000 and 12,000 BP, and after 11,000 BP (Hope and Peterson, 1976). However, neither event is reflected in the pollen diagrams from upland New Guinea (Flenley, 1979), which do, however, indicate an abortive forest incursion before 13,000 BP.

The late-glacial was a period of transition and its climate appears to have alternated rapidly between glacial and interglacial modes. The impact of these fluctuations was at least as great in the low latitudes as in the temperate zone, but whether individual climatic events were in fact synchronous in both areas remains to be seen. For the moment, debate is likely to continue about whether the late-glacial climatic oscillation in the tropics - as in Europe- had one hump or two.

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KNOCKNASILLOGE MEMBER OF WEXFORD : GLACIO-MARINE, MARINE OR GLACIO-LACUSTRINE?

By D. Huddart

Introduction

In a reply to Huddart (1981), Thomas and Summers (1981) whilst agreeing with the stratigraphic succession raise some problems which warrant further discussion. They restrict their views to the Screen Hills area of Wexford and specifically query Huddart's (1981) interpretation of the sedimentology, included microfauna and origin of the Knocknasilloge Member.

Discussion on the Sedimentology

On sedimentological grounds they suggest there is nothing in the descriptions that provides evidence of marine processes and that there is no attempt to provide this definitive environmental evidence. However, it is well known that sedimentological data is usually not in itself diagnostic of an ancient shallow marine shelf sequence, although all the sedimentological data from the Knocknasilloge Member have been noted in this environment (Johnson 1978). Usually the geologist has to rely on marine body fossils, trace fossils and geochemical parameters for definitive evidence. In this case there are marine microfossils which may have been reworked but the absence of macrofossils may either reflect environmental conditions or chance. Presumably Thomas and Summers have the negative geochemical evidence to help disprove the idea that these sediments are marine.

Their alternative is that these sediments and part of the overlying Screen Member are glacio-lacustrine. They suggest a coarsening upward succession and put forward the view that the sedimentology is consistent with deposition in a shallow glacial lake margin progressively overwhelmed by prograding distal outwash sandur sediments.

Yet they provide no evidence at all for this interpretation which is ironical in view of their comments on Huddart (1981). Moreover it is possible to suggest that these sediments are not glacio-lacustrine in origin from the following points:-

a) there is no regular repetition in the beds which could be called rhythmic but the sequence does show haphazard intercalations of units of differing sedimentary structure and texture which is considered random. There are no rhythmites, which are considered characteristic of glacio-lacustrine sequences (Ashley 1975). These do not occur within, below or laterally coincident with the Knocknasilloge Member as would be expected if these sediments were glacio-lacustrine.

   Moreover, there is no evidence of deeper-water lake sediments in any adjacent area of Wexford. Indeed there is evidence of the same Knocknasilloge facies on the south coast many kilometres to the south.

b) there is no assemblage of facies types characteristic of glacial lakes as suggested by Shaw (1975, 1977), Gustavson, Ashley and Boothroyd (1975) and Cohen and Huddart (in press). There are no vertical transitions into deltaic sequences, either high energy proximal (Cohen 1979) where the sedimentary association would be diagnostic, or lower energy distal (Shaw 1977, Cohen and Huddart in press). The Knocknasilloge Member does not show these vertical, lateral and regional changes which you would expect if they were deposited in such an environment.

c) extensive parallel laminated units with norhythmites have been noted by Theakstone (1976) in a glacial lake sequence but these pass up into low gradient deltaic foresets. This type of association is not present in the Knocknasilloge Member.

d) the absence of varves and rhythmites appears crucial and their absence has suggested to Lindsey (1971) that part of the Pre-Cambrian Gowganda Formation was marine rather than glacio-lacustrine and to Pantin (1978) that his Quaternary pro-glacial lagoon beds were marine rather than glacio-lacustrine.

The conclusion from these points is that the Knocknasilloge Formation is not of glacio-lacustrine origin.

Discussion on the Foraminifera

Whilst not querying the interpretation of the foraminiferal assemblages, Thomas and Summers do suggest that they are reworked and, therefore, environmentally useless. There seems no doubt that there has been much reworking of marine sediments in the Irish Sea basin by ice and all glaciogenic sediments contain a microfauna and that even in the marine environment sorting takes place. One of the problems stressed in the original paper was reworking but it seems pertinent to point out the following:-

a) Lamplugh (1903) described a series of marine deposits (Ayre Marine Silts) that included richly fossiliferous sands and silts and Thomas (1976) was quite happy to use them, with no definitive evidence for the marine environment, as partial evidence for a Hoxnian sea level.

b) In the same paper he used a foraminiferal species list obtained by Wright (1902) and Wright and Reade (1906) to try and decide whether the Dog Mills Series was glacio-lacustrine or glacio-marine. He stated that if the fauna was in place, deposition was either cold water marine with an introduced brackish water element, or more likely considering the laminated nature of much of the Dog Mills Series, estuarine-intertidal, with a current-swept open-water element. Later Thomas (1977) confirmed this interpretation by further foraminiferal analysis and it was stated that "good preservation makes it unlikely that the fauna has been reworked". The same statement could apply to the Knocknasilloge Member.

c) In these papers there was no proof of marine origin for the sediments apart from the included microfauna. Again this is an ironical situation in view of the comments in Thomas and Summers. Nevertheless if at all possible, proof of the marine environment must be found. This does not happen because of the difficulties discussed earlier. It is common to find that microfossils are used to diagnose a marine environment rather than sedimentological or geochemical evidence, for example, in Fisher, Funnell and West (1969), Kidson, Haynes and Heyworth (1974) and Pantin (1977, 1978).

d) Thomas and Summers say that Huddart (1981) states that the fauna in the Knocknasilloge Formation is of wholly Ipswichian age. In fact what was stated was that this alternative of three possibilities seemed the most likely, but that the marine Pleistocene of the Irish Sea was poorly known and documented. When further evidence is found it may support one of the other alternatives outlined. The assemblage present contains some cold water species, such as Elphidium clavatum, Cassidulina obtusa, Oolina borealis, Guttulina glacialis and Buccella frigida but these are only in minor quantities. Usually in cold waters the clavatum/obtusa assemblage dominates. Yet today around the British coasts clavatum is not found. The faunal diversity is high for the Knocknasilloge Formation and the faunal dominance low compared with arctic foraminiferal assemblages. These points are again suggestive of interglacial conditions.

Is the Knocknasilloge Formation of glacio-marine origin?

If Thomas and Summers' view of the foraminifera is correct then it is possible to return to Huddart's (1976) original interpretation of the Knocknasilloge Formation. This was that it was glacio-marine in origin and deposited from density underflows, flow tills and suspension sedimentation in a distal floating ice shelf environment. This interpretation was based on the presence of flow tills with strong microfabrics, some dropstone material and the vertical transition with the underlying Castleannesley Till. This was tentatively suggested as being deposited from a grounded ice shelf and it is interesting that Dreimanis (pers. comm.) suggested that the laterally equivalent till along Rosslare Harbour was of glacio-marine origin. There certainly seems less immediate problems with this interpretation. It is pertinent to point out too that Thomas (1977) has suggested the possibility that marine conditions may have accompanied the Devensian ice margin throughout its history. In part supporting this view is the description and interpretation of well bedded, proglacial water-laid sediments from the northern Irish Sea (Pantin 1977, 1978). These sediments are muddy, with sand and silt laminae, have dropstones, have virtually no macro-organic remains yet have foraminifera locally present. These characteristics are similar to the Knocknasilloge Formation apart from the lack of ripple beds and flow tills. Pantin (1978) interprets the sediments as deposition in a body of water connected to an open sea, which was colder and less saline than the present day Irish Sea. They are a type of glacio-marine sediment and are overlain by marine beds. Again they appear similar to the Marr Bank Beds of the North Sea (Thomson and Eden 1977). In both these latter cases the included foraminifera are interpreted as indicating arctic seas. There is no consideration that they may be reworked.

Conclusions

a) there is no dispute over the stratigraphy. There is no dispute over the Blackwater and Ballynadrishoge till members despite what Thomas and Summers state. These tills were derived from the Irish Sea ice sheet. The fabric patterns suggest ice movement from the NW-N quadrant and their erratic contents are dominated by Cambrian purple, green and blue-grey siltstones; Carboniferous Limestone and chert; Ordovician volcanics; greywackes, sandstones and quartzites; schist; Leinster granite and flint. These are derived from the coastal plain to the north and from the underlying Castleannesley Till. The latter unit shows fabrics indicating ice movement from the north to north-east quadrant.

b) there is some dispute over the interpretation of the Knocknasilloge Formation. Evidence has been presented to suggest that it cannot be glacio-lacustrine as put forward by Thomas and Summers. The penecontemporaneous deformation mentioned by them could equally well have occurred in a glacio-marine environment.

c) if the foraminifera are reworked then it is suggested that a glacio-marine environment is the most likely. If the foraminifera are not reworked then we have all the problems associated with an inter-glacial mentioned by Thomas and Summers. It does seem possible that this faunal assemblage, indicating colder conditions than at present in the Irish Sea but not arctic temperatures, could have lived in a sea adjacent to floating ice. However, it seems unlikely. There still remains a problem here with the present state of our knowledge.

d) the first aim of Huddart's (1981) paper to stimulate discussion has been achieved. The problems of interpreting certain 'marine/glacio-lacustrine' sediments, especially where they contain micro-fossils, has been shown. It has focussed attention on what must be achieved initially - the correct sedimentological interpretation. The controversy that has always seemed to be present in discussions of Irish Sea Quaternary sediments is still with us. Nevertheless, it seems unfair to suggest that Huddart's (1981) paper does nothing but confuse our understanding of Quaternary events in south-east Ireland. It draws attention to a complicated sediment sequence; has suggested certain alternatives; has stimulated discussion and hopefully, further work in the area. There is still much to learn about the Quaternary of the Irish Sea basin, particularly the relationships between the ice and contemporaneous sea levels. So far there seems to be one or two pieces of the jigsaw which are difficult to interpret but many of the pieces are so far undiscovered.

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NEW EVIDENCE FOR LATE-DEVENSIAN MARINE LIMITS IN EAST-CENTRAL SCOTLAND - SOME COMMENTS

by D.E. Smith
R.A. Cullingford

In their account of marine limits in east-central Scotland, Browne et al. (1981) describe occurrences of Late Devensian marine clays which are claimed to show that in the case of the two higher Perth shorelines, the drop in the marine limit whilst the ice lay at Stirling was less than estimated by Sissons and Smith (1965), and that in the case of the earlier East Fife Shorelines, the inland limit of shorelines EF4, 5 and 6 lay to the west of the limits postulated by Cullingford and Smith (1966). On this basis they conclude that "an extremely cautious approach be adopted to the interpretation of evidence that appears to relate former ice front positions to contemporaneous sea levels" (p. 13).

The records of marine clay occurrences presented by Browne et al represent a useful contribution to studies of marine limits in Scotland. It is certainly true that these deposits are very much in need of further study. However, Browne et al have overlooked important morphological evidence and have made certain stratigraphical assumptions which together throw doubt upon their interpretations. Their paper also contains errors and misrepresentations concerning published statements by the present authors and by Sissons.

Reading the account of Browne et al, the impression is gained that the inland limit of the shorelines identified by us and Sissons is simply the occurrence of the most westerly shoreline fragment. However, in the case of both the higher Perth shorelines in the Forth valley and of three East Fife shorelines (EF3, 4 and 6), the inland limit is marked by outwash and related fluvioglacial features. For the sea to have extended further inland at the height of the shorelines or even subsequently to have transgressed the shoreline fragments would require modification of the outwash surfaces, which in some cases contain meltwater channels and kettle holes. Browne et al. do not mention such evidence, although they do allude briefly to the paper by Armstrong et al. (1975) in which such outwash and ice-contact landform assemblages immediately beyond the westward terminations of different raised shorelines in east-central Scotland are all conveniently attributed to the wasting of detached masses of dead ice stranded by the inland recession of the ice-sheet margin, and outlasting the period of marine inundation. This interpretation meets serious difficulties when some of the detailed fluvioglacial landform evidence is examined, but even if this were not the case it still fails to explain why well developed raised shorelines and beaches are conspicuously present to the east of the related fluvioglacial landforms, and conspicuously absent to the west, even though greater shelter and more abundant sediment supply should have ensured the better development and survival of raised estuarine flats in that direction.

In order to compare the altitudes of the clays with those of the shorelines, Browne et al. project some of the shoreline altitudes westwards. All the shorelines recognised by the authors were depicted by linear regression lines calculated from shoreline altitudes whose distances were measured from a common origin along a line normal to the presumed isobases. The shoreline diagrams used by us and by Sissons are all of the height-distance or 'equidistant' type, and are not shoreline relation diagrams as stated by Browne et al. We have never used relation diagrams because of the dubious validity of the assumptions on which they are based, as explained elsewhere (Cullingford, 1977; Cullingford and Smith, 1980). One of the alleged shoreline relation diagrams (Smith et al., 1969, Fig. 3) in fact shows isobases of the Main Perth Shoreline. More importantly the practice of projecting our regression lines far beyond the areal limits of the data upon which they are based is both statistically and geomorphologically unsound and not a reliable basis from which to draw important conclusions about the marine limit. It should also be noted that in the case of the East Fife shorelines, Cullingford and Smith (1966) only considered the area between St. Andrews and Leven, as was clearly stated in that paper, and not the Howe of Fife.

The conclusions drawn by Browne et al. about the raised shoreline/ ice margin relationships with which we were concerned should be examined against the background of the previous paragraph, and in the light of the fact that laminated clays occur very widely in eastern and central Scotland, often beneath fluvioglacial deposits of demonstrably different ages, and in some cases at altitudes far in excess of the highest raised shorelines. In Angus such clays also occur interbedded with outwash deposits (Cullingford and Smith, 1980). All of these occurrences, like those described by Browne et al., are puzzling, not least because their precise stratigraphic relations are unknown. It is not even clear how many phases of deposition are represented by these clays, nor how many of them are in fact marine. We contend that the onus is on Browne et al. to demonstrate unequivocally that the clays they have identified belong to the same depositional sequence as the deposits associated with the raised shorelines, and not to some earlier episode(s). We further suggest that qualitative statements alleging that clays are 'identical' to others in the area need to be supported by detailed sedimentological and micro-fossil studies before they can be accepted.

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NEW EVIDENCE FOR LATE-DEVENSIAN MARINE LIMITS IN EAST-CENTRAL SCOTLAND - A REPLY

by M.A.E. Browne
M. Armstrong
I.B. Paterson
A.M. Aitken

Basic to our recent paper (Browne et al. 1981) is the considered belief that the Devensian marine clay therein described was laid down during the prolonged period of glacial retreat when the Lateglacial raised beach sequence was formed. This view is implicit also in earlier papers (Paterson 1974: Armstrong et al. 1975; Browne 1980), dealing inter alia with sea-level/ice-front relations in the Tay-Earn and east Fife areas, and also in a recent detailed account (Paterson et al. 1981) of the distribution, stratigraphy and fauna of the widespread marine clay deposit. Our belief is justified by the observation that in east-central Scotland, outwith the limits of the Loch Lomond Stade glaciers, there is no authenticated locality where the marine clay is overlain by till, incorporated within till, markedly overconsolidated (compare with Browne and Graham 1981) or glacially deformed. We are aware that at a number of locations, some of which we have previously discussed (Paterson 1974; Browne 1980), the marine clay has been recorded beneath sand and gravel deposits of demonstrably different ages. This does not invalidate our general conclusion, however, as in such sequences the clay is, as always, younger than the till. We do not accept that the stratigraphical relations of the marine clay can fairly be described as 'unknown'.

