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Quaternary Newsletter is issued in February, June and November. Contributions comprising articles, reviews, notices of forthcoming meetings, news of personal and joint research projects, etc. are invited. They should be sent to the Quaternary Research Association Newsletter Editor. Closing dates for submission of copy for the relevant numbers are 1 January, 1 May and 1 October.

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EDITORIAL

The supply of material for Quaternary Newsletter has gradually declined over the past year. Members are reminded that short papers, news of research projects and correspondence are most welcome. Suitable contributions received by the closing dates (see opposite) are usually published in the next issue.

QN: articles

A HAMMER SEISMIC REFRACTION SURVEY OF A SCOTTISH LACUSTRINE DELTA USED TO ESTIMATE SEDIMENT YIELD

Tim Stott and Rob Duck

A hammer seismic refraction survey of a downstream lacustrine delta has been used as an alternative and independent approach to evaluate sediment yield from a Scottish upland moorland glen. The upper part of the glen is a gauged catchment from which the sediment yield has been estimated as part of paired catchment experiment investigating the effects of forestry on the water balance and sediment yields. Sediment yield estimates made from the volume of the delta deposits do not match the contemporary yields measured in the upper part of the glen. It is proposed that the fine nature of the sediment leaving the gauged catchment (97% is suspended sediment) results in only a small proportion being trapped in the delta, the remainder being deposited elsewhere on the loch bed.

Introduction

As part of a consortium-funded, paired catchment experiment investigating the effects of forestry on water balance and sediment yields at Balquhidder in the southern Scottish highlands, contemporary sediment yields have been estimated by the Institute of Hydrology for the upper 7.7 km^2 catchment in the moorland Monachyle glen. Some 4 km down the glen from the catchment outlet and gauging station the mainstream (Monachyle burn) has deposited a delta which has almost entirely divided Loch Voil (to the east) and Loch Doine (to the west). A location diagram of the study area and plan of the delta are presented in Figure 1. According to the 1899 Bathymetric survey of the Scottish freshwater lochs by Murray & Pullar (1910), these two lochs once formed "at no very distant date a continuous loch, which has been divided into two portions principally by the deposition of material brought down Monachyle glen by the river". Previous studies have used volume measurements of such lacustrine deltas to estimate sediment yields (e.g. Lambert 1982). In summer 1986 an investigation of the structure of this delta was conducted under the assumption that some or all of the delta is composed of sediment derived from Monachyle glen. One of the objectives of this project (which forms part of a wider Ph.D. study on the catchment sediment yields) was to use a completely different approach to attempt to produce a second, independent estimate of the sediment yield of Monachyle glen.

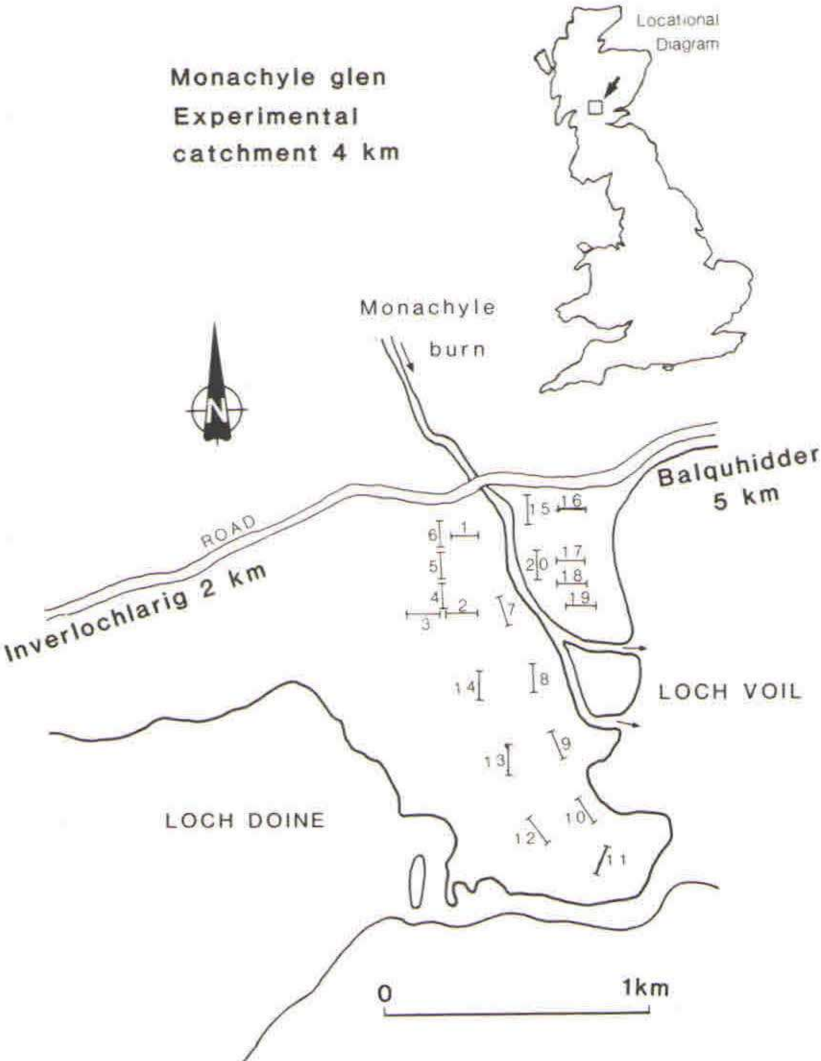


Figure 1. Location diagram of the study area and plan of Monachyle delta showing the locations of the seismic traverses.

Method

The investigation of the delta was performed using the hammer seismic refraction method. The technique utilises the fact that seismic waves travel at different velocities in different materials, depending upon their density and elastic moduli and that the waves become refracted when they pass from material of one velocity to material of another. The instrument used in the survey was a portable Bison Signal Enhancement Seismograph (6 channel, Model 1580). In the method used, 'shock' waves are introduced into the ground by a sledge hammer striking a metal plate. Vibrations which have travelled through the ground are received by geophones, positioned at fixed points along a traverse line, and displayed as wave forms on the oscilloscope of the seismograph. Electronic filters and a signal enhancement memory facility are used to distinguish the first signals to reach each geophone from any background noise. The times of arrival of seismic waves (in milliseconds) at each point on the traverse are plotted against the distance (in metres) between the hammer point and each geophone position. Four geophones were deployed simultaneously thus minimising the number of hammer blows required.

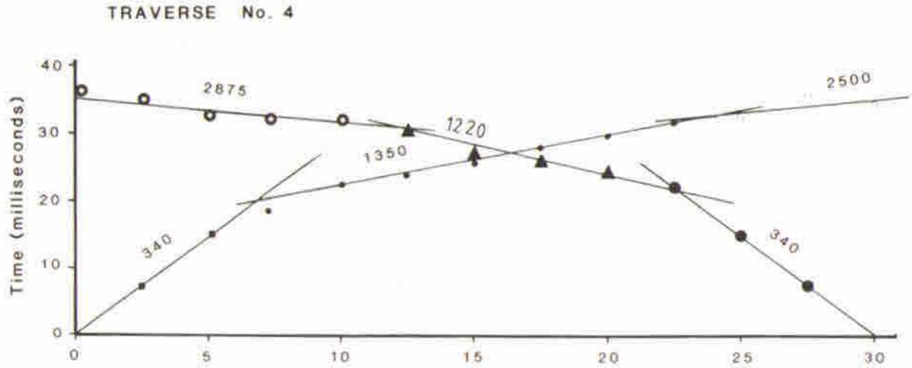
The slopes and forms of the time-distance graphs produced (e.g. Figure 2) give the velocities at which seismic waves travel through the sub-surface materials and the depths to various types of interfaces. They do not, however, describe the materials without ambiguity but are a useful guide to their type.

If the hammer is at short distances from the geophones, the first shock wave to arrive has travelled through the surface soil layers and the reciprocal of the slope of the time-distance graph gives the seismic velocity of that layer (V_1). Beyond a certain critical distance (Xc) the first shock wave to arrive at a geophone has travelled at a faster rate through deeper, more dense or elastic layers and the slope of the graph beyond Xc is a measure of the seismic velocity of the lower layer (V_2). The depth to the interface between the two layers (D) is given by:

$$D = Xc/2 \qquad V_2 - V_1 \;/\; V_2 + V_1$$

Similarly, the depth to deeper interfaces can be established by using the appropriate velocities, critical distances and formulae. Seismic refraction profiles are usually reversed so that actual (rather than apparent) velocities are recognised and that overall inclinations of the interfaces can be determined. In this study a total of 20 reversed traverses distributed over the surface of the delta (Figure 1), each 30 m in length, were surveyed using geophone spacings of 2.5 m.

It must be emphasised that a major drawback of this technique is it cannot detect the presence of "slow" formations beneath "fast" layers. However, this is not considered to present a problem in this particular study. Full details underlying the principle of the technique and interpretation may be found in Handbook of Engineering Geophysics Vol I: Seismic published by Bison Instruments Inc. (1981). The advantages of the Bison model over other seismographs are discussed by Kesel (1976) and need not be repeated here.



Xc1a	6.9 m	Xc1b	7.5 m
Xc2a	23.3 m	Xc2b	18.5 m
D1a	2.7 m	D1b	2.8 m
D2a	8.5 m	D2b	8.1 m

Figure 2. Example graph of seismic wave travel time (milliseconds) v. distance from hammer for Traverse 4 on Monachyle delta. All velocities on the graph are in m s^{-1}. Xc is the critical distance and D1 and D2 are the depths (m) to the first and second interfaces between layers (see text for details). All traverses were surveyed in both directions so that two depth estimates to the interfaces are made, one in each direction - 'a' below the graph on the left and 'b' on the right.

Results

The total catchment area draining to the delta is 17.2 km^2 (digitised from 1:50,000 O.S sheet 57). Sediment output monitoring by the Institute of Hydrology from the 7.7 km^2 catchment in the upper part of Monachyle glen in the calibration phase of the experiment (1982-5) gave an estimated suspended sediment yield of 38 t km^{-2} yr^{-1} (Ferguson & Stott in press, Stott 1987). This yield estimate falls within the range estimated from reservoir surveys by McManus & Duck (1985), Duck & McManus (in press) and Ledger et al. (1974) for similar upland moorland catchments in east central Scotland. Making the assumption that this yield applies to the whole of the glen upstream of the delta and also that the contemporary sediment yield has operated since the termination of the Loch Lomond stadial of the last glaciation ($\sim 10^4$ years ago) it is possible to make an estimate of the mass of sediment which would be deposited in Lochs Voil and Doine and the delta assuming a 100% trap efficiency (not unreasonable since the loch outlet is 6 km east from the delta):

The total sediment output = catchment area x measured sediment yield x number of years accumulation (since last glaciation)

$$= 17.2 \text{ km}^2 \times 38 \text{ t km}^{-2} \text{ yr}^{-1} \times 1 \times 10^4 \text{ yr}$$

$$\sim \underline{7 \times 10^6 \text{ t}}$$

The majority of the seismic refraction profiles are indicative of a two-layered situation. However, several of those located to the north and north-eastern portion of the delta reveal the occurrence of three layers by the presence of three slope segments on the time-distance graphs (e.g. Traverse 4, Figure 2). The seismic velocities of the uppermost materials range from 320 - 420 m s^{-1} whereas those of the second layer vary between 1100 and 1700 m s^{-1}. Where identified, the seismic velocities recorded for the third and lowest unit lie in the range 2250 to 4200 m s^{-1}.

The upper discontinuity was detected at depths ranging from 0.8 to 2.9 m with a mean depth of 2.2 m (n = 40, s.e. = 0.1). Without the availability of coring equipment we believe that this discontinuity represents the interface between fluvially deposited sediments derived from Monachyle glen and glacially deposited till. This is strongly supported by the seismic velocities which are typical of alluvial materials and tills respectively. The possibility of this discontinuity being the water table was discarded since the difference between the height of the loch surface and the delta surface is less than 2.2 m.

The highest seismic velocities recorded for the lowest unit identified in the delta sequence are indicative of bedrock (Dalradian schists) which is present at depths of between 6.0 and 10.5 m at the north end of the delta. The lower values may, however, result from the presence of a second till, more compacted than the one overlying it.

The surface area of the delta estimated from the 1: 10,560 scale O.S. map (surveyed in 1863, second edition 1901) is 85 400 m^2. Assuming that the average depth of fluvially deposited sediment is 2.2 m over the whole delta then the volume is the product of the area and average depth. The average bulk density of sediment accumulating in bedload traps in the upper part of the Monachyle catchment has been estimated as 1.37 t m^{-3} (Stott 1987). However, it is reasonable to suppose that sediment accumulating in a delta such as this will become compacted over time and therefore have a higher average bulk density. Frostic & Reid (1986) used an average bulk density of 1.6 t m^{-3} for similar calculations on a delta in northern Kenya. Using this value of density, which seems more reasonable, allows a crude estimate of the sediment mass to be made:

Mass of sediment on delta surface = area x depth x density

$$= 85\ 400\ m^2 \times 2.2\ m \times 1.6\ t\ m^{-2}$$

$$\sim \underline{0.30 \times 10^6 t}$$

This represents a sediment yield of almost 2 t km^{-2} yr^{-1} from the whole of Monachyle glen averaged since the last ice retreat ($\sim 10^4$ years) and therefore only accounts for about 5% of the contemporary sediment yield? This represents approximately 460 years of sediment accumulation at the present rate of production of sediment from the gauged catchment in the upper part of the glen.

If alternatively we disregard the seismic refraction findings and assume that the whole of the delta is composed of sediment derived from Monachyle glen since the last ice retreat, a simple calculation of the whole delta volume can be made: the maximum depth of Lochs Voil and Doine as surveyed by Murray & Pullar (1910) near the delta is 15 m (converted from feet). A method of predicting delta profiles has been derived (Matyas 1984), but for the purposes of a first approximation a slope angle of 30° is assumed from the surface of the delta to the deepest point in the loch either side. In this way the volume of the delta cone was estimated as 1.29×10^6 m^3 which represents 2.06×10^6 t of sediment (using an average sediment density of 1.6 t m^{-3} as before). This corresponds to a sediment yield of about 12 t km^{-2} yr^{-1} when averaged over the last 10^4 years or about 30% of the present sediment yield and would represent around 3000 years accumulation at the present rate of sediment production from the catchment in the upper part of the glen.

Discussion

These estimates are very approximate indeed but nevertheless it seems that measured contemporary sediment yields in the upper part of Monachyle glen do not match estimated yields reconstructed from sediment deposited in the delta downstream. There are two possible explanations: first, more that 97% of the contemporary sediment yield is suspended sediment as reported by Stott et al. (1986) - it is probable that only the coarser fraction of this is actually deposited on the delta, the remainder travelling in suspension to more distant parts of the loch before becoming deposited or possibly even leaving the loch as part of the sediment load of the outflowing river Balvag at the east of the loch. Two bulk sediment samples taken with a trowel from the banks of the mainstream flowing across the delta revealed median grain sizes of 0.125 and 0.18 mm and two samples from the delta surface using a standard soil auger (depth 30 cm) both had a median grain size of 0.125 mm. The fine nature of these samples to some extent reflects the sampling methods, but nevertheless indicates that the surface layers of this delta are composed of quite fine, fluvially deposited sediments which have been brought down Monachyle glen in suspension and deposited more recently in the form of overbank sedimentation.

A second, but less likely explanation for the mis-match of the present sediment yield with delta accumulation is that contemporary sediment yields were lower than in the past and so the delta represents sediment deposited in a time of higher yields. There is no onshore evidence for the delta aggrading at present, its area not having changed significantly since the 1863 Ordnance survey. However, evidence from elsewhere (e.g. Battarbee et al. 1985, study of loch sediments) indicates that contemporary sediment yields are higher than in the past.