Given our view of the age of the marine clay, an incompatibility between certain high level occurrences and some of the ice-fronts, postulated on the basis mainly of geomorphological evidence by Cullingford and Smith (1966) and Cullingford (1977), is apparent when the clay positions are plotted on the shoreline diagram. In suggesting that the clay, wholly or in part, may relate to episodes other than that in which the shorelines formed, Smith and Cullingford (this Newsletter) demonstrate their awareness of this incompatibility. In so doing, however, they in effect concede that extrapolation of the shorelines is admissible, despite their statement that such a practice is statistically unsound.

We are aware that our interpretation of the high level clay must, in the final analysis, be reconsiled with the evidence of fluvioglacial features and deposits cited by Smith and Cullingford in support of their postulated ice-front positions. The initial brief statement (Armstrong et al. 1975) announcing the discovery of the 'incompatible' high level clay occurrences attempted no re-assessment of such evidence but in a subsequent more detailed account (Browne 1980) the inferred ice-fronts at Dunning and Almondbank were further investigated, and in our opinion shown to be of dubious validity. At both localities, the sand and gravel deposits, considered by Cullingford (1977) to be outwash issuing from ice-fronts, are in the form of deltas (the fan-complexes of Cullingford) built out over marine clays northwards into Strathearn from the valley of the Dunning Burn and southwards into the Methven depression from the Almond valley. It would therefore appear that the drainage responsible for the deposits did not in fact issue from trunk glaciers in the principal valleys. The subsequent dissection and reworking of the deltas, with the production of gully systems and lower terraces, are explicable as the reaction to the fall of the late-Devensian sea to and below the Main Perth Shoreline. It is not necessary or, given the pattern of the gully systems, plausible to ascribe these features to the prosimity of an ice-front and to the activity of related proglacial meltwater rivers. Equally, the dead-ice features which exist in the Dunning and Almondbank areas do not necessitate a nearby ice-front. Survival of buried ice until the time of the Main Perth Shoreline is consistent with the frigid climate indicated by the fauna of the marine clay, specifically the fauna of the 'arctic' Errol Beds, the older division of the late-Devensian marine clay in the Tay-Earn area (Paterson et al. 1981).

In contrast to the situation at Dunning and Almondbank, the ice-front position at Stirling seems well authenticated, with an outwash plain, apparently derived from the former Forth glacier, giving way eastwards to a well marked raised beach a little below the level of the Main Perth Shoreline (Sissons and Smith 1965). The new clay occurrences to the west are not incompatible with this relationship although they do suggest that the fall of sea-level while the Forth glacier remained at this ice-limit was less than previously supposed.

In the Cupar-St Andrews area, a considerable problem exists in reconciling the evidence of the Devensian marine clays with that of the fluvioglacial features and deposits on which Cullingford and Smith (1966) based ice-front positions corresponding to shorelines EF-4 and EF-6. Not only are there the high level 'incompatible' clay occurrences in the Howe of Fife and elsewhere but there is also a low level uniform development of marine clay which can be traced from St Andrews, east of the ice-front positions, into Stratheden to their west. That the low level clay is all of the same general age seems a not unreasonable conclusion. This was recognised by Chisholm (in Forsyth and Chisholm

1977 p. 242-247) and Cullingford (1972 p. 91) who pointed out, however, that a uniform age for the clay is irreconcilable with the existence of the postulated ice fronts unless a glacial readvance over the marine clays had taken place. However, the Stratheden-St Andrews clay is nowhere known to be overlain by till or to be glacially compacted or deformed, and this lack of evidence of glacial overriding, a characteristic which the Stratheden-St Andrews clay shares with Devensian marine clay throughout east-central Scotland, proves in our opinion that the postulated ice-front positions west of St Andrews must be invalid. This conclusion is in accord with our deductions in Newsletter 34 from the evidence of the high level clays of the Howe of Fife. The features between St Andrews and Guardbridge which Cullingford and Smith (1966) considered to be of glacial outwash origin constitute the primary evidence for their ice-front positions in this area. Other explanations of these features are possible, for example, that they form part of the subglacial topography as Chisholm (in Forsyth and Chisholm 1977 p. 244) suggested.

In discussion of our interpretation of shoreline/ice-front relations Smith and Cullingford ask why shorelines well-developed to the east of the postulated ice-front positions are not represented by recognisable features to the west of them. May we comment that the existence of empty spaces between shorelines on a shoreline diagram demonstrates that the absence of a marine feature does not in itself prove that there has been no marine presence. Even the most prominent raised shorelines are not uniformly well-developed. Thus the Main Perth Shoreline is conspicuously developed in the Errol area of the Carse of Gowrie but on the steep slopes rising to the Braes of the Carse and the Fife Ochils it is barely represented and it is therefore, not surprising that the older and higher shoreline EF6 has not been recognised there. As no detailed levelling of features has yet been undertaken in the Howe of Fife it is possibly premature to conclude that no shoreline features exist there. Finally, if as is commonly accepted, shoreline formation is promoted by the stable sea-level conditions arising from balance between isostatic and eustatic movements then as the former increases differentially towards the centre of isostatic uplife there must be a tendency for shoreline development to diminish in that direction.

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IPSWICHIAN MAMMAL FAUNAS - A REPLY TO STRINGER AND CURRANT

By Alan Turner

Stringer and Currant (1981) have recently raised a number of points in response to my suggestion that large-mammal bones in Ipswichian cave deposits are largely the work of hyaenas, that such assemblages may be of Ipswichian Zone II age, and that the absence of "Ilford-type" mammalian assemblages in caves may reflect an absence of this accumulating agent after Zone II of the interglacial (Turner 1981a). I would like to offer this reply to their comments, and to clarify my view. As implied in both my original paper and Stringer and Currant's reply, human activity as an agent is excluded from this discussion.

The points raised by Stringer and Currant are twofold. Firstly, that I oversimplify the possible range of explanations for cave assemblage formation and take inadequate account of agencies other than hyaenas. I am therefore, in their view, mistaken in giving such prominence only to the part played by hyaenas in bone accumulation. Secondly, that the evidence from their continuing excavation at Bacon Hole directly contradicts my suggestion that hyaenas were confined to Zone II and absent from Zones III and IV of the Ipswichian. It will be convenient to reply to each point in turn.

1. Although I deliberately mentioned a number of sites where natural trapping appears to have produced assemblages of bones also, I concede that my wording implies an almost total reliance on hyaena activity as an explanation for bone accumulations. I do not wish to claim that hyaenas alone were responsible for all large-mammal bone accumulations in caves, or that their presence was a pre-requisite for such accumulations, and I do not deny that other agencies may have been involved, but I <u>would</u> argue that a very high proportion of the examples in caves of this country seem to have resulted from hyaena activity.

The range of possible accumulating agencies is perhaps not particularly vast for the material under discussion, although occasional, rather unusual events, may from time to time have contributed towards an assemblage. However, most large-mammal bones are likely to have been accumulated in a cave through predator activity, by natural trapping, or by the animal entering the cave deliberately and dying there. These three agencies, singly or in combination, are probably adequate to account for most of the large-mammal fossils in most of the deposits of the sites which Stringer and Currant mention. However, natural trapping is likely to have been a relatively rare event, being so dependent upon suitable circumstances of terrain. Ungulates are likely to have entered caves of their own accord only very rarely, and although their doing so could, as in the case of a trap, add a large number of skeletal elements to an assemblage, this should perhaps be classified as an occasional and unusual event. The range of body parts and their completeness should in either case render such events liable to detection.

The greatest incidence of volitional inclusion is, therefore, likely to have resulted from either bear denning, as indeed the Tornewton material and a substantial part of the Westbury deposits amply demonstrate, or the use of a cave as a retreat by hyaenas and other predators who would also tend to accumulate bones of their prey. But, while I do not deny that these other predators may also have accumulated food debris in caves, I doubt that they did so with the frequency and to the extent that hyaenas appear to have done because the association between cave bone-assemblages and hyaena remains in Upper Pleistocene Britain is simply too strong. One could choose to believe that another predator accumulated both the hyaena remains and those of the ungulates, but this latter possibility is ruled out by the extent of damage to the bones, which precisely parallels that observed in cases of modern hyaena activity (Sutcliffe 1970; Henschell, Tilson and Von Blottnitz, 1980). This is not to say that wolves or lions could not have contributed to assemblages produced largely by hyaenas. However, wolves seem to use dens for shorter periods than hyaenas and tend to accumulate less bone in them (Mech 1970; Binford 1981), features which appear related to the more rapid development of wolf cubs. Moreover, wolf bone-assemblages appear to result from a mixture of defecation and bone-chewing activities which tend to take place at the entrance or actually outside the den (Binford 1981: 199), further reducing the likelihood of any substantial build-up. I have been unable to find any comparative information on bone accumulation by modern lions, and it would seem that they do not tend to produce such material. While modern data does not necessarily reveal the total range of possible behaviour in a species, it therefore seems highly probable that predator damaged bone in caves relates largely to hyaena activity, even if some of the bone was actually scavenged from other sources. Bacon Hole (discussed below) aside, the only clear potential example of non-hyaena predator activity in British Upper Pleistocene cave deposits of which I am aware occurs in the Mendip site of Picken's Hole (Tratman 1964) where the lowest levels had traces of wolf in conjunction with a number of fragmentary prey species remains. Hyaena was absent, but interpretation of that absence is not without difficulty. It is evident, but perhaps worth emphasising, that brief or single occupations by any large predator would not necessarily leave any evidence in the form of bones of that species, and that inference of presence might have to be based on food remains.

In these circumstances, the potential activities of such a major agent as the hyaena must be considered carefully in any interpretation of bone assemblage formation which utilises presence and absence data, the main point of my initial argument. In particular, the paucity of an "Ilford-type" fauna in cave deposits should not be argued simply to result from the greater age of such assemblages relative to Ipswichian Zone II material if it is possible that the absence of hyaenas after Zone II may have been largely responsible for their non-collection. The place of "Ilford-type" faunas in the chronological sequence should, therefore, be established and supported by other means. In saying this, I would accept that other agencies might be expected to have accumulated some elements of the post-Zone II Ipswichian fauna if hyaenas were completely absent, and mentioned Bleadon in my original paper as a possible example of trapping which may be of this period, although the date of the material remains to be clearly established. But even if my argument about the extent of hyaena versus other predator bone-collecting activity is largely correct, then the paucity of Zone III and IV mammalian assemblages in caves clearly warrants further investigation, and I would certainly not consider the matter closed.

The absence of hyaenas at Bacon Hole, associated with what Stringer and Currant term their "main interglacial fauna", need not be at odds with my argument for their importance. The large-mammal assemblage collected to date from that level is very small, with most of the species represented by no more than 2-3 identified specimens, and its taphonomic history is unclear. Most of the bone is fragmentary and the damaged specimens are similar to those seen at sites of undoubted hyaena activity, being sharp splinters of larger bones with clear evidence of predator attack of the kind discussed by Bunn (1981) in a number of instances. Lion is present in the deposit and could have been responsible for some of the damage and wolf scats could also have produced such debris, but hyaena activity cannot be ruled out for the origin of at least part of material. We must await further excavations at the site, and a more extensive sampling of this phase of deposition, before it is possible to understand more about the context of accumulation and to comment in greater detail on the absence of hyaena remains. If hyaenas were genuinely absent during a phase of deposition at the site which appears to equate with Ipswichian Zone II then this will be an interesting observation which I would certainly not wish to gloss over.

2. The relevance of the Bacon Hole evidence to the question of hyaena presence in Britain after Ip Zone II is rather more problematic.

It is difficult to equate a proposed sequence of events and environmental changes established at Bacon Hole with events and changes determined from caves elsewhere when the precision of recovery at Bacon Hole is virtually unique among such investigations. In addition, the site has a distinct advantage in its provision of evidence for sea-level variation in association with changes in deposition and included animal remains in a way which is impossible for most terrestrial deposits. As Stringer (1977: 36) points out, the evidence of climatic fluctuations deduced from deep-sea core evidence suggests three major temperate phases between the last two main glaciations, with the first as the warmest. This evidence appears to conflict with the picture obtained by pollen zonation based on material from British terrestrial deposits, where a single interglacial seems to be indicated immediately prior to the Devensian glaciation (Mitchell, Penny, Shotton and West, 1973; West 1977). I would agree with Stringer and Currant that their "main interglacial fauna" at Bacon Hole probably equates with the Ipswichian *Hippopotamus* fauna familiar from so many sites (Turner 1981a: Table 1), a fauna recently established as correlating well with oxygen-isotope stage 5e on the basis of a speleothem date from Victoria Cave (Gascoyne 1981) performed on a sample later found to contain a *Hippopotamus* calcaneum (Stringer and Currant pers. comm.). This equation is reinforced by the high sea level which is indicated at Bacon Hole during deposition of the material. As I pointed out in my original paper, the association of hyaenas with this fauna is well established in both open-air and cave sites and, as discussed above, the absence of hyaenas from the assemblage at Bacon Hole could be largely a reflection of sample size. This *Hippopotamus* fauna would seem to be tolerably well associated with pollen of Ip Zone II character.

Whether the subsequent deposits at Bacon Hole and the shifts in environmental conditions inferred from them may in turn be correlated with later substages if isotope stage 5 is open to question but may be thought highly probable. However, correlation of such substages with the conventional subdivision of the Ipswichian into pollen zones remains difficult. Stringer and Currant suggest that the "main interglacial" deposit at the site is followed by a drop in relative sea level, accompanied by more boreal conditions as indicated by, among other things, presence of mammoth and northern vole, during which phase hyaena first appears in the assemblage. This phase is in turn followed by a "climatic amelioration", as indicated by the return of straight-tusked elephant instead of mammoth and by the evidence of land snails, with hyaena and northern vole continuing to be represented and the sea remaining lower than in the previous temperate phase. This sequence would, in Stringer and Currant's view, suggest that hyaenas continued to be present for a substantial period of the Ipswichian after Zone II, implying an ability on their part to accumulate "Ilford-type" assemblages were such a fauna present. Two questions are thus raised by this interpretation of the sequence of events. Firstly, can the Ipswichian be considered a standard for comparison, and secondly, do the deposits above the "main interglacial" level at Bacon Hole record events within the "standard" Ipswichian. Answering no to the first point or yes to the second would tend to refute my argument directly.