More work in the form of augering to depths of at least 3 m is required if the nature and composition of the sediments in this delta are to be related to the sediment yield from Monachyle glen. Offshore work using echo sounding to investigate the delta profile, possibly combined with some loch bed coring should also prove worthwhile. In the past five years the Monachyle glen has undergone progressive ploughing and drainage ditching in preparation for afforestation. It appears that this ground preparation is associated with at least temporarily increased sediment yields (Stott 1987). Future work coring the loch sediments at the mouth of the Monachyle mainstream may reveal layers of sediments corresponding to the ploughing phases (cf. Battarbee et al. 1985, Duck 1985).

Conclusion

A hammer seismic refraction survey of a lacustrine delta was used as an alternative method to gain an independent estimate of sediment yield from a Scottish upland moorland glen. Sediment yields measured in the upper part of the glen did not match estimates made from the delta accumulation, and were in fact far higher than either the surface sediment layer or even the whole delta volume indicate. It is suggested that the mis-match be due to either lower past sediment yields or most of the fluvially derived sediment being very fine in nature and therefore deposited elsewhere on the loch bed and not just in the delta. Nevertheless, hammer seismic refraction has been a useful tool in this investigation and its usefulness should not be overlooked by Quaternary scientists undertaking similar studies.

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References

Battarbee, R.W., Appleby, P.G., Odell, K. & Flower, R.J. 1985. ^{210}Pb Dating of Scottish Lake sediments, afforestation and accelerated soil erosion. Earth Surf. Proc. and Landforms, 10, 137-142.

Duck, R.W. 1985. The effect of road construction on sediment deposition in Loch Earn, Scotland. Earth Surf. Proc. and Landforms 10, 401-406.

Duck, R.W. & McManus, J., in press. Sediment yields in lowland Scotland derived from reservoir surveys. Trans. Royal Soc. Edinburgh: Earth Sciences.

Ferguson, R.I. & Stott, T.A., in press. Forestry effects on suspended sediment and bedload in the Balquhidder catchments. Trans. Roy. Soc. Edinburgh: Earth Sciences.

Frostick, L.E. & Reid, I. 1986. Evolution and sedimentary character of lake deltas fed by ephemeral rivers in the Turkana basin, northern Kenya. In, Frostick, L.E. et al. (eds.). Geol. Soc. Spec. Publ. No. 25, 113-125.

Kesel, R.H. 1976. The use of refraction-seismic techniques in geomorphology. Catena, 3, 91-98.

Lambert, A.M. 1982. Estimation of erosion and sediment yield by volume measurements on a lacustrine river delta. Int. Ass. Hydrol. Sci. publ. No. 137, 171-176.

Ledger, D.C., Lovell, J.P.D. & McDonald, A.T. 1974. Sediment yield studies in upland catchment areas in south-east Scotland. J. Appl. Ecol. 11, 201-206.

Matyas, E.M. 1984. Profiles of modern prograding deltas. Can. J. Earth Sci. 21, 1156-1160.

McManus, J. & Duck, R.W. 1985. Sediment yield estimated from reservoir siltation in the Ochil hills, Scotland. Earth Surf. Proc. and Landforms, 10, 192-200.

Murray Sir. J. & Pullar L. 1910. Bathymetrical survey of the Scottish freshwater lochs. Vol. II. Challenger Office, Edinburgh.

Stott, T.A. 1987. Forestry effects on sediment sources and yields in the Balquhidder catchments, central Scotland. Unpublished Ph.D. thesis, University of Stirling.

Stott, T.A., Ferguson, R.I. Johnson, R.C. & Newson, M.D. 1986. Sediment budgets in forested and unforested basins in upland Scotland. In, R.F. Hadley, Drainage Basin Sediment Delivery. Int. Ass. Hydrol. Sci. publ. no. 159, 57-69.

IN DEFENCE OF THE WOLSTONIAN STAGE

P.L. Gibbard & C. Turner

In the last issue of Quaternary Newsletter, Jim Rose (1987) made a strong case for the correlation of the glacial sequence of the Coventry area with that in eastern England, thereby potentially demonstrating that both series of deposits are of Anglian age. This fundamental reassignment of the classic glacial sequence of the Midlands from the Wolstonian to the Anglian Stage has been mooted for some time, particularly by BGS workers, such as Sumbler (1983a, b). However, Jim Rose's arguments have been strong enough to convince many Quaternary workers to accept his conclusions, though there are still critical questions to be answered before the matter can be regarded as proven. Whatever the outcome of this debate, where we differ from Jim Rose and what we discuss here is his statement that "the term 'Wolstonian' should be abandoned for the stage between the Hoxnian and Ipswichian Stages [and] it is proposed that until further evidence is available glacial episodes during this interval should be referred to as 'those occurring between the Hoxnian (*sensu stricto*) and Ipswichian (*sensu stricto*) Stages' ".

The term Wolstonian was selected for the 'glacial' stage intermediate between the Hoxnian and the Ipswichian temperate Stages by the Geological Society of London Stratigraphy Committee in 1969 (Shotton & West 1969). A fuller committee later compiled the Special Report 4 - *A correlation of the Quaternary deposits of the British Isles* (Mitchell *et al.* 1973). The definition of the Wolstonian Stage was based substantially on the pioneering work of Shotton (1953) in which the glacial sequence of the Coventry, Rugby and Leamington areas had been mapped, centred on a stratotype locality close to Wolston village (cf. Shotton 1983). The Wolstonian Stage name replaced an earlier informal term Gippingian, the latter based on till which was later found to represent predominantly the upper, often weathered, zone of East Anglian Lowestoft Till (see arguments summarised in Bristow & Cox 1973, Perrin, Rose & Davies 1979). More recently a series of useful reviews of developments in the Midlands Pleistocene sequences by Shotton (1983 , 1986) have pointed to the stratigraphical evidence from Nechells and Quinton. These two localities include fossiliferous sediments correlated with the Hoxnian Stage, overlain by glacigenic deposits but lying outside the Devensian ice maximum limit. The details of the critical site at Quinton are still unpublished but are, in general, not disputed.

In keeping with a tradition that extends back to the work of Penck & Brückner (1909), 'glacial' stages have been named from the occurrence of glacial, glaciofluvial and glaciolacustrine deposits. Whilst this practice may seem natural and obvious it has serious limitations, not the least of which is that lithostratigraphy of glacial sequences, as we now know, is fraught with difficulties. Indeed, it is surprising how little it has been necessary to amalgamate or separate major glacial episodes, in view of the lithological similarity of deposits repeatedly derived from the same source rocks at geologically, shortly-separated intervals.

What is at issue here is the question of stratigraphical terminology and not solely whether a sequence of sediments should be assigned to one stage or another. A problem arises because in Pleistocene terminology the words glacial, interglacial, stadial and interstadial were originally and often still are used as substitutes for the terms stage and substage respectively. There is of course a fundamental difference between these terms. Glacial and interglacial etc. are geological-climatic units based on climatic events from inferred geological sequences and as such are used almost exclusively in the Quaternary. They can also only be truly valid in glacierised areas particularly in the temperate regions of the Northern Hemisphere for which they were originally conceived. In contrast, stage and substage are chronostratigraphical units, the function of which is clearly defined by the International Stratigraphic Guide (ISG) (Hedberg 1976). A stage is a chronostratigraphical unit of relatively minor rank, considered to be the most suitable for interregional correlation. The boundaries of stages are ideally isochronous surfaces between fixed points both within and beyond the type area (cf. Hedberg 1976).

The usage of the descriptive term 'glacial' stage has been discouraged (West 1963, 1984, in press) in favour of cold stage (cf. Lüttig 1965). It could be argued that we must have glacial deposits in order to define a 'glacial' stage. However, on the one hand glaciation may be difficult to demonstrate, for example in the Early and early Middle Pleistocene. On the other, the stages themselves are virtually never represented in the geological record solely by glacial deposits. All recognised cold stages include sediments laid down under periglacial, non-glacial and indeed even shortlived (interstadial) temperate climates, particularly outside the area of actual glaciation.

The term Wolstonian has been used to refer to a glaciation but it is formally defined as a Stage and undoubtedly represents a long period, generally of cold climate with glacial episodes, between the Hoxnian and Ipswichian Stages. Indeed the possibility of a further cold-temperate stage cycle between these limits has been mooted (Erd 1970, Menke 1968, 1980, Cepek 1967, 1986). Jim Rose (1987) has proposed that the stratotype from which the stage is named has become unsatisfactory. There is therefore a dilemma for which there are two possible solutions in terms of formal stratigraphical procedures.