The zonations of the Ipswichian were based upon a compilation of pollen sequences from a number of sites, rather than a complete sequence from a single location (West 1977: 358). It could, therefore, be argued that two or more distinct warm phases have been wrongly combined to provide a single temperate episode. However, recent work suggests that the pollen deposition record at Wing, Rutland, (Hall 1980) spans what seems to be Ip Zones II-IV and part of the earlier Devensian, giving some confidence in the integrity of the Ipswichian sequence. Correlation of the Hippopotamus fauna with isotope stage 5e, Zone II pollen and a high sea level may then suggest that the entire Ipswichian sequence itself belongs within 5e. The change of climate in stage 5d appears to have been "certainly of glacial character" (Shackleton 1977: 179), and might then be thought to equate with the deposit at Bacon Hole in which hyaena remains first appear in association with M. oeconomus, mammoth and a drop in sea level. Such a view would imply that this latter deposit at Bacon Hole was actually of early Devensian date, and that the subsequent climatic amelioration in which hyaena continues to appear was an early interstadial equating with isotope stage 5c. The possibility of this kind of correlation between terrestrial evidence and isotope stages was suggested by Shotton (1977: 180), who pointed out that by implication such a view would necessitate a considerable revision of the proposed dates for earlier Devensian interstadials which are, at present, based on enriched-sample C14 assays. (Interestingly enough, Butzer (1981) has recently stated his distrust of early last glaciation dates, and his working assumption that any such finite estimates are of little value). The presence of Palaeoloxodon antiquus in this higher amelioration phase at Bacon Hole need not argue against this interpretation of events recorded at the site, since our knowledge of the large-mammalian faunal changeover during early stages of glacial onset cannot be regarded as sufficiently precise to rule out such an appearance in an early interstadial.

Shackleton (1977: 180) suggested that the glacial climate of stage 5d and the likely size of the Laurentide ice sheet was "probably sufficient to have lowered sea level to a point where the English Channel was no longer marine". If a land bridge existed at that time, then the hyaenas which appear in the phase of climatic deterioration and lowered sea level at Bacon Hole may well represent early Devensian immigrants, a fresh stock replacing those which may have died out locally during the Ipswichian (Turner in preparation). If that is the case, then the specimens recorded from Bacon Hole should exhibit morphological characteristics which enable Devensian hyaenas to be separated from those of the Ipswichian (Kurten 1963, 1969; Turner 1981b). Unfortunately, the present sample is of inadequate size for this purpose, but I hope to undertake such an analysis once the material is to hand.

Concluding Remarks.

If the higher levels in which hyaena does appear at Bacon Hole record major climatic changes, then it seems likely that these correlate with post 5e portions of oxygen-isotope stage 5 and may represent early stages of the Devensian glaciation. In that case, they do not necessarily refute my argument about the apparent confinement of hyaenas to Zone II of the Ipswichian. Furthermore, the absence of hyaena from the "main interglacial fauna" at Bacon Hole does not refute my hypothesis on hyaena-produced bone-accumulation because I do not wish to claim uniqueness for this agent, merely importance. If I failed to make this clear in my original discussion then I hope to have done so here. However, my expression of this view does not, as emphasised above, imply that I consider the matter of large-mammal assemblage taphonomy closed. Further work at Bacon Hole, and a detailed examination of larger samples as they come to light, is likely to help resolve many of the problems which surround this issue. As Stringer (1977: 37) pointed out, Bacon Hole, together with other sites on the Gower, presents a unique opportunity for us to integrate sea level and palaeotemperature inferences from deep-sea core evidence with terrestrial material and sequences. To permit full realisation of this potential, however, we must give careful consideration to the taphonomy of material included in the deposits, particularly when seeking to extrapolate from coastal locations to inland sites on the basis of large-mammal assemblages. Presence and absence data for these assemblages must be evaluated carefully, and will clearly tend to be most useful when the accumulation has resulted from the activities of a catholic predator able and likely to incorporate such material into the deposits.

I should like to thank Dr. Christopher Stringer and Andrew Currant for a full and useful discussion of this subject and for every possible assistance and facility in examination of the material from Bacon Hole and other sites in their care. I am also grateful to Dr. Allan Hall and to Terry O'Connor for commenting on the manuscript. The opinions expressed of course remain my own.

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DATE OF BLANKET PEAT INITIATION IN UPLAND SOUTH WALES

By F.M. Chambers

There has been much discussion as to the age of inception of those Flandrian deposits in Wales commonly referred to as blanket peats. The literature reveals an apparent range of opinion covering some 6000 years from the beginning of the Atlantic to post-Roman times (Bowen, 1974: Crampton, 1966), although Taylor (1973) cautioned the need for more radiocarbon dates before coming to any general conclusion regarding blanket peat initiation in Wales. However, in 1975, Moore reviewed the available evidence and concluded that the elm decline horizon "at about or just before 5000 yr bp" was a reliable guide to the date of origin of many British blanket peats (Moore, 1975 p. 267), the exceptions being mainly the deeper peats of the Southern Pennines which earlier studies (Conway, 1947; Tallis and Switsur, 1973) had shown to be Atlantic in age. The technique of radiocarbon dating has since been applied in a study into the age and origin of peats in upland south Wales (Chambers, 1980). This paper examines whether Moore's assertion regarding peat initiation data applies in this area.

Blanket peat sites were deliberately chosen from "moisture-shedding" facets of the landscape on the major remanent plateau surfaces at four locations (see Fig. 1): Brecon Beacons, Cefn Ffordd, Cefn Gwernffrwd and Coed Taf (2 sites, A and B). Pollen diagrams were prepared for each of the peat profiles and slim (2 cm) sections of the peat were prepared for radiocarbon dating using a rigorous pretreatment designed to remove the potentially more mobile "humic acid" fraction and to minimize contamination from modern rootlets. The fine particulate fraction (F-fraction, <250 µm) was dated as it had previously been found that this was likely to give the most reliable estimate of the true radiocarbon age of blanket peat samples (Dresser, 1970).

The dates obtained for the horizons of mineral soil-peat transition are presented in Table 1. It can be seen that the peat initiation dates are not synchronous between the four locations. The oldest date was provided by the highest altitude site at 715 m O.D. on the Brecon Beacons on the "Summit Plain" of Brown (1960). Cefn Ffordd on Brown's "High Plateau" at 600 m O.D. provided the next oldest date. The other sites,

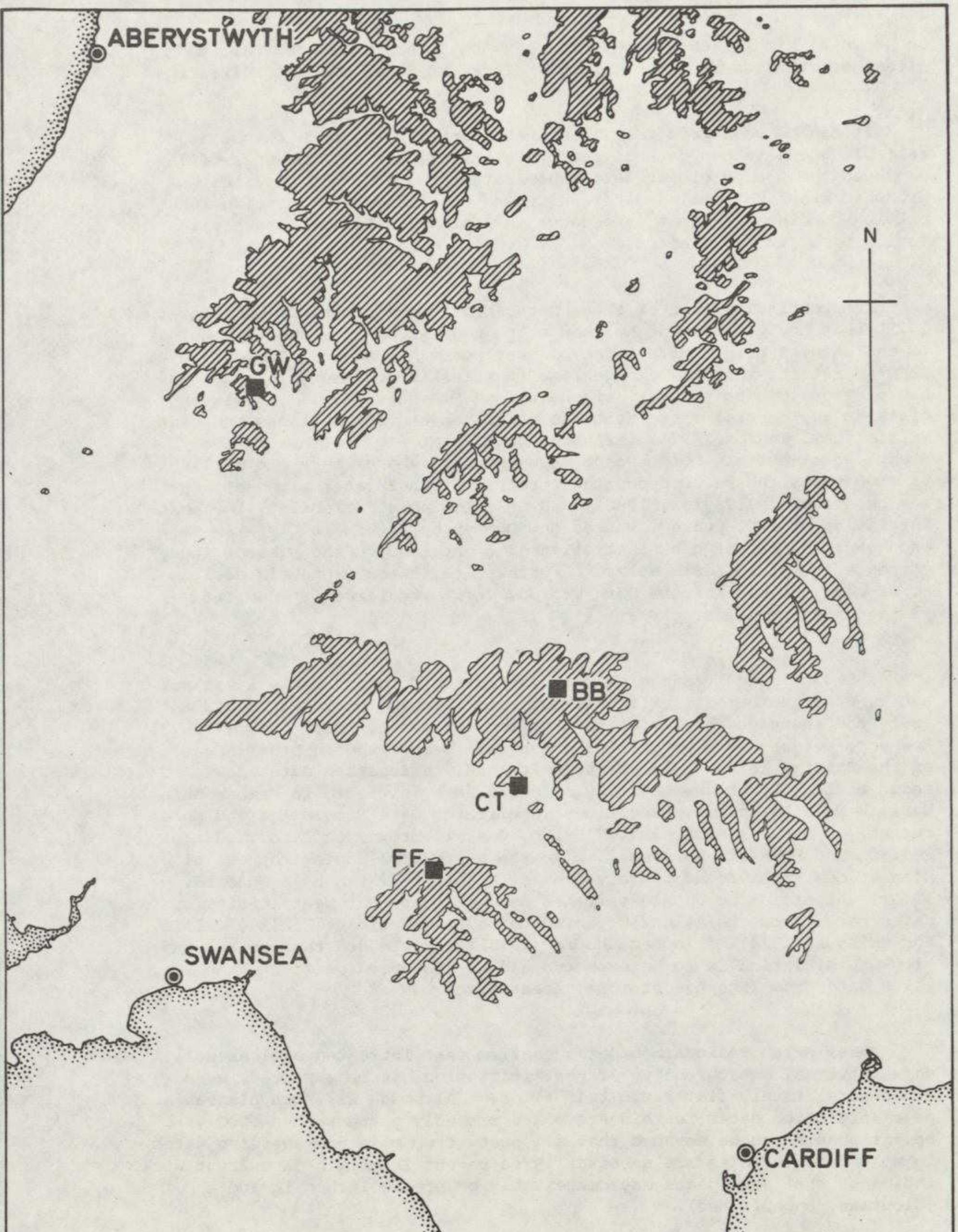

Fig. 1. Site locations on map of southern Wales. BB - Brecon Beacons; CT - Coed Taf; FF - Cefn Ffordd; GW - Cefn Gwernffrwd. Land over 400 m shown.

on Brown's "Middle Peneplain", though younger than the higher altitude sites nevertheless provided markedly different dates of peat initiation.

It can be seen from the Table that overall peat depth is not a reliable guide to the date of peat initiation: the shallowest profile produced the second oldest date, whereas the two Coed Taf profiles produced basal F-fraction dates which are statistically indistinguishable, notwithstanding the great difference in peat depth between these sites (which were just 50 m apart).

Interestingly, none of these dates confirms the contention (Moore, 1975) that the elm decline horizon of c. 5000 yr bp is a reliable guide to the date of origin of British blanket peats. However, Taylor (1974: 1980) maintains that the elm decline in Wales is not as synchronous as had previously been thought (cf. Smith and Pilcher, 1973). Whilst not claiming any general association in Wales between elm declines and peat initiations, Taylor (1974) instanced basal peat elm declines in the Bronze Age; but his more recent assessment of the primary elm decline is ±500 years and he concedes the possibility that later elm declines may be secondary (Taylor, 1980). Even allowing a variability for peat initiation of ±500 years (centred on 5000 yr bp), this still fails to encompass the oldest peat initiation date obtained in the present study of peats in upland south Wales. Furthermore, there is no elm decline at or near the base of the Cefn Ffordd, Cefn Gwernffrwd or Coed Taf plateau peat profiles.

The considerable range of peat initiation dates in Table 1 was not anticipated in the earlier studies of Welsh blanket peats which did not apply the technique of radiocarbon dating (Crampton, 1966; Moore, 1973). However, metachronous initiation dates have been found in other areas of the British Isles. In Northern Ireland, radiocarbon dates have shown that although the majority of peats were initiated in Beaker and Early Bronze Age times, exceptions (Neolithic, Late Bronze Age and more recent) do occur (Smith, 1975; Smith, Gaskell-Brown, Goddard, Goddard, Pearson and Dresser, in press). In the North York Moors, the age of blanket peats was found to vary from site to site (Simmons & Cundill, 1974), whilst in the Pennines it has been claimed that peat initiation dates range from the Atlantic period to Mediaeval times (Radley, Tallis and Switsur, 1974). Indeed, Moore (1975) acknowledged that metachroneity of initiation is to be expected and he instanced peats on Exmoor which date from Iron Age or more recent times.

These Welsh radiocarbon dates confirm that intra-regional as well as altitudinal metachroneity of peat initiation can be expected, even between relatively flat "summital" sites. Although all such plateau peat initiation dates in this study are markedly younger than 5000 yr bp, it should not be assumed that all peats from moisture-shedding sites in upland south Wales are necessarily so recent in origin as current work indicates that some peats may conceivably be pre-Neolithic in age (Cloutman, unpublished).

Table 1

Location	Site Code	Altitude (m)	Grid Ref.	Depths (cm)	Age (yr bp)	Code No.
Brecon Beacons	(BB)	715	SO 043196	100-102	4380±70	CAR-51
Cefn Ffordd	(FF)	600	SN 906032	24-26	3625±80	CAR-9
Cefn Gwernffrwd	(GWA)	400	SN 738494	68-69	3465±70	CAR-19
Coed Taf	(CTA)	400	SN 988108	28-30	1435±55	CAR-77
Coed Taf	(CTB)	400	SN 989108	70-72	1310±70	CAR-48F

Table 1. Radiocarbon dates for the mineral-peat transition in five peat profiles from southern Wales. The ages are in conventional radiocarbon years before present (bp). Quoted precisions (uncertainties) of the dates are one standard deviation and derive mainly from counting statistics. The laboratory code numbers of the radiocarbon samples are given. Each Radiocarbon sample was 2 cm thick and covered an area of 8 cm x 8 cm (16 cm x 16 cm in the case of CAR-9).

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ABSTRACTS OF PAPERS READ AT A DISCUSSION MEETING ON "THE UNITED KINGDOM CONTRIBUTION TO IGCP.24, QUATERNARY GLACIATIONS IN THE NORTHERN HEMISPHERE".

This meeting was held at University College, London on the 2nd and 3rd January, 1981

URANIUM SERIES DATING OF SPELEOTHEMS AND THEIR PALAEOCLIMATE SIGNIFICANCE

T.C. Atkinson, Department of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ.

Speleothems are secondary mineral deposits in caves. The common calcite stalagmites, stalactites and flowstones usually contain 0.1 - 10 ppm of uranium which can be used to radiometrically date the deposit. The principal method employed is to measure the growth of ^{230}Th by decay of ^{234}U. The basis of the age calculation is to measure the activity ratio of ^{230}TH/^{234}U, which is assumed to have an initial value of zero, and can be shown to approach a value of unity after about 350,000 years. Intermediate values of this ratio provide an estimate of the age of specimens up to 350,000 years. A correction must be applied for the growth of ^{234}U from its parent ^{238}U which will also be present in the sample. A crucial assumption is that the speleothem contains no ^{230}Th initially. This is reasonable because although U is easily co-precipitated with calcite, Th is insoluble and tends to adhere onto organic or clay mineral detritus. Thus, if the speleothem is free of detritus, it should also be free of initial Th. This can be checked for individual specimens by measuring the radioactivity of ^{232}Th which has a very long half life commensurate with the age of the earth itself. If a speleothem contains appreciable ^{232}Th, it is probably contaminated with initial ^{230}Th also and its calculated age will differ from the true age. Other sources of error include the possibility of migration of U or Th since deposition, which can be avoided by choosing specimens free from signs of leaching. Recent inter-laboratory comparisons suggest that the main uncertainties in calculated age are due to radiometric counting and calibration errors and that accuracy is about ± 10%.

Since speleothems are commonly found interbedded with other materials in cave entrance deposits, they provide an invaluable means of dating sequences containing fossil biota, archaeological deposits or sedimentary evidence of past environmental conditions. The next few years will probably see a variety of applications to cave entrance sites in Britain and Europe (Gascoyne, 1981).

The speleothems found in deep cave interiors are of palaeoclimatic interest also. They are principally formed by two mechanisms. The first involves solution by infiltrating water of CO_2 gas from the CO_2-enriched atmosphere of the soil. This solution then dissolves limestone but, on reaching a cave, loses CO_2 by out-gassing. The loss of CO_2 causes the solution to become super-saturated and to deposit calcite, and speleothem growth results. This mechanism requires a vegetation cover to produce the enrichment of CO_2 in the soil air. A second mechanism, the 'common ion effect' does not require a vegetation cover. If a water first becomes saturated with calcite, and then encounters either dolomite or a source of calcium sulphate (gypsum or oxidation of pyrite in limestone), continued solution of the dolomite or $CaSO_4$ will force the solution to become super-saturated with calcite. The two mechanisms can be distinguished at the present day by study of groundwater chemistry. Waters containing high Mg/Ca or SO_4/Ca ratios indicate that the second mechanism is possible.

In terms of palaeoclimatic conditions, the occurrence of ancient speleothems indicates that the climate was certainly warm enough for groundwater recharge to occur. This means that the area above the cave must have been free of permafrost and that, regionally, permafrost must have been either absent or discontinuous. In caves where present groundwater compositions indicate that the 'common ion' mechanism is not possible, ancient speleothems indicate a well-vegetated environment of the time of their formation.

In Britain, a plot of speleothem frequency against dated age shows fluctuations which broadly agree with the deep ocean isotope record. The more detailed record for the Devensian shows intermittent and patchy speleothem growth throughout the mid-Devensian in N.W. Scotland, Yorkshire and Somerset. Thus the climate then was not continuously cold enough to prevent groundwater infiltration by permafrost. After 26 ka, speleothems are absent until 16 or 17 ka in Yorkshire, later in Scotland and the Mendips, corresponding to the period of Main Devensian glaciation.

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THERMOLUMINESCENCE DATING OF SEDIMENTARY DEPOSITS.

By A.G. Wintle. The Godwin Laboratory Sub-department of Quaternary Research, Free School Lane, Cambridge.

Over the last fifteen years dates have been obtained by thermoluminescence (TL) techniques for loesses and for a variety of fluviatile and glacial deposits in the Soviet Union. Only recently has this work come to the notice of Western Quaternary geologists due to its use for giving dates for Palaeolithic sites in Tadjikistan, Soviet Central Asia. In the last five years TL dating of sediments has been reported by workers in Poland, Hungary, China, two more laboratories in the Soviet Union and by TL workers in Canada and England. Within the last year TL workers in several other countries have started to examine sediments and it is now a good time to review the current state of research and to assess the results. This is particularly interesting at present because each laboratory has developed its techniques in isolation and only in the last year has there been any significant contact between the groups. TL dating has been found to be most successful for aeolian, marine and fluviatile deposits.

This talk will be presented in full in a paper by Wintle and Huntley to be published in Quaternary Science Reviews later this year.

ABSTRACTS OF PAPERS TO BE PRESENTED AT THE Q.R.A. DISCUSSION MEETING IN CAMBRIDGE, JANUARY 4-5 1982

POLLEN ANALYSIS AND QUATERNARY PALAEOECOLOGY:

RECENT DEVELOPMENTS

Introduction

H.J.B. Birks,University of Cambridge

In the last 15 years there have been considerable methodological advances in Quaternary pollen analysis. These have involved studies on modern processes of pollen dispersal, deposition, and sedimentation, the development of quantitative numerical methods for the analysis of pollen data, the detailed use of plant macrofossils to supplement the pollen-stratigraphical record, and improved laboratory and field techniques. In addition, pollen analysts have been paying increasing attention to the question of selecting sites for study that are appropriate to the temporal and spatial scales of the problems under study. The aim of this meeting is to review some of these methodological advances and to illustrate the importance of spatial and temporal scale and site-selection in Quaternary palynology with a series of case-studies that range from the European continental scale to the scale of individual woodland stands.

The Selection of Sites for Palaeovegetational Studies

R.H.W. Bradshaw, University of Edinburgh

Sites for pollen analysis may be chosen to obtain data from a new geographical area or to answer a particular problem of vegetational dynamics in a previously studied area. In both cases the pollen source-area of the basin is the most important characteristic of the sampling site. Lakes, peat deposits, and small hollows, humus, and soils all have unique properties and problems as sites where fossil pollen may be preserved. Combinations of large and small basins in one area may be the best method of describing and reconstructing past vegetation at both local and regional scales.

The Role of Plant Macrofossils in Quaternary Palaeoecology

Hilary H. Birks, University of Cambridge

Plant macrofossils can often be identified to species level, in contrast to pollen grains. Because of the generally limited dispersal of plant macrofossils from their parent plants, they are most valuable in determining local vegetational successions. Because of the relatively low numbers produced and the limited dispersal, quantitative macrofossil stratigraphy cannot be used for regional stratigraphy, in contrast to the abundantly produced and widely dispersed pollen. Instead quantitative stratigraphic macrofossil studies complement fossil pollen in the elucidation of past local palaeoecology. In addition, the presence of macrofossils of a pollen taxon can suggest more precisely the taxonomic origin of the pollen, and can also indicate that the taxon was growing near the site of deposition. These features of plant macrofossils are particularly useful when migration of species is being considered. Examples of the value of studying macrofossils in conjunction with pollen will be discussed with reference to late and post-glacial deposits in Scotland and North-America.

Some Recent and Possible Future Developments in Palynological Techniques

J.R. Flenley, University of Hull

Attention is drawn particularly to the following developments:

1. Improvements in preparation, especially those designed to avoid harsh chemical treatments. Ultrasonic filtration will receive special mention here.

2. Aids to optical analysis. Advances are being made in electronic hardware which could assist visual recognition. New software could provide more efficient multiple-access keys with which to inspect photographic images or computer data-banks.

3. Possible alternatives to optical analysis. The possibility of using other properties for recognition is discussed, with particular reference to measurement of specific gravity on density gradients.

Numerical Methods and Pollen-Vegetation Calibration Functions

I.C. Prentice, University of Southampton

Multivariate methods assist the interpretation of pollen data and facilitate communication with specialists in other disciplines. Zonation is an optimal partitioning problem in cluster analysis with stratigraphy as an external constraint. Ordination methods are best understood through a multidimensional scaling approach. A basic 'core' of multivariate methods should be used routinely by pollen analysts.

Pollen-vegetation calibration functions represent a more experimental and controversial field. Recent statistical studies have defined the limitations of the R-value model. Some generalizations of the R-value model allow better use of the information in surface-pollen and tree-inventory data and therefore look more promising in terms of the development of calibration functions, of which the best-founded still have somewhat restricted application. Further progress requires the continued development of source area modelling alongside the collection of critical empirical data.

Mapping European Pollen Data and Reconstructing Tree-Migration Routes

B. Huntley, University of Durham

Pollen data spanning the last 13000 years have been mapped using the technique of isopall maps for sites throughout Europe. Maps have been constructed at 500 year intervals for all of the major, and some minor, pollen taxa. These maps form the basis for reconstructing the migration patterns of the major European trees since the last glaciation, as well as giving new insights into their areas of glacial refuge. The results will be illustrated by means of selected examples.

History of the Major Forest Zones in Labrador

H.F. Lamb, University of Cambridge

The composition of the local vegetation mosaic is not clearly related to pollen percentages in surface sediments taken from Labrador lakes. Interpretation of pollen stratigraphic changes in lake sediment cores through comparison with surface samples is, therefore, valid only at the scale of the major vegetation zones. The correspondence between modern and fossil pollen spectra is greatest after 5000 B.P. suggesting that the present vegetation zonation became established at about that time.

Flandrian tree-migration patterns within the British Isles

H.J.B. Birks, University of Cambridge

The large number of radiocarbon-dated pollen diagrams from the British Isles provides a basis for constructing isochrone maps for the major tree pollen taxa. Such maps are interpreted to reflect the patterns in space and time of the first arrival, expansion, and subsequent migration of the tree taxa. Maps will be presented and discussed for <u>Pinus</u>, <u>Corylus</u>, <u>Quercus</u>, <u>Ulmus</u>, <u>Alnus</u>, <u>Tilia</u>, <u>Fraxinus</u> and <u>Fagus</u>.

Patterns of Vegetational History in East Anglia

K.D. Bennett, University of Cambridge

Cores have been studied from a group of small lakes in Norfolk. Percentage and absolute pollen diagrams have been constructed. The lakes are within areas of contrasting soil types. Comparison between these sites and previous work in East Anglia has made possible the reconstruction of vegetational history within predominantly chalky boulder clay areas and with areas of sandy soils.

The lakes of Highland Britain: an assessment of their contribution to palaeoecology

Winifred Pennington, University of Leicester

The open-water sediments of lakes in catchments of moderate to high relief have contributed to knowledge of palaeoecology by providing data on soil dynamics in parallel with results of percentage pollen analysis, and constitute a valuable source of information on those changes - climatic, edaphic, anthropogenic - which have affected the whole environment. Recent palynological work which has sought to improve understanding of pollen-vegetation relationships by attempts to quantify the inputs to these lake sediments has shown that, while the number of variables affecting the composition of the pollen/spore assemblage is so great that these sites are unlikely to be rewarding for some problems of numerical pollen analysis, there is much information on the palaeoenvironment coded into the relationship between the estimated pollen/spore influx and sediment geochemistry. Some interpreted changes in the processes of water transport of pollen may possibly be as informative with respect of palaeoclimate as are changes in the pollen-producing vegetation.

Some preliminary and tentative models of present and past recruitment of pollen to typical lakes will be suggested. Hypotheses will be tested against data from some of the few lakes which have such restricted catchments that they approach the situation of an enclosed lake.

Late-Glacial and Holocene Vegetation and Landscape in the Burren, Co. Clare, Ireland.

W.A. Watts, Trinity College, Dublin

The Burren is a karst region with large areas of limestone pavement. The modern vegetation is a mosaic of hazel scrub often on residual boulder clay, and meadows or pavement with a species-rich flora including many arctic-alpine and Mediterranean species. The landscape development has two main features of interest: (1) During the late-glacial there were two periods of severe erosion of mineral sediments into lakes, the younger of which corresponds to the Younger Dryas Period. (2) The early Holocene was forested. After the Elm Fall yew was very abundant briefly. Subsequently man-caused deforestation was progressive, culminating in the extinction of pine, which has been abundant on the pavement, in the early centuries A.D.

Pollen Stratigraphy and Patterns of Deglaciation in Scotland

J.J. Lowe and M.J.C. Walker, City of London Polytechnic and St. David's University College, Lampeter

Pollen-stratigraphic evidence is presented from several sites in the Grampian Highlands and the Island of Mull, Scotland, that lie within mapped limits of Loch Lomond (Younger Dryas) Stadial ice. Local vegetational histories and regional pollen zones are briefly described, but attention is focused on the basal pollen spectra identified at each site.

These are analysed in the light of recent proposals by Pennington (1978) and Lowe and Walker (1981) that such evidence can be used to gauge the time-transgressive nature of deglaciation at the end of the Loch Lomond Stadial. Radiocarbon dates afford poor resolution in the limited time period of the Lateglacial/early Flandrian transition, and relative age estimates based on biostratigraphy may provide an important key for determining patterns of deglaciation. The problems involved with this type of approach are discussed.

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Reconstruction of Vegetation from Historical Records and Pollen Analysis in the Big Woods of Minnesota

E.C. Grimm, University of Minnesota and University of Cambridge

The records of the United States public land surveys provide valuable data for reconstructing vegetation immediately prior to severe disturbance and deforestation by European man. The land surveyors marked "bearing trees" along surveyed lines and recorded them into notebooks. These bearing trees provide a systematic but low-density sample of the vegetation (maximum of 3 trees/sq km). Because of the low density of sample points, the scale of reconstructed vegetation from these data is on the order of 100 sq km. The pollen assemblage that accumulates in the sediments of a small lake (10-20 ha) represents the vegetation on a scale similar to that provided by bearing-tree data. In the Big Woods region, spatial comparison of presettlement vegetation reconstructed from bearing-tree data to coincident pollen spectra facilitates temporal reconstruction of vegetation at single sites.

Ecological History of Wooded Islands in Scottish Lochs

P.D. Kerslake, University of Cambridge

A number of lake mud and peat cores have been analysed from wooded islands in two north-west Highland lochs. Percentage and absolute diagrams have been prepared. The woodland history of islands and mainland is compared to see whether island vegetation has developed independently of mainland vegetation. Comparisons are also made between sites on the same group of islands, and with other work in the area.

Ecological History of Oakwoods in Wales

Mary E. Edwards, University of Washington

Pollen preserved in sediments accumulated in very small (5-10 metre diameter) basins within woodlands reflects changes in canopy composition over recent times (*circa* 500AD to present). In addition woodland history over the last few hundred years can be pieced together from documents, field evidence, and tree-ring counts. Four *Quercus petraea* oakwoods in Merionedd, North Wales, were studied using all these methods and their recent histories reconstructed. In each case past land management practices have influenced the state of the woodland today. In certain woods management appears to have played an important part in the survival, or otherwise, of rare species of Atlantic bryophytes. The abundance of these plants in a few woodlands has caused these sites to be made Class I National Nature Reserves,[1] while other woods, apparently similar, contain no rare species.

[1]Ratcliffe, D.A. (1977). A Nature Conservation Review. Cambridge.

Future Prospects

H.J.B. Birks, University of Cambridge

Potential future developments in Quaternary pollen analysis will be outlined. These include the analysis of pollen-stratigraphical records as records of changing plant populations through time, the use of time-series techniques to analyse pollen-stratigraphical data, increased temporal resolution of pollen-stratigraphical changes by analysing annually banded sediments present in some British lakes, and the use of paired large and small basins within the same catchment to reconstruct regional and local vegetational history. Pollen analysis has contributed much to Quaternary stratigraphy. It has much still to contribute to plant ecology, ecological theory and palaeoecology.

REPORT ON A SHORT FIELD MEETING IN EASTERN CUMBRIA 15-18 MAY 1981

By J. Boardman

Twenty five members assembled at the Appleby Manor Hotel on the evening of 15 May including a number of survivors of the North Wales Field Meeting.