The first is replacement of the stage name. A formally defined chronostratigraphical unit CANNOT, according to International Commission on Stratigraphy (ICS) procedure, be abolished UNLESS it is replaced by an alternative or unless the time represented can be shown not to have 'happened'. This is because all geological time must be represented in stages. Since so much of our regional successions is dependent on correlation with stage units, although not necessarily directly with the type sequence, one cannot simply remove a time period by re-assigning the stratotype deposits.

The second solution is to change the locality of the stratotype. There are several important precedents for this. The classic example is the transfer of the Carboniferous Namurian Series stratotype from Belgium to Derbyshire (Ramsbottom 1969), but Quaternary examples include the relocation of the Calabrian stratotype to Vrica (Selli et al. 1977) and that of the Devensian, placed originally at Chelford (Shotton & West 1969) to Four Ashes (Mitchell et al. 1973). It is perhaps unfortunate that the term Wolstonian, unlike Anglian and Devensian, is so localised in its etymology; nevertheless, it has become widely accepted over nearly 20 years.

In either case a new stratotype will have to be found if the sediments in the Wolston section are confirmed to be of Anglian age. Shotton (1986) has already reviewed the various divergences of opinion on the Wolstonian Stage and stressed the occurrence of proven post-Hoxnian, pre-Devensian glacigenic sediments in the Birmingham area, so that the search might focus on this region. The Wolstonian cold period is, of course, also well represented in extra-glacial areas such as the Thames Valley by three major terrace accumulations (Gibbard 1985) and in many other rivers, for example, the Waveney (Coxon 1984) and Nar (Ventris 1986). However, fluvial deposits are as incomplete as glacial sequences, though they contain a better biostratigraphical record.

The potential recognition that the Wolston section is unsatisfactory as a national stage stratotype provides us with an important opportunity to point out certain deficiences in the typification of the British Pleistocene succession. The unit stratotypes for the Wolstonian and the Devensian, the only two stages hitherto defined outside East Anglia, and likewise the Anglian, have been selected because of their glacigenic sediment sequences. Nevertheless they all provide inadequate boundary stratotypes because each has an erosional base. This lack of boundary stratotypes for the British late Middle and Upper Pleistocene cold stages is a serious lack of precision in our formal chronostratigraphical sequences. The use of boundary stratotypes, i.e. localities where the bases of stages (and thus by inference the tops of the previous stages) are defined in continuous sediment sequences is strongly recommended in the ISG (Hedberg 1976), and in the formal ICS guidelines (Cowie et al. 1986).

The identification of such points has been much discussed by stratigraphers particularly in connection with marking the actual boundary point either actually or notionally with a 'golden spike' (see discussion in Holland 1986). Furthermore, there is no reason why such boundaries should not be defined for this country since they are already recorded at sites in Britain. For example, the boundary between the 'early Wolstonian (e Wo)' and the underlying Hoxnian (Ho IVb) has been defined in continuous sediments at Marks Tey where it was recorded at 345 cm in borehole II and 300 cm in borehole III (Turner 1970). It is, however, uncertain that this horizon marks the onset of the Wolstonian sensu stricto in view of the evidence from Germany (Erd 1970, Cepek 1967, 1986, Menke, 1968, 1980), and to a lesser extent the Netherlands (Zagwijn 1973), that a separate cold period (Fühne) and temperate stage (Dömnitzian Interglacial/Hoogeveen Interstadial) intervene before the onset of the Saalian Stage, generally held to be correlative with the Wolstonian. In addition, at Hoxne there is the possibility of a second temperate interval possibly equivalent to the Dömnitzian/Hoogeveen 'Stage', separated from the type Hoxnian by a period of cold climate (Wymer 1983). The upper boundary of the Wolstonian is in effect already defined at the Ipswichian unit and boundary stratotype at Bobbitshole. There the base of the Ipswichian Stage is defined by West (1957) at 5.9 m in borehole 3 at the stage boundary.

Similarly, an excellent boundary stratotype for the Devensian Stage might be defined at Wing, Rutland where the boundary occurs at 5.67 m in core B (Hall 1980). We are not proposing the replacement of the unit stratotype for the Devensian Stage at Four Ashes, but the use of an auxillary boundary stratotype as permitted by the ICS (Cowie et al. 1986, p. 5).

Recommendations

There is demonstrably a post-Hoxnian, pre-Ipswichian time interval characterised by cold and, in part, glacial climate. Thus the term Wolstonian cannot simply be removed unless replaced. When and if replaced it should be redefined correctly following ISG and ICS rules at a stratotype locality preferably in a non-glacial area where the range of potential evidence is far greater than in a glaciated locality. Reinvestigation of the Nechells and Quinton sequences and their relation to the glacial deposits is clearly due in this respect. At present the term Wolstonian HAS to be conserved and indeed there may well be a strong case for retaining this name attached to a new unit and boundary stratotype when that can be defined. If a new stage name is proposed in order to avoid confusion etc., it should be non-site-specific.

Ideally future stage names should be defined not by an individual author but should be scrutinised for validity and function by a committee possibly established under the auspices of the QRA to act in accordance with the guidelines of ICS. Uniform methods should be adopted for temperate stages as well as for substages within cold stages (stadials, interstadials etc.)

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References

Bristow, C.R. & Cox, F.C. 1973. The Gipping Till: a reappraisal of East Anglian glacial stratigraphy. J Geol Soc. 129, 1-37.

Cepek, A.G. 1967. Stand und Probleme der Quatärstratigraphie im Nordteil der DRR. Ber. Deutschen Gesell. geol. Wissensch A, Geol. Paläont. 12, 375-404.

Cepek, A.G. 1986. Quaternary stratigraphy of the German Democratic Republic. Quat. Sci. Rev. 5, 359-364.

Cowie, J.W., Zeigler, W., Boucot, A.J., Bassett, M. & Remane, J. 1986. Guidelines and statutes of the International Commission on Stratigraphy (ICS). Cour. Forsch.-Inst. Senckenberg 83, 1-14.

Coxon, P. 1984. The terraces of the River Waveney. In: P. Allen (Ed.) Gipping and Waveney Valleys Field Guide. Cambridge: Quaternary Research Association. 80-94.

Erd, K. 1970. Pollen-analytical classification of the Middle Pleistocene in the German Democratic Republic. Palaeogeogr. Palaeoclimat. Palaeoecol. 12, 129-145.

Gibbard, P.L. 1985. Pleistocene history of the Middle Thames Valley. Cambridge: University Press. 155 pp.

Hall, A.R. 1980. Late Pleistocene deposits at Wing, Rutland. Phil. Trans. R. Soc. Lond. B 289, 135-164.

Hedberg, H.D. (Editor) 1976. International Stratigraphic Guide. Wiley Interscience. New York: John Wiley and Sons. 200 pp.

Holland, C.H. 1986. Does the golden spike still glitter? J. Geol. Soc. 143, 3-21.

Lüttig, G. 1965. Interglacial and interstadial periods. J. Geol. 73, 579-591.

Menke, B. 1968. Beiträge zur Biostratigraphie des Mittelpleistozäns in Norddeutschland. Mehniana 18, 35-42.

Menke, B. 1980. Wacken, Elster-Glazial, marines Holstein-Interglazial und Wacken-Warmzeit. In: H.E. Streme & B. Menke (Eds.) Quartär-Exkursionen in Schleswig-Holstein: IGCP 24, 26-35. Kiel: Geologisches Landesamt Schleswig-Holstein.

Mitchell, G.F., Penny, L.F. Shotton, F.W. & West, R.G. 1973. A correlation of the Quaternary deposits of the British Isles. Geol. Soc. Lond. special report 4, 99 pp.

Penck, A. & Brückner E. 1909. Die Alpen im Eiszeitalter. Leipzig. 1199 pp.

Perrin, R.M.S., Rose, J. & Davies, H. 1979. The distribution, variations and origins of pre-Devensian tills in Eastern England. Phil. Trans. R. Soc. Lond. B 293, 385-418.