The purpose of the meeting was to examine recent work in the north eastern Lake District, Ravenstonedale and Swaledale, and the Eden Valley. Excursions were led by Drs. J. Boardman, D. Huddart, Miss J.M. Letzer (Mrs. J.M. Riley), Miss E.J. Pounder and Mr. J. Rose. A Field Guide was produced for the meeting (Boardman, 1981).

Day 1

In unsettled weather the excursion began in Thornsgill, near Troutbeck, Cumbria. John Boardman demonstrated a succession of pre-Devensian glacial deposits overlain by Devensian till and glacifluvial sands, gravels and laminated clays. Of chief interest was the Troutbeck Palaeosol developed in the pre-Devensian Thornsgill Formation. The effect of glacitectonic deformation and the influence of lithologically variable parent material on weathering and pedogenesis produced vigorous debate. The leader suggested that palaeosol development required a long period of warm temperate conditions and quoted micromorphological, XRD and SEM evidence in support of his views.

A reddened (rubified?) soil developed in Devensian till at the Laddray Wood site stimulated a useful, if inconclusive, exchange of opinions. Dr. J. Conway suggested that the red argillic coats could have been preferentially preserved at the site due to burial by a landslip. Others argued that red coloration is not uncommon in Flandrian soils particularly where it occurs on structural faces rather than in the soil matrix.

After lunch in the White Horse at Scales the group walked to Wolf Crags corrie where the moraine ridge and corrie morphology were discussed. John Boardman then attempted to convince the group that the terraces, palaeochannels and large-scale bars in Mosedale were a result of outwash from the Younger Dryas corrie glacier at Wolf Crags. Dr. R. Cornish preferred an earlier origin associated with the melting of a regional ice-sheet. The mode of transport of boulders in excess of 1m in length was the subject of comment.

The Quaternary stratigraphy was demonstrated at a number of sites in Mosedale including the Caral Gully section where 15m of weathered till containing rotted boulders appeared to convince some sceptics of the severity of pre-Devensian weathering. Others were impressed by a new exposure of a red (2.5YR 4/8) palaeoargillic horizon apparently within the weathered till.

A site currently being investigated, where a buried organic bed lies within till, was also visited. The consensus view was that the peat lay on pre-Devensian Thornsgill Till and was overlain by similar, though reworked, till. Pollen and macroscopics from the peat have been described by Drs. J.J. Lowe and D.T. Holyoak and recorded in the Field Guide.

Day 2

The morning was spent in the Upper Eden Valley, mainly in Ravenstonedale, where Jocelyn Letzer's main theme was the direction of ice movement across the area. A stop was made to examine prominent Shap Granite erratics. For many of the group, the concept of megadrumlins and superimposed drumlins was new and maps of the features were used to demonstrate their reality. Jocelyn Letzer explained that the earlier Lake District suite of drumlins associated with ice moving eastwards towards Stainmore could be distinguished from a smaller suite resulting from Howgill ice moving northwards towards the Vale of Eden, the latter in some areas being superimposed on the former.

The final site prior to lunch was a superb exposure at Scandal Beck where two tills appear to overlie an organic bed which itself rests on a basal till. A lively debate ensued as to the mode of deposition of the tills, the interglacial pollen diagram from the organic bed, and the reliability of the ^{14}C date (>42,000 years BP). The site had altered since it was first described (Carter et al, 1978) and Jocelyn Letzer presented the results of more recent work.

Lunch in Nateby, near Kirkby Stephen, was followed by an afternoon punctuated by showers. En route to Keld, Eileen Pounder and Jim Rose discussed the formation of river terraces in Upper Swaledale. At Keld, a two hour walk began controversially with Jim Rose attempting to convince the group that esker sediments could be remarkably poorly sorted. The walk illustrated the history of the diversion of the Swale from a former course along Skeb Skeugh into its present valley, a change resulting from glacial and ice wastage events. Late and Post Glacial fan development and landslipping - some of which is still active - aroused comment, and in particular, the section in the fan at the mouth of Swinner Gill suggested to a number of participants that a debris flow or solifluctional origin was more probable than a fluvial one for the sediments.

Day 3

On the final day Dave Huddart led a tour of glacifluvial landforms and sediments in the Eden Valley and the Brampton Kame Belt. At Lazonby and Baronwood the main theme of the discussion was whether a model invoking stagnating ice in the Eden Valley, and associated ice-dammed lakes, could adequately explain input of sediment from (ice free?) upland areas to the west.

Lunch in the String of Horses at Faugh provided time for these matters to be discussed and an afternoon shortened by the necessity to catch trains from Carlisle was climaxed by Dave Huddart's obvious enthusiasm for the first British example of an ice-walled lake plain at Carrow Hill, sadly now transformed into an interchange on the M6. (No chance of SSSI designation?).

A vote of thanks was proposed by Dr. R.H. Johnson to the leaders of the various excursions and the mini-bus drivers. The success of the meeting was in no small part due to the comfort and splendid food of the Appleby Manor Hotel.

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REPORT ON A SHORT FIELD MEETING IN NORTH WALES 1-4 MAY 1981

By J.M. Gray, J. Ince and S. Lowe

Thirty-eight members and their guests assembled at the Royal Oak Hotel, Betws-y-Coed for this meeting. After dinner Murray Gray expressed apologies from the Local Secretary, John Lowe, who was unable to attend due to an unforeseen circumstance. Mother and baby are doing well.

He went on to outline his work on cwm moraines and small-scale erosional features in Snowdonia and showed slides of some features the group would not see for a variety of reasons. John Ince gave the background to his Lateglacial and early Flandrian pollen stratigraphic work, and his radiocarbon dating of sediments from sites inside and outside the proposed Loch Lomond (Younger Dryas) Stadial ice limits.

Day 1

First stop was Cwm Idwal where Murray Gray suggested that it was not often that a QRA meeting could begin with a quote from Charles Darwin's description of the field area. In his autobiography Darwin describes how he visited Cwm Idwal with Adam Sedgwick in 1831.

> "On this tour I had a striking instance how easy it is to overlook phenomena, however conspicuous, before they have been observed by anyone ..... neither of us saw a trace of the wonderful glacial phenomena all around us ..... yet these phenomena are so

conspicuous that ..... a house burnt down by fire did not tell its story more plainly than did the valley."

Unfortunately the details of the story are still not resolved 150 years later. The traditional interpretation is for an "Older Series" Moraine to be present at the lip of the cwm and a Younger Dryas moraine to occur at the constriction half way along Llyn Idwal. Murray Gray said that he felt that in previous work in Snowdonia there had been a tendency to regard any group of moraines as marking a glacial terminus whereas they may not be directly related to a glacier snout. In Cwm Idwal the moraines extend well beyond the constriction in the llyn and he argued for a Loch Lomond Advance limit near its northern end. This point seemed to be accepted but there was greater controversy over the origin of the moraines on the western side of the llyn. Early workers believed them to be lateral moraines but recently the main ridge has been reinterpreted as a protalus rampart. There was little support for the latter. Murray Gray suggested that they might be fluted moraines such as occur within Loch Lomond Advance limits in Scotland but many were sceptical about this and preferred the lateral moraine explanation.

Malcolm Howells and Eddie Watson then had a long argument about the provenance of erratics in the cwm. Leaving them to it, the party walked round the head of the llyn to a point where Dave Bridgland, John Ince and Stephen Lowe had already taken a basal 1m core with a Russian peat sampler from an infilled basin on the western side of the llyn, inside the mapped ice limit. This revealed the presence of basal clay deposits overlain by a series of organic detrital sediments. The core from 6m depth revealed a similar basal early Flandrian lithostratigraphy to that described by Godwin and Seddon, and there was some discussion of Godwin's early Flandrian pollen diagram. It was noted that Godwin's diagram had been constructed before Juniperus was confidently recognised by pollen analysts, and that there was some discrepancy in the maximum depth of sediment analysed by Godwin and those recorded by Seddon and revealed in the boring. It was agreed that, although the site had considerable potential for dating of the cwm moraines, this potential had not been fully realised.

John Ince went on to describe his own pollen analytical investigations at the nearby inside site of Cwm Cywion (SH 632604) which, in view of its altitude (600m O.D.) and steepness of climb, the party did not have time to visit. Employing a large scale pollen diagram he illustrated how the early Flandrian vegetation of the cwm, following decay of the last cwm glacier, had consisted of pioneer herbaceous communities characterised by abundant grass and Rumex species. The similarities to the early Lateglacial grassland communities were emphasised. There was some discussion of the Juniperus curve and it was generally agreed that migration and altitudinal factors rather than regional climate, may have played a more influential role in shaping the nature of the early Flandrian vegetation at this site. A series of radiocarbon dates were quoted which provide a minimum date of around 10,000BP for deglaciation of the Cywion glacier.

In Nant Ffrancon, Murray Gray pointed out the massive protalus rampart on the eastern slope, but Malcolm Howells believed it to be a lateral moraine whose location and limited extent were geologically controlled. John Ince described the lithostratigraphic and biostratigraphic investigations conducted by Seddon and Burrows on the Lateglacial limnic deposits of Nant Ffrancon. In terms of the history of the final cwm glaciation the presence of Lateglacial deposits within Nant Ffrancon was taken to indicate that the main valley was free of ice during the Loch Lomond (Younger Dryas) Stadial. The absence of reliable C14 dates from Nant Ffrancon led to the suggestion that further studies in conjunction with fresh investigations at Idwal may prove beneficial both in terms of chronology and vegetational history.

After braving the dim and cold pubs of Bethesda at lunchtime the party climbed to Cwm Llugwy on the north side of the Ogwen valley. Murray Gray pointed out the hummocky drift between the northern shore of the llyn and the backwall of the cwm and again suggested that this did not represent a terminal moraine. A core from an infilled hollow between the moraines was obtained and John Ince explained John Lowe's skeleton pollen diagram from the site. However, in view of the failure to obtain basal sediments (owing to the presence of hard compressed organic deposits at depth) he argued that the biostratigraphy was of limited use for the study of deglacial chronology at this site. He reiterated the importance of obtaining the deepest and hence oldest sediments, and of bottoming the basin, if the pollen analytical investigations and C14 dates were to be used to support geomorphological deductions.

The party then walked south crossing a number of transverse moraine ridges some at least of which probably represent recessional snout positions. Murray Gray argued that the Loch Lomond Advance limit was located c. 600m south of the llyn where there is a conspicuous drift and boulder limit and a marginal meltwater channel. Colin Lewis felt that, in comparison to Lough Nahanagan, the moraines were too large to belong to the Loch Lomond Stadial.

The final stop was within the Gwydr Forest where John Ince explained his Lateglacial pollen diagram from the basal sediments at Llyn Goddionduon (SH753583). A core was taken from the infilled section of the llyn in order to demonstrate the tripartite Lateglacial lithostratigraphic sequence. Interpreting the biostratigraphic record he showed how the early Lateglacial species rock grassland communities had been invaded by juniper and birch.

Unlike the Lake District and Eastern England the point was made that the development of birch in North Wales was more restricted during the Lateglacial and this was clearly illustrated at Clogwyngarreg (SH560538) a site he had analysed to the west of Snowdon. Pollen analytical evidence for environmental instability towards the close of the Lateglacial Interstadial was presented and the familiar Artemisia pollen zone of the Loch Lomond Stadial was described. Attention was drawn to the marked lateral variation in sediment thickness which had been encountered and he explained how magnetic susceptibility measurements (conducted by J. Bloemendal, Liverpool University) had proved extremely useful in correlating overlapping core segments and in verifying core overlaps based on biostratigraphical data.

Day 2

The morning was scheduled for a long walk around Cwm Dyli and Llyn Llydaw but heavy rain forced the group into the Pen-y-Pass cafe where John Ince explained his Flandrian pollen diagram from the lip of Llyn Llydaw (SH632543). Undeterred by coffee mugs and steaming kagouls, he explained how the early Flandrian vegetation of the Llydaw area was characterised by herb communities reminiscent of the early Lateglacial Rumex-dominated grasslands. A radiocarbon date on the earliest organic deposits to accumulate in the Llydaw basin provided, as at Cwm Cywion, a minimum date of around 10,000 BP for deglaciation of the last cwm glacier. The sequence of Flandrian woodland development was outlined and evidence for deforestation in late Neolithic/early Bronze Age times was presented. Attention was drawn to the re-appearance in the pollen profile of several typical Lateglacial herbs which had survived the period of Flandrian forest dominance and recolonised the Llydaw area upon deforestation.

Murray Gray then described the work that he and John Lowe had done on striae, roches moutonnees and friction cracks in the Llydaw area. In particular, to explain the crossing striae near the Llydaw causeway, he suggested a different direction of ice movement in the Loch Lomond Stadial from that of a previous ice sheet. A long discussion followed in which doubts were expressed about the proposal that ice flowed from Llydaw into and down the Pass of Llanberis. By mid-morning there was no let-up in the torrential rain so the group reluctantly left the comfort of the cafe for the inevitable soaking on the Miners' Track. At Llydaw the party examined crescentic gouges. p-forms, roches moutonnees and striae. Jim Rose made an important discovery that indicated the relative ages of the crossing striae but by this time most of the group were on their way back to the cafe. As the last person returned the rain stopped. By public demand the group returned to the hotel for a change of clothing and reassembled at Llanberis after lunch. Needless to say heavy rain returned soon afterwards but the party were able to examine the unweathered glaciated slate and grit exposed on the bed of Llyn Peris which had been drained in connection with the Dinorwic pumped storage scheme. Striae, friction cracks, large glacial grooves and p-forms were all examined but for most, the highlight of this "underwater tour" were the miniature crag and tails formed by iron pyrite crystals in the slate.

By the end of the day the sun was shining and the last stop was at Marchlyn Mawr which is the upper reservoir of the same scheme and which was also drained. After parking at the dam, the party examined the crescentic fractures and a remarkable pothole while John Ince described Rosemary Walker's diatom and pollen analyses made on a Mackereth core taken before the llyn was drained. A dash back to the hotel was followed by a third excellent dinner. Jim Rose remarked that the day had been unusual in being almost exclusively devoted to erosional features. The highlight of the evening was the barmaid who didn't believe in using a measure to pour the Glenmorangie!

Day 3

Dry sunny weather on the final morning gave fine panoramic views over the southern Snowdonia National Park as the eastern flank of

Moelwyn Mawr was approached from Llyn Stwlan, two kilometres west of Blaenau Ffestiniog. Vegetated, unsorted stripes were particularly well-developed here and John Taylor described some of his research on these features. A feature interpreted as a possible fossil rock glacier by Stephen Lowe and Jim Rose on the north face of the mountain was then examined. Stephen Lowe emphasised the continuum of form represented by transitions from glacier to ice-cored rock glacier systems. The well developed lateral moraines were suggested as being of true glacial origin with subsequent recession from this position being accompanied by transition to an ice-cored rock glacier. This latter phase was inferred from the inner zone of debris cover, comprising a "staircase" of transverse ridges and steep scarp fronts, with areas of pitted boulder strewn terrain. The shallow depression toward the headwall, and the relatively small size of the former accumulation area were also commented upon.