Ramsbottom, W.H.C. 1969. Interim report of the Namurian working group. C.R. 6me Cong. int. Strat. géol. Carb. (Sheffield 1967) 1, 71-77.

Rose, J. 1987. Status of the Wolstonian glaciation in the British Quaternary. Quat. Newsl. 53, 1-9.

Selli, R., Accorsi, C.A., Bandini Mazzanti, M., Bertolani Marchetti, D., Bigazzi, G., Bonadonna, F.P., Borsati, E., Cati, F., Colalonga, M.L., D'Orofrio, S., Landini, W., Menasini, E., Mezzetti, R., Pasini, G., Savelli, C. & Tampieri, R. 1977. The Vrica section (Calabria, Italy), a potential Neogene-Quaternary boundary stratotype. Giorn Geol. 42, 181-204.

Shotton, F.W. 1953. Pleistocene deposits in the area between Coventry, Rugby and Leamington and their bearing on the topographic development of the Midlands. Phil. Trans. R. Soc. Lond. B 237, 209-260.

Shotton, F.W. 1983. The Wolstonian Stage of the British Pleistocene in and around its type area of the English Midlands. Quat. Sci. Rev. 2, 261-280.

Shotton, F.W. 1986. Glaciations in the United Kingdom. Quat. Sci. Rev. 5, 293-297.

Shotton, F.W. & West, R.G. 1969. Stratigraphical table of the British Quaternary. Appendix B1. In: George, T.N., Harland, W.B., Ager, D.V., Ball, H.W., Blow, W.H., Casey, R., Holland, C.H., Hughes, N.F., Kellaway, G.A., Kent, .P.E., Ramsbottom, W.H.C., Stubblefield, J. & Woodland, A.W. Recommendations on stratigraphical usage. Proc. Geol. Soc. Lond. 165, 155-157.

Sumbler, M.G. 1983a. A new look at the type Wolstonian glacial deposits of central England. Proc. Geol. Ass. 94, 23-31.

Sumbler, M.G. 1983b. The type Wolstonian sequence - some further observations. Quat. Newsl. 40, 36-39.

Turner, C. 1970. The Middle Pleistocene deposits at Marks Tey, Essex. Phil. Trans. R. Soc. Lond. B 257, 373-440.

Ventris, P. 1986. The Nar Valley. In: R.G. West & C.A. Whiteman (Eds.) North Norfolk and the Nar Valley Field Guide. Cambridge: Quaternary Research Association. pp. 7-29.

West, R.G. 1957. Interglacial deposits at Bobbitshole, Ipswich. Phil. Trans. R. Soc. Lond. B 241, 1-31.

West, R.G. 1963. Problems of the British Quaternary. Proc. Geol. Ass. 74, 147-186.

West, R.G. 1984. Interglacial, interstadial and oxygen isotope stages. Diss. Bot. 72, 345-357.

West, R.G. (in press). The use of type localities and type sections in the Quaternary with especial reference to East Anglia. New Phytol.

Wymer, J.J. 1983. The lower Palaeolithic site at Hoxne. Suffolk Inst. Archaeol. Hist. 25, 169-189.

Zagwijn, W.H. 1973. Pollen analytic studies of Holsteinian and Saalian Beds in the northern Netherlands. Meded. Rijks. Geol. Dienst 24, 139-156.

STRATIGRAPHIC NOMENCLATURE FOR THE BRITISH MIDDLE PLEISTOCENE - PROCEDURAL DOGMA OR STRATIGRAPHIC COMMON SENSE?

J. Rose

Introduction

This note is a response to "In Defence of the Wolstonian Stage" by P.L. Gibbard and C. Turner which was written as a consequence of my paper entitled "Status of the Wolstonian Glaciation in the British Quaternary", published in Quaternary Newsletter 53 (1987). Firstly, I would like to thank Drs. Gibbard and Turner for their implicit support for the concept outlined in my paper that the deposits at Wolston are the same age or earlier, than the Anglian glacial deposits of East Anglia (rather than younger as hitherto proposed, Mitchell et al. 1973). The paper in Quaternary Newsletter only outlines the 'bare-bones' of the evidence. Fuller details are to be published shortly and further investigations are being carried out by Simon Lewis, a research student at Birkbeck College and several officers of the British Geological Survey who are currently mapping relevant areas.

I am pleased to respond to Gibbard and Turner on the wider topic of stratigraphic procedures and fully support their recommendation that this matter be pursued in future activities of the Quaternary Research Association. However, I must say that I am very apprehensive about this area of Quaternary Research coming under the 'dead-hand' of committee bureaucracy similar to that implied in the publication of the International Commission on Stratigraphy (ICS) (Cowie et al. 1986).

The main points at issue

The discussion by Gibbard and Turner relates to three main issues:

i) The retention of the stage name 'Wolstonian' for the inverval between the Hoxnian (s.s.) and the Ipswichian (s.s.) Stages.

ii) The nature of the stratigraphic sequence between the Hoxnian (s.s.) and the Ipswichian (s.s.) Stages.

iii) The importance of boundary stratotypes in the derivation of a stratigraphic scheme for the Quaternary.

These three points are taken in isolation for the purpose of preliminary discussion. However in reality, they are intimately linked, and it is only by considering them together that one can judge whether it is acceptable to:

i) maintain the term 'Wolstonian';

ii) introduce an alternative stage name now;

iii) postpone the introduction of a name for the interval between the Hoxnian and Ipswichian Stages.

At the end of this discussion I wish to maintain the recommendation I made in the original paper (p. 6), that "until further evidence is available ... this interval should be referred to as [that] 'occurring between the Hoxnian (s.s.) and the Ipswichian (s.s.) Stages'. Unfortunately this is at variance with the recommendation of Gibbard and Turner and clearly identifies a problem which is only likely to be solved by future experience and practice.

Discussion

i) The retention of the stage name 'Wolstonian' for the interval between the Hoxnian (s.s.) and the Ipswichian (s.s.) Stages.

In the sections on 'revision or redefinition of previously established units' and the role of 'priority' in the use of stratigraphic names, Hedberg (1976) recommends that "names of long standing and common usage may be preserved" (p. 20), and "priority in publication of a properly proposed, named, and defined unit should be respected" (p. 19). Although this refers to 'adequately established units' it clearly indicates that there is a procedural case for retaining the term 'Wolstonian'. However in both cases stress is placed on the need for flexibility and common sense so that the meaning and usefulness of a name is retained.

The criteria used to justify the selection of Wolston as the type site for the glacial stage following the Hoxnian temperate Stage are outlined in (Mitchell et al. 1973, p. 4). The critical evidence is identified at the sites of Nechells (Kelly 1964) and Quinton (at that time not described in detail) in the West Midlands. Both sites are reported as showing glaciogenic sediments above organic deposits with a pollen spectrum similar to that of the type Hoxnian, and both are considered to be beyond the limit of the Devensian Glaciation. However, the succession recorded at Nechells was not observed but inferred, and a full description of the succession at Quinton is still awaited (although the work is complete and a first draft written, A. Horton pers. comn.). The quality of the fossil evidence attributed to the Baginton-Lillington gravels has been placed in serious doubt (Sumbler 1983a, b). Most important, however, is the fact that there has been no detailed mapping or lithostratigraphic analysis of the deposits at and around Nechells and Quinton so that it is impossible to relate these sites with the glaciogenic deposits around Wolston. Thus, none of the criteria given in Mitchell et al. (1973) are valid. My observations simply provide a lithostratigraphic linkage with other parts of the British Pleistocene and this link clearly indicates that the deposits at Wolston do not follow the Hoxnian. In these circumstances any justification for retaining the term 'Wolstonian' must be other than geological.

When I first presented the findings of this research to the QRA at the Discussion Meeting in Leicester on January 6th 1987, Russell Coope, who was in the chair, suggested that precedence should be given to the term 'Wolstonian' because the deposits around Coventry which include those at Wolston were described before (Shotton 1953) those at Corton in East Anglia (Banham 1971, Pointon 1978). Although this is the case, reference in Shotton's 1953 paper is made to the Saalian of continental Europe and the name 'Wolstonian' was only proposed in 1969, at the same time as the term Anglian (Shotton and West 1969). Consequently it is hard to justify the retention of the name 'Wolstonian' on the basis of priority.

In these circumstances, and bearing in mind the need for common sense, it seems to me that although the name 'Wolston' can readily be retained in a lithostratigraphic sense (i.e. Wolston Clay), if the deposits at Wolston are of the same age or earlier than those at the stratotype for the Anglian Stage, then the retention of the name in a chronostratigraphic sense can only lead to confusion, and at the worst be misleading. Consequently I can see no basis for its retention as a stage name.

ii) The nature of the stratigraphic sequence in the interval between the Hoxnian (s.s.) and the Ipswichian (s.s.) Stages.

In many respects, this is a far more important problem that the semantics of stratigraphic nomenclature. It is now generally accepted that the stratigraphic sequence between the Hoxnian (s.s.) and the Ipswichian (s.s.) is more complicated than proposed in Mitchell et al. (1973) with evidence existing for at least one additional temperate stage, and at least one additional cold/glacial stage. This evidence is in accord with the Oxygen Isotope record from ocean cores (Shackleton 1987) and the details are reviewed in Shotton (1983), Shotton (1986) and Bowen et al. (1986). Additional evidence from East Anglia and continental Europe is also give by Gibbard and Turner.

The situation therefore exists whereby the stratigraphic requirement is no longer a single name for a single cold stage, but rather several names for several episodes, both warm and cold, each with the status of 'stage'. However, even this situation is complicated, because the various components of the jigsaw that constitutes the evidence for this stratigraphic interval cannot yet be related either temporally or geographically. For instance the river and lake deposits from the Thames valley and Midland England which provide evidence for an additional temperate stage (Briggs et al. 1985, Green et al. 1984), cannot yet be related to similar evidence from East Anglia (Gibbard & Turner 1988), and it is not yet possible to relate either of these bodies of evidence to the evidence for an additional glacial episode from northeast England, Midland England or South Wales (Bowen et al. 1986). It is not even possible to say whether the glacial deposits from these areas were formed during the same climatic episode!

Clearly these are problems that should be resolved with additional geological and geomorphological mapping, adequate and accurate site description (using all stratigraphic methods) and further developments with Amino-Acid, U-Series, ESR and TL geochronology. Therefore, although it is necessary that relevant formal stratigraphic names such as Welton Till or Stanton Harcourt Gravels should be introduced now, their climatostratigraphic/chronostratigraphic context is far from clear and it is my opinion that it would be premature to introduce a formal stage name until a more adequate body of stratigraphic information is available.

iii) Importance of boundary stratotypes in Quaternary stratigraphy.

Following the recommendations of Cowie et al. (1986) Gibbard and Turner have drawn attention to the importance of boundary stratotypes because they define precisely a particular stratigraphic subdivision, identify the base of a stratigraphic unit, and refer to a unique point in time (golden spike, Holland 1986). While this is clearly the case two points need to be stated. i) Logically, a boundary can only be defined after the units which it separates have been identified; therefore, a unit stratotype must be identified before a boundary stratotype, even if both are eventually formally defined at the same time. ii) The Quaternary has practical problems created by the types and wide range of stratigraphic information that are not typical of much of the rest of the geological column.

These problems can be illustrated clearly by the example of Marks Tey referred to by Gibbard and Turner. At this site, the junction between the sediment identified by pollen analysis to Hoxnian (Ho IVb) and sediment identified by pollen analysis to early Wolstonian (e Wo) records an acceptable stratigraphic boundary (Turner 1970). However, this cannot yet be formally defined as a boundary stratotype as it does not yet define the base of any British stratigraphic unit, unless this unit is to be defined at Marks Tey itself. It is certainly not possible on the basis of available evidence to relate this boundary to the unit defined by the sediments at Wolston, as apparently these are equivalent to the deposits which underly the Hoxnian sediments at Marks Tey!

As a cautionary note I would like to suggest that without an adequate, published biostratigraphic description of the upper temperate deposits from Hoxne, it is premature to make correlations with the Domnitzian interglacial of the continent.

Consequently, although I fully agree with Gibbard and Turner that more attention should be given to boundary stratotypes, I suggest that their introduction should only accompany or follow the identification of the stratigraphic units themselves. The relevance of this recommendation to the interval between the Hoxnian (s.s.) and Ipswichian (s.s.) stages can clearly be seen.

Recommendations

With the above discussion in mind I think it is now necessary to consider the point made by Gibbard and Turner that according to the International Commission on Stratigraphy (ICS) (precise reference not given) a "formally defined chronostratigraphic unit CANNOT .. be abolished UNLESS it is replaced by an alternative or unless the time represented can be shown not to have 'happened'". Looking at the three alternatives listed at the beginning of this note I would suggest the following.

i) Retention of the term 'Wolstonian' lacks general and geological common sense and can only be justified on strict procedural dogma, something that is certainly not advocated by Hedberg (1976) or Holland (1986, p. 8).

ii) With the current state of knowledge I do not believe that there is the basis for introduction of a new stage name (not even Marks Teyian!). It could be possible to suggest that the interval be called 'pre-Ipswichian' in the fashion of pre-Pastonian (West 1980), but in view of the general awareness of the nature of the evidence associated with this interval I do not think this name would be appropriate.

iii) In these circumstances I can only conclude with the recommendation that the interval concerned be defined by preceding and succeeding stages and, temporarily, be known as the 'interval between the Hoxnian (s.s.) and Ipswichian (s.s.) Stages'. This is certainly not satisfactory, but I do feel that it is a true reflection of the state of the subject, and will be readily abandoned as appropriate stratotypes are discovered.

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References

Banham, P.H. 1971. Pleistocene beds at Corton, Suffolk. Geol. Mag. 108, 281-285.

Bowen, D.Q., Rose, J., McCabe, A.M. & Sutherland D.G. 1986. Correlation of Quaternary Glaciation in England, Ireland, Scotland and Wales. Quat. Sci. Rev. 5, 299-340.

Briggs, D.J., Coope, G.R. & Gilbertson, D.D. 1985. The chronology and environmental framework of early man in the upper Thames valley. Brit. Arch. Ser. 137.

Cowie, J.W., Zeigler, W., Boucot, A.J., Bassett, M. & Remane, J. 1986. Guidelines and statutes of the International Commission on Stratigraphy (ICS). Cour. Forsch.- Inst. Senckenberg 83, 1-14.

Gibbard, P.L. & Turner, C. 1988. In defence of the Wolstonian Stage. Quat. Newsl. 54.

Green, C.P. et al. 1984. Evidence of two temperate episodes in late Pleistocene deposits at Marsworth, U.K. Nature 309, 778-781.

Hedberg, H.D. 1976. International Stratigraphic Guide. Wiley, New York.

Holland, C.H. 1986. Does the golden spike still glitter? J. Geol. Soc. 143, 3-21.

Kelly, M.R. 1964. The middle Pleistocene of north Birmingham. Phil. Trans. Roy. Soc. Lond. B 247, 533-592.

Mitchell, G.F., Penny, L.F., Shotton F.W. & West R.G. 1973. A correlation of Quaternary deposits in the British Isles Geol. Soc. Lond. Spec. Rep. 4, 99 pp.

Rose, J. 1987. Status of the Wolstonian Glaciation in the British Quaternary. Quat. Newsl. 53, 1-9.

Shackleton, N.J. 1987. Oxygen isotopes, ice volume and sea level. Quat. Sci. Rev. 6, 183-190.

Shotton, F.W. 1953. Pleistocene deposits in the area between Coventry, Rugby and Leamington and their bearing on the topographic development of the Midlands. Phil. Trans. Roy. Soc. Lond. B 237, 209-260.

Shotton, F.W. 1983. United Kingdom contribution to the International Geological Correlation Programme, Project 23, Quaternary Glaciations of the Northern Hemisphere. Quat. Newsl. 39, 19-25.

Shotton, F.W. 1986. Glaciations in the United Kingdom. Quat. Sci. Rev.5, 293-297.

Shotton, F.W. & West, R.G. 1969. Stratigraphic table of the British Quaternary. Appendix B1. In: George, T.N., et al. Recommendations on stratigraphical usage. Proc. Geol. Soc. Lond. 165, 155-157.