After lunch in Ffestiniog, the party proceeded to Llyn Arenig Fach, a mountain tarn impounded by a series of moraines believed, on the basis of pollen analysis, to be of Loch Lomond Stadial age. Here a technique for obtaining basal sediment cores from the lake bed was demonstrated by Kim Wagstaff and Dave Holland of the City of London Polytechnic sub-aqua club. After acclimatizing to the icy waters they retrieved a sediment core (Russian corer with 50cm long chamber) from 12m below the lake surface, having penetrated 3.5m of lake sediment to hit bed-rock. The corer was brought ashore to reveal the Lateglacial/Early Flandrian transition with 15cm of grey clay in the base grading upward into a brown fine detritus gyttja. Another core was then taken using a 1m long Russian corer which replicated the first.

The meeting ended as it had begun with a quotation. This time not from Charles Darwin but from the slightly less well known Henry Stolterfoth who, in 1880, described a diatomaceous deposit on the partially drained bed of the llyn. He returned some months later, "but, alas! I found the lake again full, and all the wondrous deposit at least ten feet below the surface; and unless something goes wrong with the Bala waterworks, there is little chance that human eye will again rest on what may be termed one of the secrets of the deep". Little had he reckoned with aqualung diving!

QUATERNARY RESEARCH ASSOCIATION EXCURSION GUIDE - LEWIS AND HARRIS

By J.D. Peacock

This guide largely follows an account produced by the writer for a group of 11 members which visited the island in the first week of June 1981. Transport was entirely by private car, though it would be possible to use public transport for some sections if time were not pressing. The itineraries for Days 2 and 3 include fairly hard walking over rough ground.

Introduction

The objects of the excursion as a whole are firstly, to examine the evidence for the Quaternary history of an island peripheral to Devensian events on the mainland and secondly, to demonstrate a wide range of glacial features and deposits in an area where these are better displayed than in most other parts of the British Isles. Recent work (see references) has shown that, contrary to earlier opinion, Lewis and Harris together with the islands to the south supported an independent ice-cap during the last glaciation. That it took so long (over 100 years) to reverse the idea, first put forward by James Geikie that the island was crossed by mainland ice during the last glaciation, is a measure both of the small amount of research carried out since then and of the (subconscious) unwillingness of most of the human race to use their eyes when there is apparently nothing new to be seen!

From the mountains outwards, there are four categories of glacial landscape

1. A zone more or less coincident with the mountains of Lewis and Harris, characterised by hummocky moraine, with 'fluted' drift in places and features resembling washboard moraines.

2. A zone of bare rocky hills, chiefly drift free, but with patches of hummocky drift of drumlinoid character. This is best developed in South Harris.

3. A zone characterised by crag and tail, well seen in central Lewis.

4. A till plain, developed in northern Lewis.

5. A zone peripheral to the last (in extreme northern Lewis) which was apparently outside the limit of late Devensian ice.

Zones 4 and 5 are areas with maximum development of peat.

There are no late- and post-glacial raised beaches on Lewis and Harris, but a pre-late Devensian beach occurs in north Lewis, where it is overlain in places by lodgement till of the last glaciation. The beach rests either on older glacial deposits or on a water-eroded rock surface, which itself is part of a much older rock platform and cliff.

Excepting for the Stornoway area, which is underlain by conglomerates and sandstones of Permo-Triassic age, the island is formed of Precambrian basement rocks (Lewisian). These comprise for the most part grey gneiss with hornblendic streaks and patches, traversed by dykes and irregular bodies of metadolerite and amphibolite. In southwest Lewis and Harris there are extensive areas of granite and granite veins. More varied rocks occur in South Harris where there are large bodies of metamorphosed intermediate and basic igneous rocks as well as metasedimentary rocks. From the geomorphological point of view, the chief interest is in the relatively uniform nature of the lithology and the numerous lines of structural weakness which control both the coastline and the major through valleys. Clasts of reddish arkose and quartzite in the raised beach and till of north Lewis have presumably been derived from Torridonian and Cambrian strata on the mainland.

Quaternary History

A full discussion of the Quaternary history is beyond the scope of this account, but the sequence is broadly as follows:

(Youngest)	(e)	Valley glaciation of Harris and SW Lewis
	(d)	Ice cap glaciation (excepting the extreme north of Lewis).
	(c)	Formation of raised shingle beach.
	(b)	Glaciation (from the Scottish mainland?): formation of multiple deposits of till, gravel, sand and silt in N Lewis.
(Oldest)	(a)	Formation of rock platform and cliff.

Though the raised beach (c) could be of interglacial age, the possibility that it formed under very cold conditions is discussed under the excursion guide for Day 4. The valley glaciation is thought to post-date the late Devensian maximum glaciation (d), but pre-date the Loch Lomond Readvance of the Scottish mainland.

Maps

The area of the excursion is covered by the following OS 1:50 000 Sheets: Stornoway and North Lewis (Sheet 8), West Lewis and North Harris (Sheet 13). Tarbert and Loch Seaforth (Sheet 14) and Sound of Harris (Sheet 18).

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Day 1. South Harris from Tarbert (half-day)

South Harris was crossed by ice which extended south-east from an ice centre over the western mountains of North Harris. As far as can be judged, the ice crossed the summits of the highest hills, but the evidence has been obscured by frost-shattering above 300 metres and by the development of features of mass movement such as boulder lobes. There was a small late-stage glacier in the corrie on the north-east face of Roneval (460m) at the south of the island. The evidence for the south-east movement of ice in the form of striated, plucked rock surfaces can be seen at numerous localities for instance near the road junction (NG 134943).

Hummocks by the roadside at Loch Laxdale (NG 113963) and Loch Carran (NG 087961) are formed of boulders and immature till (deformation and lodgement till) derived from the rock almost imediately underlying. The material is best seen in quarries at the latter locality, where granitic gneiss sheared across till by ice action is visible. Drumlinoid mounds of this type with or without an orientation parallel to the direction of ice movement or to some underlying structural feature are common in the Outer Hebrides and also occur in the Scottish Highlands.

Day 2. Clisham and Glen Skeaudale from Tarbert

This excursion can be varied according to weather conditions. The object is to examine hummocky moraines, 'fluted' drift, push or washboard moraines and other types of moraine ridges as well as evidence bearing on the age of these features. Tarbert lies on the borderline of Zones 1 and 2. Hummocky moraines extend westwards from the town on the north side of the loch, whereas to the east and south the ground is chiefly bare rock.

1. Ascent of Gillaval Glas (471m OD). The beautiful striated surfaces of gneiss and amphibolite on the slopes above Tarbert are replaced upwards by frost-shattered rock. Striations trending ESE can be traced to about 350m. There are small stone lobes below the summit of the hill. From near the top a view can be obtained of the fluted drift in Glen Skeaudale.

2. Glen Skeaudale. This can be approached either as a continuation of the above, or from the road north of Tarbert. Following the retreat of the Late Devensian ice, Glen Skeaudale was occupied by a valley glacier which flowed in the opposite direction to that of the ice sheet. At a locality (NB 152031) , parallel, longitudinal ridges 0.2 to 0.5 metres high and 15 to 20 metres apart lie in part on the proximal sides of transverse asymmetrical moraines. Their maximum length is about 100 metres. At a nearby locality (NB 147029), parallel morainic ridges (lateral moraines?) extend obliquely downstream from glaciated slabs on the south wall of the valley. They are between 2 and 5 metres high, sharp-crested and about 20 metres apart and are parallel to striations on the slabs. One ridge seems to be formed entirely of boulders. At the first locality, one transverse moraine is 4 to 6 metres high and another 1 to 2 metres high, concave upstream, with a fluted proximal face. It is likely that most of these features are formed of sandy and silty till similar to that seen in road cuttings at the mouth of the valley. The flutes seem to be larger than the superficially similar flutes described from modern glaciers.

3. Ardvourlie bridge. (NB 183099) and Glen Scaladale. A cutting on the north side of the bridge has yielded stumps of pine below the peat and members of the Macaulay Institute have recently found many more remains of pine in the peat further down the valley. This is one of several localities where pine stumps are known below peat in the island, and it can be suggested that small pine woods were present before the start of blanket peat formation (c. 4000BP.?), though there were probably no continuous forests such as occurred on the mainland.

A number of transverse moraines are distributed at intervals up the Scaladale valley from the road bridge to Loch Vistem. For the most part these are at right angles to the course of the glen and tend to be almost straight or very gently convex downstream. The large, composite ridge at the bridge is 600 metres long and up to 15 metres high and is composed predominantly of fine-to coarse-grained sandy gravel inter-bedded with till. None of the ridges have pronounced asymmetry, though that immediately east of Loch Vistem shows a tendency for the distal side to be steeper than the proximal. If these are ice frontal features, they point to a mass of ice with an exceptionally straight ice front and unusually large for a normal retreating valley glacier. The upper corrie about Loch nan Eang is floored by smooth drift which passes upslope into boulder lobes. Kettled boulder drift is present in the small lower corrie to the east of this loch. Flutes and moraines which occur below the north wall (Aonaig Mhor) of Clisham predate the boulder lobes which have formed on them.

The valley glaciation in Glen Skeaudale and Glen Scaladale evidently predated a period of periglaciation which can be correlated with that associated with the Loch Lomond event of the Scottish mainland. Fluted drift, which is associated on the mainland almost entirely with the Loch Lomond Readvance was formed here during an earlier period of active valley glaciation which also post-dated the Devensian maximum.

Day 3. South-west Lewis

In south-west Lewis the Devensian ice flowed north-west into the Atlantic, but during the retreat an extensive series of meltwater channels and deposits were formed with a hydraulic gradient from south-west to north-east. There are sharply delineated areas of fluted drift and moraines in the mountains, the outer edges of which probably mark the limits of the valley glaciation which predated the Loch Lomond Readvance.

1. Tarbert to south-west Lewis. The limit of hummocky moraines is crossed at the north end of Loch Seaforth and the road then crosses the rocky, partly peat-covered area of Zone 2. From the turning to cross the island at Leurbost, westwards to the south end of East Loch Roag the crag and tails of Zone 3 are well displayed, showing that the ice fanned out north-east and north-west from the mountains to the south. A subsidiary ice-shed probably extended northwards through the south end of East Loch Roag, defining the northward extension of an ice dome. From East Loch Roag to Carishader the route again crosses Zone 2.

2. Carnish area. Loch Scaslavat is dammed by a spectacular glacio-fluvial delta. Large scale deltaic foresets and topset beds in sand and gravel can be seen from time to time in a pit south-east of Carnish on the eastern (distal) side. The surface is kettled and channelled. At the west end of Loch Scaslavat are kames which were probably formed in the subglacial portion of the river which deposited the subaerial delta. This seems to have been deposited in lake rather than an arm of the sea (there is no evidence for raised beaches or for marine deposits on land). The Carnish delta is the lowest of a series of deposits which include kettled glaciofluvial terrace gravels deposited by an eastward-flowing river at the base of Flodraskarve Mor (NB 045297).

3. Ardroil and Uig Lodge. The features here have been described as terminal moraines formed by a glacier in the Loch Suainaval valley. However, they seem to be formed of bedded sand and gravel and are more likely to be north-east trending kames and eskers deposited under the hydraulic gradient mentioned above. A well-formed crag and tail feature occurs a km east of Ardroil (NB 055320).

4. Glen Valtos meltwater channel. This 2 km long channel is entirely excavated in rock to a depth of 60 metres and is presently occupied by a small stream. The eastern half of the channel is straight, probably following a fault, but the western part is sinuous and terminates upstream in three blind ends. Deposits associated with the channel are limited to a mound of morainic gravel at Miavaig (NB 086345). Till occurs locally on the valley side and may also occur on the

unexposed valley floor. The channel was formed by an east flowing subglacial river, probably the precursor of that which formed the Uig kames.

5. A visit to the stone circles of Callanish, which predate blanket peat formation, can be made on the return journey.

Day 4. North Lewis (From Stornoway)

This part of the island seems to have been at the periphery of the late Devensian glaciation. Though a clear ice limit can be demonstrated on the north coast, the extent of the ice-free area has not been satisfactorily elucidated. The raised beach at 10 to 14 metres OD is an important marker horizon, being overlain by lodgement till of late-Devensian age in the south but by solifluction deposits only north of the ice limit. In several places it overlies till which can be correlated at least in part with the thick glacial deposits of the north coast, which are thus likely to be of pre-Late Devensian age.

1. Port of Ness. In the cliffs south of the village, Geikie (1894) recorded upper and lower boulder clays separated by an 'interglacial' bed, whereas Baden-Powell (1938, p399-401) refers to a massive almost unbedded purple coloured shelly silt with irregular stone beds, passing northwards into a deposit of boulders and gravel. The silt was regarded as being in some sense a marine deposit and was termed the Glacial Marine Bed. Examination of this section suggests that it is more complex than envisaged by both these authors. At the north end, where the small stream from Loch Stiapavat enters the bay, there are about 8 metres of crudely bedded bouldery gravel varying from well to very poorly sorted. The clasts in the better sorted beds, which include open-work gravel, show a greater degree of rounding and a higher sphericity. At one locality the imbrication of plate-shaped clasts indicates transport to the north-west. On the east side of the stream, the bouldery gravel is at the surface, but elsewhere it appears to be overlain by brown till which can be traced southwards across the remainder of the section. The gravel passes southwards into a succession with several tills of a reddish brown and dark grey colour interbedded with gravel and sand, the deposits reaching a thickness of 10 metres in places. Pending a detailed survey, these deposits are tentatively interpreted as the remains of a complex debris fan, the source being ice lying to seaward. The fauna from the shelly tills (Baden-Powell, 1938) is of boreal to low arctic type.

2. Traigh Sands to Traigh Chumil. Approach from Eoropie. The exposures of interbedded till, sand and gravel here are continually changing because of coastal erosion and landslipping. At a locality (NB 508642) a little south of Traigh Sands, calcite-cemented raised beach gravel up to 1.5 metres thick is banked against brown sandy till, which also slumps across it. The gravel is underlain by 0.3 metres of the same till, which passes northwards into interbedded sand, gravel and diamicton typical of the multiple deposits of this area. This section is one of several where till can be seen below the raised beach, but not *in situ* above it.

At Swainbost Sands (NB 504637), there are about 4 metres of interbedded dark grey to light brown clays, silts and sands with subsidiary beds of gravel. These overlie about a metre of dark grey to brown till at the base. All these beds contain shell fragments, which are particularly common in the till, and the gravel includes clasts of Torridonian sandstones.

Southwards the deposits thicken to about 25 metres between localities (NB 501634) and (NB 496632) at Traigh Chumil. This is the section illustrated by Baden-Powell (1938, p.398), who described an upper and lower till separated by about 3 metres of shelly sand, thought to be an interglacial marine bed. Examination of undisturbed sections here suggests that, while there is an overall capping of brown gravelly or cobbly till between 2 and 5 metres thick, the underlying strata in the upper half of the cliff are complex, with interbedded water-sorted sand and gravel, till and sandy silt. The lower part of the section includes horizontally bedded locally pebbly silty sands and finely laminated dark silts with numerous beds of dark diamicton upwards of a centimetre thick, Fossil lists are given by Baden-Powell (1938).