Sumbler, M.G. 1983a. A new look at the type Wolstonian glacial deposits of central England. Proc. Geol. Assoc. 94, 23-31.

Sumbler, M.G. 1983b. The type Wolstonian sequence - some further observations. Quat. Newsl. 40, 36-39.

Turner, C. 1970. The Middle Pleistocene deposits at Marks Tey, Essex. Phil. Trans. Roy. Soc. Lond. B 257, 373-440.

West, R.G. 1980. The pre-glacial Pleistocene of the Norfolk and Suffolk Coasts. C.U.P., Cambridge.

QN: conference reports

RECENT RESEARCH ON THE EUROPEAN PALAEOLITHIC

A report by the organiser on an international discussion seminar held at London University on 6 and 7 January 1988

Esmée Webb

A two-day meeting to discuss the current state of research into all aspects of the Palaeolithic in Europe from the earliest industries to the beginnings of the incipient domestication by people of their food supply was held on 6 and 7 January 1988 at Connaught Hall, University of London. It was attended by about 50 people, mostly staff and students of British and continental European Universities, but also including independent researchers and amateurs. Belgium, France, Hungary, Israel, Italy, the Netherlands, Poland and Portugal, as well as the United Kingdom, were represented.

A resume of the main themes, new ideas and conclusions to emerge from the meeting is given here. Fuller detail must await the final publication of the conference papers.

The first three papers discussed the effects of recent efforts to establish a chronological framework for the European Palaeolithic. Charles Turner (Milton Keynes) discussed the problems of attempting to correlate the available fragmentary terrestrial evidence with the deep sea oxygen isotope record arguing that the Holsteinian or 'great' interglacial can either be correlated with isotope stage 11 (420-370 ka), because that stage was the last time, prior to stage 5e, when ice volume equated with the present interglacial, or with stage 7 (230-190 ka) on the basis of the complexity of that stage. Both attributions cause problems for the interpretation of different classes of archaeological information, as

Esmée Webb (Perth) noted in her discussion of the chronology of late Middle and early Upper Pleistocene events suggested by radiometric datings. For example the date for the hominid fragment from Vértesszöllös (Simán personal communication) would suggest that it falls into stage 7, as would those from Arago, Bilzingsleben, Steinheim and Swanscombe, yet they represent rather different physical types (Stringer 1981). However, all these finds have been assigned by most authors an 'Holsteinian' age on bio- or litho-stratigraphic grounds. Clearly evidence for some of the interglacials recorded in the isotope record is missing on land. The problem of whether archaeological sites attributed to the Holsteinian/Hoxnian belong in stage 11 or later interglacials remains to be resolved. A consensus seems to be emerging amongst archaeologists that while it is still legitimate to use the terms 'Würm' and possibly 'Riss' to mean isotope stages 5d/4-2 and 6 respectively, the terms 'Mindel' and 'Günz' can only be used very loosely to mean 'sometime in the earlier Middle Pleistocene'. This will no doubt annoy Quaternary geologists but at least shows that archaeologists are at last becoming aware of the problems inherent in their terminology.

Paul Callow (Cambridge) reviewed the new ideas about the Lower Palaeolithoic of northwest Europe imposed on us by recently excavated sites. Such dates would suggest that typological criteria are useless as a guide to chronology in the Lower Palaeolithic. Geologists, please note! For example, the sophisticated Acheulean industry from Boxgrove, excavated by Mark Roberts, now seems to be generally accepted as being on the order of 400 ka and is probably the oldest Palaeolithic site in Britain. However, the industry also includes undoubted Clactonian cores and flakes which suggests first that Ohel (1977, 1979) may have been right after all, even if for the wrong reason, and second that the archaeological evidence from Clacton, Hoxne and Swanscombe should be reviewed. The Hoxne report is eagerly awaited (Wymer forthcoming). The transition between the Lower and Middle Palaeolithic now appears to be as confusing as the evidence provided by the earliest industries. Conventionally it used to be argued that the Upper Acheulean, made presumably by archaic Homo sapiens, disappeared at the end of the Riss glaciation, which can credibly be correlated with isotope stage 6 (160-120 ka), and was replaced by 'Würm I' times by Mousterian industries made by H. sapiens neanderthalensis. This cozy scheme will no longer work. In the first place evidence from sites like Pontnewydd suggests that Neandertals were alive and well in northwest Europe by about 200-150 ka. Moreover, those radiometric dates available from recently excavated sites such as Abri Vaufrey, Biache-Saint-Vaast and la Cotte be Saint Brelade suggest on chronometric and stratigraphic grounds that industries clearly attributable on typological and technological grounds to the Middle Palaeolithic were already established by stage 6 times.

The clearest message to emerge from these papers was that we cannot rely upon the typology of Palaeolithic artefacts to provide more than the haziest cultural chronology, that equally we cannot trust implicitly in the ages now being produced by radiometric techniques, many of which are still in their experimental stages, and that many problems still remain to be ironed out of the lithostratigraphy, both of Europe as whole and of archaeological sites in particular. At present one can select to cite only those ages which fit one's preconceptions because there is little objective possibility of assessing the validity of the few dates available. The way to solve our very serious chronological problems is not to throw every conceivable radiometric technique at any site in a desperate attempt to 'prove' it as old as the excavator believes, as was done at Petralona (Wintle & Jacobs 1982), nor is it to attempt to date the fragmentary remaining deposits at key archaeological sites, particularly if there is any doubt about the surviving stratigraphy,but to carry out planned dating programmes, in which the samples are selected by the scientists who will process them and using as many techniques as possible, on sites while they are in course of excavation. Only thus can a body of dates be built up, comparable to that based on radiocarbon now available for the Upper Palaeolithic and later periods, which will enable us to eliminate the oddballs.

No papers dealt exclusively with the Middle Palaeolithic sensu stricto which reflects, I think, current confusion over early Upper Pleistocene chronology and the models heretofore used to explain techno-typological variations in these industries. New interpretative approaches will be needed before the assemblages attributed to the period about 200-30 ka begin to be understood, but clearly there was some measure of cultural continuity and Acheulean industries overlapping the 'Mousterian' at its beginning while debate continues over the nature of the Middle to Upper Palaeolithic transition at its end.

Aspects of the Upper Palaeolithic were surveyed by four speakers. Francois Djindjian (Paris) discussed the origins of the Aurignacian which remain as obscure as ever. This is one of many problems which the Russians, had they been able to attend, might have helped to clarify. Based on the radiocarbon dates now available an Aurignacian chronocline, which is often linked to the invasion of Europe from the Middle East by H. sapiens sapiens, appears to spread westwards across Europe about 40-30 ka. However, according to the specialists (Bergman personal communication), the Levantine Aurignacian cannot be interpreted as the possible precursor to the European Aurignacian. In Italy, contrary to expectation, human occupation was not continuous. Margherita Mussi (Rome) presented evidence that the peninsula was abandoned for several millenia between its occupation by early Aurignacian people and its recolonisation in late Gravettian times. No satisfactory explanation for this hiatus has yet been proposed. Marcel Otte (Liège) suggested that northwestern Europe was abandoned at the height of the last glaciation, that the stylistically distinctive Solutrean 'leaf points' might have been an enforced response to consequent social crowding and that the Magdalenians spread north again before the late glacial climatic amelioration was well underway. Finally, Katalin Simán (Budapest) argued that the earlier Szeletian had techno-typological links with the central European Middle Palaeolithic with blattspitzen, but disappeared without trace about 35 ka, while the later Szeletian is linked to the Gravettian whose origins lie probably further to the east. Their papers clearly demonstrated that for much of the last glaciation parts of Europe were probably only marginally suitable for human occupation, certainly the archaeological record is patchy over most of central and northwest Europe during the Upper Palaeolithic. Given the amount of fieldwork that has now been carried out in these countries, these gaps in the cultural record are likely to represent real human absences.