3. South Galson. Here is to be found the most extensive area of raised beach on the island, extending WSW for 2km from the South Galson River. It reaches a maximum width of about 200 metres and a thickness of 5 metres and is formed chiefly of well rounded pebbles of high sphericity. The grain size is commonly between 1 and 5cm, but coarser beds come on to the south. The clasts are mainly of Lewisian gneisses, but red siliceous sandstones are common, up to the size of small boulders. In places there is soliflucted till up to 1.5 metres thick overlying the gravel, this locally being overlain by soliflucted beach gravel with a red, clayey matrix. The upper metre or so of the deposits is cryoturbated. All these deposits lie on the raised rock platform, which, with its denuded cliffline, is a marked feature of the coast.

A feature of the raised beach is the generally small size of the pebbles compared with those in the modern storm beaches. It may thus have formed in a low energy environment with inshore winter ice and offshore pack ice rather than under interglacial conditions.

4. Melbost Borve. In this area the raised beach was overrun by the edge of the late Devensian ice-sheet. At a locality (NB 408573) west of the village, an exposure shows about 3 metres of hard brown till (probably lodgement till) overlying a metre of raised beach gravel, which in turn overlies about 0.5 metres of rock fragments (?head). The beach dips eastwards and seems to be a raft transported a short distance by the passage of the Late Devensian ice. Along the coast to the north, striations can be seen trending between 330 and 340 degrees, and at another locality (NB 412580) remnants of the beach are overlain by up to 4 metres of grey sandy till. In places a thin layer of angular rock fragments intervenes between the beach and till, this being either head or material transported a short distance by the ice (the immature till of previous excursions). Where the beach has been removed, till, with or without the thin head-like deposit below, rests on the striated surface of the old raised rock platform. At Breivig (NB 414582) the character of the coast changes sharply, with a marked increase in rock breakage and solifluction, an absence of till, and the presence of stretches of raised beach unaffected by ice action. This is taken to be the limit of late Devensian ice.

5. Cladach Lag na Greine (NB 387558). At this locality there is a critical section showing the relationships of the raised beach to glacial deposits and features. Here the beach overlies a waterworn, pitted surface, and is overlain by till. Traced seawards, the shingle thins to zero and it can be seen that the waterworn surface is striated where it projects slightly above the level of the beach. This is taken as firm evidence that the raised beach was overrun by ice.

Day 5. The Eye Peninsula and Tolsta Head (From Stornoway)

Ice from the west or south-west seems to have crossed the Eye Peninsula and Tolsta Head during the last glaciation, though erratics of Torridonian sandstone derived from the east occur in the till. Remnants of the raised beach occur below till on the east coast of Eye as well as traces of the raised rock platform and cliff. Tolsta Head itself is almost till-free excepting at the interstadial site described below.

1. Sheshader Bay. Confirmation of the eastward movement of ice across the peninsula is given at two close localities (NB 559337) by striae and plucked surfaces. A rock nearby (Dorus Beag, NB 558338) seems to be a former sea stack rounded by the passage of ice.

2. Lower Bayble Bay. At this locality (NB 527304) , beach gravel up to 1 metre thick underlies several metres of till. Though the till in these sections could be soliflucted it is more likely that it was deposited by the eastward moving ice.

3. Garrabost. The village is built on a north-west trending kame or moraine which has been truncated by the sea at its northern end. The deposits are at least 30 metres thick and include interbedded till, clay, sand and gravel, all of which contain shell fragments. Sections are unfortunately few and the beds on the coast are landslipped.

4. Tolsta Head. At a locality (NB 55724682) , laminated silt and dark brown organic lake detritus some 0.5 metres thick rest on bedrock and are overlain by up to 2.5 metres of till (Von Weymarn and Edwards, 1973). The pollen spectra from the deposits (which are peaty washes rather than true lake deposits), indicate an open landscape with a flora consistent with a cool maritime climate. A radiocarbon date of 27,333 ± 240 BP (SRR-87) was obtained from these sediments. According to the authors, the overlying till contains numerous erratics of Torridonian sandstone and this, together with a partial fabric diagram suggests derivation from the Minch. However, other evidence in the área, such as the distribution of some of the Lewisian erratics, features of ice movement and another fabric diagram at New Tolsta suggests that the last ice to cross the area was from the west. Another possibility is that the 'till' which is much disturbed in its upper part, is a solifluction deposit.

5. New Tolsta. At a locality (NB 537496) hummocks of bouldery debris at the foot of the steep rocky slopes appear at first sight to be of periglacial origin, but are more likely to be a form of lee-side deposit quarried by the action of eastward moving ice.

Points raised in discussion

Before the 1981 excursion, the writer was still in some doubt concerning the age of the valley glaciation, but is now convinced that it almost entirely predated the Loch Lomond Readvance of the Scottish mainland and followed the ice-cap phase (d) with little or no interruption (see Postscript).

In Glen Skeaudale (Day 2), the writer suggested that the ridges at locality (NB 147029) were large flutes, on the basis of their regularity as seen on air photos and because they are parallel to striations on the nearby valley wall. Several participants however, argued strongly that these are lateral moraines, pointing out that there are other lateral terraces in the valley. Also on Day 2, the kettled boulder drift in the lower Clisham corries was the object of heated discussion between proponents of a glacial origin and those supporting the view that it originated from a former rock glacier. No conclusion was reached.

On Day 3, the possibility was raised that the Glen Valtos meltwater channel was formed subaerially rather than subglacially. However, the form of the channel as well as the discovery of till on the valley side (by Donald Sutherland) supports the subglacial hypothesis.

The origin of the raised beach of North Lewis (Day 4) gave rise to some discussion, with Francis Synge supporting Jost Von Weymarn's idea that the well-rounded gravel indicates a high energy (interglacial) regime, as at present. The writer was impressed by the small size of the pebbles compared with those in the modern storm beaches and wondered if the rounding were a function of time as well as energy. If this were so, the beach could have been formed under an arctic regime. Some comment from workers studying modern polar coasts would be useful.

It was not possible for the party to visit Eye (Day 5), but Francis Synge found striae on a quartz vein on the east side of the peninsula, with a suggestion of movement from the sea. This conflicts with evidence found by the writer and Jost von Weymarn (see text).

<u>Postscript</u>

The discovery of a vigorous valley glaciation predating the Loch Lomond Readvance, but post-dating the main late-Devensian glaciation in the Outer Hebrides is clearly significant, in that it possibly indicates a marked increase in snowfall as the polar front moved north across the area c. 13 000 BP. A similar and probably contemporary valley glaciation predating the Loch Lomond Readvance can be recognised on Skye, about both the Cuillins and Kylerhea Glen in the east of the island. Members crossing Skye to Harris should use the Glenelg Ferry and examine the hummocky moraines in Kylerhea Glen (Peach et al 1910), a locality where C.T.Clough some 90 years ago noted moraines aligned in the direction of ice movement. Hummocky moraines descending to the level of the Flandrian beach can be seen between Broadford and Sligachan, and also north of the latter locality. These areas are outside the Loch Lomond Readvance limit in southern Skye as mapped by Sissons (1977).

Peach, B.N. et al 1910. The geology of Glenelg, Lochalsh and South-east part of Skye. Mem. Geol. Surv. Scotland.

Sissons, J.B 1977. The Loch Lomond Readvance in southern Skye and some palaeoclimatic implications. Scott. J. Geol. vol. 13 pp. 23-36.

This guide, which is partly abstracted from a forthcoming publication, is published with the permission of the Director of the Institute of Geological Sciences (NERC).

REVIEWS

The Quaternary in Britain : Essays, Reviews and Original Work on the Quaternary published in honour of Lewis Penny. Edited by J. Neale and J. Flenley. 1981 Pergamon Press, Oxford. 267 pp price £14.50

This volume is a representative of a class of book rather rare in British Quaternary circles - the festschrift written in honour of a distinguished member of a discipline on their retirement. Lewis Penny, as one of the founder members of the QRA is as eligible a person as any to receive such an honour, and this volume of twenty-two individual papers is a worthy way in which to mark his retirement.

The book is biased in its content towards glacial geology and the Quaternary sequence in eastern England, the two subjects in which Lewis Penny has had a lifelong interest, but other studies both of local and regional interest are interspersed between papers on these two main themes.

Of the twenty-two studies seven or eight are on glacial topics in that they give a straightforward account of the history of glaciation in various regions of Britain. In eastern England the papers by Edwards, Gaunt and Smith all provide contributions to further our knowledge of the areas north and west of the region dealt with in Catt and Penny's classic paper of 1966. Further afield, the chapters by Bridger and Peake provide details on the glaciation of Charnwood and the northern part of the Welsh Borders respectively. Particularly interesting in terms of the historical development of ideas of glaciation are the chapters by Boylan and by Catt and Madgett. The former gives an account of the origin of the glacial theory in Britain, and provides a fascinating series of descriptions of some of Agassiz and Buckland's key sites which can still be seen after 140 years. The latter gives a very detailed description of the work of Lewis Penny's predecessor in East Yorkshire, W.S. Bisat.

Four further chapters take a wider view of glacial sequences and the correlation of events across Britain. Cox uses new evidence to update his 1973 views on the number of glaciations and interglacials, and Catt examines the basis for the subdivision of Quaternary in Britain to decide that at least six glacial episodes can be recognised. Shotton takes a historical view of the contribution made by studies in North-East England from the time of Lamplugh to current ideas of the Quaternary sequence in Britain, and Bowen uses the same historical stand-point to re-examine the South Wales End Moraine.

Other chapters are less concerned with the glacial sequence, but consider palaeontological or geomorphological events associated with glaciation in Britain. Such papers as those by Coope, Peacock and Sissons all highlight particular aspects of the later phases of the Devensian glaciation, while Jardine considers the status and correlation of these phases.

As must always be the case in a volume of this kind some papers stand at some distance from the themes of the majority. The chapter by West on a Hoxnian site in Suffolk, Francis' classification of till types and the paper on aspects of periglacial structures in Kent by Worssam come into this class. As papers in their own right these are excellent but they do not perhaps fit the theme which is implicit in the rest of the contributions.

Unlike some of the earlier volumes produced by the now familiar Pergamon method of reproduction direct from typescript, this book is very well produced with few of the small errors which have marred previous works. It will make a valuable addition to the library of anyone concerned with the British Quaternary, and especially to researchers in that area which was the particular concern of Lewis Penny, the glacial geology of Eastern England.

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<u>The Physics of Glaciers: 2nd Edition.</u> By W.S.B. Paterson 1981. Pergamon Press, Oxford. 380pp. Price £20 (hard cover), £7.25 (flexi cover).

Twelve years ago Stan Paterson wrote the first general introduction in the English language to the physics and mechanics of glaciers. That book was very well-received and the present volume retains the same aims and attempts to incorporate the developments which have taken place in glaciology over the past decade. The text has been lengthened and includes new chapters on Ice-core studies, Glacier Hydrology and Structures and Fabrics in Glaciers and Ice Sheets. As the author points out in his preface, "Extensive new field data have shown that, although the basic concepts developed in the 1950s still stand, many of them are over-simplified. As a result, theories have become more complicated and, in addition, computer modelling has added a new dimension to glacier studies". The author clearly presents the various glaciological theories relating to ice movement, boundary conditions, glacier hydrology, surges and glacier response to climatic changes, while at the same time pointing out the strengths and weaknesses of the various theories in the light of the available field observations.

The links between glaciology, glacial geology and glacial geomorphology have tended to become less obvious as the field of glaciology has increasingly become the concern of the physicist and theoretician. The necessity for greater co-operation between the theorists and field-workers is indicated by two conclusions stated by Paterson:

p.128 "No existing theory provides a realistic basal boundary condition for the glacier flow problem", and

p.129 "A comprehensive sliding theory will have to treat the physics of sliding including rock-rock friction, the theory of water flow at the glacier bed, the formation of cavities, and processes in the gravel layer".

Those glacial geologists and glacial geomorphologists concerned with sediments and landform genesis who look to the glaciologists for assistance in solving problems related to sub-glacial environments must await further developments in the field of glaciology.

In the wider context of Quaternary Studies the part played by large ice sheets in controlling sea-level fluctuations and affecting, and being affected by, climatic changes is of great significance. Unfortunately, Paterson concludes that it is still not certain whether the Antarctic and Greenland ice sheets are presently gaining or losing mass and that the history of these ice-sheets throughout the Quaternary Era is till poorly understood. It is disappointing that many questions posed by workers in allied fields cannot yet be answered by the glaciologist.

Once again Stan Paterson is to be congratulated on a clearly written summary of the present state of knowledge in glaciology. It is a pity that the text is printed in such small type and that the binding of the 'flexi-cover' edition is such that the reader finds it very difficult to gain access to some of the words because they disappear into the spine of the book.

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<u>Quaternary Studies,</u> Volume 1, 1981. Occasional Papers edited by R.H. Bryant and J.J. Lowe, and published from City of London Polytechnic. 113pp.

This is an attractive collection of four substantial 'occasional' papers representing reports derived from thesis work undertaken by members of the Masters' Degree Course in Quaternary Studies organised jointly by the City of London Polytechnic and the Polytechnic of North London. The papers form a most interesting group of investigation reports based upon detailed field and laboratory work.

1. 'The detailed investigation of a pingo remnant in Western Surrey' - C.P. Carpenter and M.P. Woodcock. pp. 1-26.

The first essay deals with the detailed description of the morphology and analysis of the sediments contained in a small bog near Elstead, Surrey. Elstead Bog is considered to lie in the remnant of a former open system pingo and a Younger Dryas age is assigned to the oldest basin deposits. It seems likely that this extreme southerly (so far) example of a pingo may be matched by others near Selbourne in north-east Hampshire. The pollen record allows an examination of the early Wealden forests to be made and it was determined that Corylus was an important element from EL5 times onward. (EL1 = close of Younger Dryas - EL7 Tilia arrived as a member of the regional assemblages, Pinus virtually disappears, and alder carr dominates the basin - author's zonation). This corresponds with easterly sited basins but is much later than in western Britain, and supports the contention that Corylus colonised Britain from the west during the Flandrian. Many herbaceous types were present late into the Flandrian, and there were areas of open ground within the forests, with the basin at Elstead dominated by alder carr rather than by sphagnum.

2. 'A contribution towards a glacial stratigraphy of the lower Lea Valley, and implications for the Anglian Thames' - D.A. Cheshire. pp. 27-69.

The second essay deals with the analysis of sediments of Anglian age in the Lower Lea Valley, with much data obtained from commercial bore-holes. Subglacial channel systems are described together with glacial tills and associated gravel deposits, and till fabrics are analysed. Lithostratigraphic relationships are examined in some detail and palaeocurrent and palaeoenvironmental reconstruction attempted.

The sequences of ice incursions (e.g. Ware Till ice from the north-west (oldest) and the Foxholes Till ice and Eastend Green Till ice (younger) are related to the gravel units in the Vale of St. Albans and lower Lea Valley, and in turn to the evolution (capture, aggradation, braiding) of the proto-Thames, as it adjusted to changing environmental conditions, notably the diversions related to topography and the position of the Anglian ice fronts.

3. An analysis of the spatial variability of glacial stria and friction cracks in part of the western Grampians of Scotland' - P.W. Thorp pp. 71-94.

The third essay represents an attempt to analyse glacial striae and friction cracks (crescentric shaped cracks with distinct 'horns') over an area of some 600 km^2 centred upon Loch Leven, and lying between Loch Linnhe and Rannoch Moor, and extending from Glen Etive in the south to Ben Nevis Range in the north. Consideration is given to the factors affecting the existence of various types of glacial marking, notably the differential weathering rates of the bedrock types, glaciological factors, periglacial activity, and the exposure of ice-scoured rock outcrops. Distinction was achieved between Late Devensian ice-sheet markings and those related to the Loch Lomond Advance (or Readvance), the former exhibiting a rather simple westward flow pattern, and the latter a complex, topographically-controlled pattern. The author considers that the use of friction cracks, and of crescentric fractures in particular, can provide valuable additional means of determining ice-flow directions.

4. 'Seismic data processing, sampled Quaternary data and pollen analysis' - I. Williamson pp. 95-113.

The fourth essay considers the arguments for and against using, or attempting to use, some of the numerical techniques linked to computer processing used by the seismic geophysicist for the analysis of Quaternary data. The author considers that there are three categories of techniques which may be of use to the Quaternary Scientist - those processes which remove undesirable elements of the data, those processes which emphasise certain elements of the data, and those processes which elicit additional information, which may not be apparent at first visual inspection. The author deals first with the problems of sampling, where the geometrical aspects of sampling can, he believes, significantly affect the sampled data, and he cites the examples of pollen analysis, oxygen isotope ratios and foraminiferal counts, and the problem of the variation between samples and sampling 'density'.

Contamination in pollen analysis, where cores are used to extract information, is then considered, and related to seismic 'profiles', where similar distortion ('smearing') may occur, and the method of solution detailed, by autocorrelation and filtering techniques. Association of variables is also considered and the value of correlations stressed, for example, for the examination of the taxa in a pollen spectrum, and the determination of correct vegetational successions and changes and their causes. Rates of change are an important part of Quaternary research, but rarely can sufficient data be obtained to enable more than simple 'change' to be evaluated. The author indicates that by using Fourier integral analysis relative amplitude changes in the frequency of data can be determined, and hence the importance of various rates of change determined.

The four essays are well-written and well-illustrated and the authors and editors, are to be congratulated upon a very attractive volume. This reviewer will look forward to further collections of occasional papers, which no doubt, will achieve the same high standard of scholarship. This, and any subsequent volumes, must be regarded as an essential component of any University or Polytechnic 'Quaternary Library'. May I make a plea, however, for a more substantial binding, my copy is already showing some signs of the pages becoming detached from the spine.

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SA2 8PP.

NOTICES

Studies in Speology - Special Offer

The William Pengelly Cave Studies Trust has available copies of backnumbers of its journal Studies in Speology. These are for sale to QRA members at the following rates:- Vol 1 pt 1 to Vol 2 pt 2 at £0.50 p per copy; Vol 2 pt 3/4 to Vol 2 pt 7/8 at £0.75 p per copy. Complete sets are also available at reduced rates. Individual copies and sets may be obtained from Mrs. L.S. Black 107 Andover Road, Newbury, Berkshire.

Centenary Open Days - British Museum (Natural History)
Wednesday 18th, Thursday 19th November 1981, 10.30 to 14.30.

As part of the Museum's Centenary celebration many of the departments and libraries will be open to those professionally involved with the earth or life sciences, to university and polytechnic students and to members of learned societies. Members of the various departments of the Museum will be on hand to discuss their research and the services the Museum provides. Tickets for admission will not be issued but those wishing to attend are asked to inform the Open Days Office at the Museum. Address -

British Museum (Natural History)
Cromwell Road,
London
SW7 5BD
Telephone: 01-589-6323 extensions 206, 667

The U.K. Contribution to IGCP Project 158: Palaeohydrological changes in the last 15000 years - Subproject B: Lake and Mire Environments

As many members will be aware the above project has been in existence since 1976 under the leadership of Professors Bjorn Berglund and Leszek Starkel and at the last meeting in Poland (22-28 September 1981) it was confirmed that the project would continue for a further five years. 'The main objective of subproject B is to understand the environmental changes in lakes and mires including their catchment areas, on the basis of multidisciplinary studies of lake sediments and peat deposits formed during the last 15000 years, paying particular attention to changes in the hydrological conditions related to climatic changes and human activity.' (Berglund, 1979, p.5). The project guide, edited in two volumes by Berglund in 1979, contains recommendations on approach and methodology and includes detailed descriptions of analytical methods.

The United Kingdom contribution to this project has so far been limited to subproject A - fluvial environments - and under the chairmanship of the UK national representative, Professor Ken Gregory, a number of meetings have been held to coordinate research on the palaeohydrology of the Severn Basin, and reviews of previous research on the area have been compiled. Active work will now go forward for at least another five years and it is now proposed that some contribution to subproject B should be coordinated with this fluvial environmental research. In fact some palaeoecological analysis of mire sites within the Severn Basin is already in progress but further cooperation here would be welcome.

Besides this we propose that some attempt should be made to produce a classification of the U.K. into palaeoecological Type Regions, along the lines proposed for Scandinavia and Poland (see Berglund 1979, volume 1, pp. 11-22), and that within these regions Reference Areas and Reference Sites (primary and secondary) should be chosen. At this stage of course all that we are doing is to compile and map sites of pollen-analytical research, judging how far they comply with the Project Guide recommendations regarding adequate C^{14}-dating and other desirable analyses, and attempting to draw some boundaries for Type Regions. We are aware that members will wish to express their views on how this exercise should be conducted which is why this note is appearing now, before any lines or dots have appeared on maps. Certain Reference Sites spring to mind immediately, while in many areas only partial or undated sequences are known to us. This is therefore, an appeal for information and comment.

It is intended that a report on UK activities for this subproject should be made to the organising committee in March 1982, with the possibility of an international joint meeting of those involved in both subprojects to be held in the UK at some time thereafter.

For further information members should consult the Project Guide (Berglund 1979) in the first instance, or the writers, or Dr. John Birks and Dr. Peter Moore who were involved at the planning stage of project 158. Please send your comments as soon as possible to:

Dr. Keith Barber and Dr. Colin Prentice
Department of Geography
University of Southampton
Telephone (0703) 559122 exts. 2258 and 554

Reference

Berglund, B.E. (ed) (1979): Palaeohydrological changes in the temperate zone in the last 15,000 years. IGCP 158B. Lake and mire environments. 2 vols: Lund.

XI INQUA Congress, Moscow, 1-9 August 1982

Potential UK participants in the XI INQUA Congress to be held in Moscow, 1-9 August 1982, are invited to notify the Royal Society and, at the same time, to advise whether they would expect to apply to the Royal Society for financial assistance (towards their travel and subsistence costs). It should be noted that grants are not ordinarily made to employees of the Research Council, the British Museum or other governmental bodies, nor to those not of Ph.D. status.

Tenth INQUA Congress Fund - Conspectus

The Royal Society set up the Tenth INQUA Congress Fund in 1978 from the surplus funds deriving from the organization in Birmingham in August 1977 of the Tenth Congress of the International Union for Quaternary Research (INQUA). The interest from the invested surplus is utilized to enhance the advancement of the science of Quaternary studies, particularly in promoting participation by British scientists domiciled in the United Kingdom in the activities of INQUA and of kindred organizations (through the provision of grants to facilitate attendance at INQUA and related international meetings).

About £1000 per year is available for these awards which are made by the Council of the Royal Society on the advice of the Quaternary Research Subcommittee (of the British National Committee for Geology).

The following principles for administering and allocating grants from the Fund have been laid down:

(a) Applicants must be British subjects who are normally domiciled in the United Kingdom;

(b) Applicants should have a primary interest in Quaternary studies and be active in this field;

(c) Applicants will be expected to be capable of furthering the repute of British Quaternary studies in international circles.

Applicants may include post-graduate research students, wishing to attend the XI INQUA Congress in Moscow, 1-9 August 1982.

Application forms are available from the Executive Secretary, the Royal Society, 6 Carlton House Terrace, London SW1Y 5AG, and should be returned by not later than 1st February. Results of applications should be made known during the following month.

Telephone enquiries: 01-839 5561
ext. 249/203

CALENDAR OF MEETINGS

November 18th and 19th 1982	British Museum (Natural History) open days. Full details of these open days occur elsewhere in this Newsletter.
January 4th-5th 1982	Quaternary Research Association Discussion Meeting - Recent Developments in Pollen Analysis and Quaternary Palaeoecology. Organiser H.J.B. Birks. Abstracts of papers to be presented at this meeting occur elsewhere in this Newsletter. Registration forms occur in the Circular accompanying this Newsletter.
March 28th-April 1st 1982	Quaternary Research Association Annual Field Meeting and Annual General Meeting - Amsterdam. Organisers R.H. Bryant (North London Polytechnic) and J.J. van der Meer.
May, 1982	Quaternary Research Association Short Field Meeting to Suffolk. Leaders P. Allen (City of London Polytechnic) and P. Coxon (Trinity College, Dublin).
May 28th-1st June 1982	Quaternary Research Association Overseas Study Course to Normandy. Leaders J.P. Lautridou (Caen) and D.H. Keen, Coventry (Lanchester) Polytechnic. Further details were included in the Circular issued with Newsletter No.34 and Registration forms will accompany Newsletter No.35.
August 1st-9th 1982	XI INQUA Moscow. Pre-Congress excursions take place from July 23rd to 31st. Post-Congress excursions from August 10th-19th. Further details on organisation in Britain may be obtained from the Royal Society (see notices elsewhere in this Newsletter). The Second Circular for the Congress has been issued and may be obtained from Dr. I.P. Kartashov, Secretary-General XI INQUA Congress, Geological Institute, USSR Academy of Sciences, Pyzhevsky 7, Moscow 109017, USSR.
August 22nd-28th 1982	XIth International Congress on Sedimentology, McMaster University, Hamilton, Ontario, Canada. Full details and conference circular may be obtained from IAS Congress, 1982, Department of Geology, McMaster University, Hamilton, Ontario, L85 4M1 Canada.
September 1982	Quaternary Research Association Short Field Meeting to South Kerry, organised by Dr. R.H. Bryant and Dr. W.P. Warren. Further details will be given in the Circular issued with the February 1982 Newsletter.

QUATERNARY NEWSLETTER.

No.35 November 1981

Contents

Compiled and printed for circulation to Quaternary Research Association members and others by the Honorary Editor, Quaternary Newsletter, Dr. D.H. Keen, Department of Geography, Coventry (Lanchester) Polytechnic, Priory Street, Coventry, CV1 5FB, England.

ISSN 0143-2826.

Quaternary Research Association

CONSTITUTION

1. The name of the Association shall be the Quaternary Research Association.

2. Membership of the Association shall be open to all interested in furthering the object of the Association. The Association may elect Honorary Life Members in recognition of distinguished contributions to Quaternary Science.

3. The object of the Association is the advancement of education and research into the problems of the Quaternary period, with the publication of the results of the research for the benefit of the public. In furtherance of this object, but not otherwise, the Association through its Executive Committee shall have the following powers: (a) To hold public meetings and exhibitions; (b) To publish pamphlets, leaflets, etc.; (c) To do all such things as will further the object.

4. The affairs of the Association shall be handled by an Executive Committee, which shall include the following officers: A President and Vice-President, each of whom may hold office for up to two years; a Secretary, Treasurer and Newsletter Editor, each of whom shall hold office for up to four years. The Executive Committee shall include six ordinary members, each of whom may serve in this capacity for up to three years. At least two new ordinary members of the Executive Committee shall be elected each year. Officers are eligible for election as ordinary members of the Executive Committee on completion of their term(s) of office. Ordinary members of the Executive Committee elected as officers may hold office for the period appropriate to the office.

5. The Executive Committee shall be elected annually at the Annual General Meeting. Officers and ordinary members shall be nominated by the retiring Executive Committee, and the list of nominations shall be sent to all members at least thirty days before the Annual General Meeting. Members of the Association may make additional nominations up to the beginning of the Annual General Meeting, providing that each nomination is supported by at least three members of not less than one year's standing.

6. The Executive Committee shall have power to co-opt to fill any vacancies which may arise in the Committee until the next Annual General Meeting of the Association.

7. At meetings of the Executive Committee, six members shall form a quorum.

8. The President shall preside at all general and committee meetings at which he is present. In his absence, the Vice-President shall preside. If neither is present, the Secretary shall invite another member to preside.

9. The Secretary shall make all arrangements for the general organisation and conduct of meetings. The arrangements for particular meetings may be made the responsibility of a Local Secretary, who shall be appointed by the Executive Committee for this purpose. The Secretary shall arrange for the minutes of the proceedings of the Executive Committee Meetings, the Annual General Meeting and any specific General Meeting to be recorded, and these shall be entered regularly in the minute books. He shall keep records of other meetings, conduct the correspondence of the Association and report to the Executive Committee matters relating to the business of the Association.

10. The Treasurer shall receive and keep account of all the monies of the Association. He shall produce accounts whenever required by the Executive Committee, and shall also present the accounts for each year ending the 31st December, so that they may be audited and submitted to the Annual General Meeting of the Association. All monies received for the Association shall be paid into such bank as the Executive Committee shall appoint.

11. A Special General Meeting of the Association may be called at any time by the President, the Executive Committee, or any twelve members on application to the Secretary. Not less than thirty days' notice of the date and purpose of such a Special General Meeting shall be given to members, and no business shall be considered at such a meeting other than that for which it was convened.

12. The Association shall not be dissolved except at a Special General Meeting convened for this purpose. The motion of dissolution must be passed by a majority of two-thirds of the members present.

13. In the event of dissolution, the funds and other property of the Association, after the payment of all proper debts and liabilities, shall not be distributed among the members of the Association, but shall be given, paid, transferred or distributed to or among such other charitable institutions having similar objects to those of the Association as the Executive Committee with the approval of the Special General Meeting shall determine.

14. The first Annual Subscription shall be paid on joining the Association, but if a member joins in November or December the subscription shall cover the whole of the following calendar year. With this exception, all Annual Subscriptions shall become due on the 1st January for the subsequent year. Members whose subscriptions are in arrears are not liable to receive circulars, and may be excluded from meetings if attendance is restricted for any reason. Members whose subscriptions are more than one year in arrears may be removed from the Association by the Executive Committee, provided that a final reminder has been sent by the Treasurer at the end of this year.

15. The Annual Subscription shall be a sum determined at the Annual General Meeting.

16. Any member not in arrears with subscriptions may resign from the Association by giving notice in writing to the Secretary.

17. No alteration or addition to the Constitution of the Association shall be made except by a majority of votes of the members present at a General Meeting, and no alteration or addition to the Constitution shall be made which would cause the Association to cease to be a charity in law.