The remaining five papers surveyed aspects of the human adaptive response to changing environmental conditions during the late glacial. In the Italian Alps Michele Lanziger (Ferrara) discussed Epi-Gravettian evidence for seasonal transhumance between lowland winter camps and high altitude summer camps. Zofia Sulgostowska (Warsaw) charted changing settlement patterns in the Dnestr-Vistula basin during the same period (12-10 ka) suggesting that the area was more densely occupied during the Younger Dryas than the Allerod period, the reverse of expectation. Human groups were by this time highly mobile, able to exploit a wide range of ecological conditions from temperate forest to tundra and capable of maintaining long-distance trading contacts, up to 600 km if the distribution of raw materials is any guide. Clive Bonsall (Edinburgh) argued on the basis of his excavations in the Inner Hebrides that people colonised Scotland before the Loch Lomond Readvance rather than after it as is usually assumed. Marek Zvelebil (Sheffield) presented a highly speculative paper suggesting that Late Palaeolithic hunter-gatherers, far from being 'noble savages' living in egalitarian social groups, were forced by deteriorating post-glacial environmental conditions into increasingly differentiated and hierarchical social structures. His thesis is difficult to substantiate but merits consideration. Finally, Nigel Goring-Morris (Jerusalem) argued that in the Levant the origins of sedentary human communities subsisting on domesticates lies in the preceding Epi-Palaeolithic period when fluctuating climatic conditions in this region caused hunter-gatherers living in marginal environments, into which they expanded under optimal conditions, to retreat from the periphery during the periods of ecological stress to optimal areas where they concentrated on collecting plant resources since the prevalent faunal resource, gazelle, was not amenable to domestication. These shifts of a growing population sufficiently disturbed the local ecological balance that by 10,000 BP Levantine hunter-gatherers were forced to cultivate their food supply.

The underlying themes to emerge from these papers were that artefact typology once an end in itself is now used merely as a means to the end of explaining past human behaviour. The determination of the processes by which stone tools were made, the extraction and distribution of the raw material on which they were made and the uses to which they were put are now of primary consideration. Typology alone has been demonstrated to be inherently unable to solve any of the chronological or socio-economic questions with which Palaeolithic archaeology is now concerned. Environmental data, both floral and faunal, have always played a larger part in stone age studies than the later archaeological periods, however the information they offer is now used with increasing sophistication in the creation of consciously structured models aimed at the interpretation of past economic systems, not just to provide a chronological framework. Archaeology is slowly coming to grips with the complexities of the Pleistocene seen from a foraminiferal perspective and beginning to be able to answer the complex questions concerning past socio-economic systems which it has always attempted to ask.

It is my intention to publish all the papers given at the meeting together with additional papers solicited both from those invited speakers who failed to attend and from additional researchers from both Eastern and Western Europe either known to me personally or recommended by those speakers who did attend. The resultant volume will provide a comprehensive up-to-date guide to current thinking by native researchers on problems in Palaeolithic Archaeology throughout Europe and should prove very useful to all those interested in this topic. A publisher is actively being sought for what is likely to prove a sizeable tome since it will comprise about 40 papers each up to 20 pages long. If anyone has any constructive suggestions, do please let me know. So far I have approached the Presses of the Universities of Chicago, Edinburgh and Sheffield since they all have well-established reputations for speedy, low cost but high quality publication in the archaeological field. It is hoped that the book will appear early in 1989.

Altogether, despite the absence of so many East European speakers, about ensuring whose attendance at future meetings I have learned a lot, the conference was, according to those who attended, a resounding success.

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References

Ohel, M.Y. 1977. On the Clactonian: re-examined, redefined and reinterpreted. Current Anthropology 18, 329-331.

Ohel, M.Y. 1979. The Clactonian: an independent complex or an integral part of the Acheulean. Current Antropology 20, 685-726.

Stringer, C.B. 1981. The dating of European Middle Pleistocene hominids and the existence of *Homo erectus* in Europe. Anthropologie (Brno) 19, 3-14.

Wintle, A.G. & Jacobs, J.A. 1982. A critical review of the dating evidence for Petralona cave. Journal of Archaeological Science 9, 39-47.

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CONFERENCE REPORT - GLACIAL FACIES MODELS

Toronto, Canada, 4th-8th May 1987. Geological Society of America Penrose Conference

Peter Worsley

Under the banner of a Penrose Conference, the Geological Society of America promotes specialised workshop-type meetings with the specific objective of generating creative discussion which will aid future research and encourage collaboration (Penrose was the principal G.S.A. benefactor). To facilitate this aim, there are guidelines laid down by the G.S.A. which the convenors of such meetings are obliged to conform to and these include a limit on the number of participants, restriction to those active in research related to the selected topic and a totally residential location.

The proposal for a conference to appraise the present understanding of glacial facies models and to seek an indication of future research directions appropriately came from Carolyn and Nick Eyles plus Andrew Miall, all at that time affiliated to the Department of Geology in the University of Toronto. Incidently all three graduated in Britain, respectively at the University of East Anglia (Environmental Sciences), University of Leicester (Geography) and Queen Mary College University of London (Geology). Followers of the recent sedimentological literature will be aware of the many contributions made by this Toronto based research group to the interpretation of glacial deposits in the geological record. Since the conference was solely a Canadian initiative, the sponsorship was widened beyond the G.S.A. to include the Geological Survey of Canada and the National Science and Engineering Research Council. Thus for five days early in May 1987 some 66 privileged participants (mainly from North America but augmented by a scattering from the other continents) were resident in the opulence of 'The Guild Inn' located directly on top of the classical Late Pleistocene Scarborough Bluffs succession bordering the shores of Lake Ontario in eastern Toronto. A total of some 38 talks was given and these were supplemented by 57 posters which were displayed throughout the meeting, and two field excursions. An exceptionally high involvement ratio ensured a lively discussion throughout.

Why, one might reasonably ask, should it be deemed apposite to have a meeting devoted to Glacial Facies Models at the present time: what might be achieved? The easy answer is to admit that facies modelling is a current bandwaggon topic in stratigraphy and hence no harm can be done by attempting a critical in depth analysis of its applicability or otherwise to Quaternary and earlier contexts. Perhaps the most convincing recent example of the value of utilising a facies analysis approach to a British Isles topic relates to the current reappraisal of the position of relative sea level during the withdrawal of the Late Devensian ice sheet from the Irish Sea Basin. In this case the evidence appears to be mounting in favour of high sea levels whilst the ice margin receded. This conclusion is at variance with the conventional wisdom and has arisen as a direct consequence of applying the facies analysis technique to sediments which had previously been interpreted as separate lithostratigraphical units rather than consanguineous associations.

The concept of facies is, of course, a long established idea in stratigraphy and its lineage can be traced back to a remarkable paper by the Swiss geologist A. Gressly who in 1883 first enunciated on the 'look' or 'aspect' of a rock. He suggested that a number of properties, which contribute to the total rock character, enable the recognition of a specific facies (derived from the latin _facia_) and this in turn led to the notion of the sediment of a given depositional environment having been influenced by the operative sedimentary and biological processes. Thus, in theory at least, the specific character of a sediment potentially leads to the identification of the depositional environment via an interpretative link which integrates process and product. At the practical level this means the classification of sediment into constituent facies on the basis of initial objective (observable) description.

Non sedimentologists may have been aware of the fashion within the last decade to adopt a coding procedure in the analysis of outcrop or borehole data - indeed this is evident in the contribution of Ian Selby to the last issue of the _Newsletter_. A facies model is an attempt to provide a generalised summary of a given depositional environment. The concept of generality is very important and facies models whether they be in the form of a vertical succession of sediments or a three dimensional diagram require a large observational data set embracing many case studies. A splendid recent work on this topic is that edited by Roger Walker (1984).

Although many of the individual contributions to the meeting tended to be site specific, the convenors valiantly tried to steer the discussion towards the more fundamental problem of the identification of the basic controls on sedimentation at the continental basin (mega) scale. It is clear that glacial depositional environments and, most importantly, glacial influenced sedimentation, particularly that associated with the marine environment, may result from other factors apart from simple climatic forcing. There is a tendency amongst Quaternary workers (and this reporter admits to being one) to automatically view environmental changes primarily in terms of climatic change rather than possibly arising from such mechanisms as tectonics, continental drift and changing patterns of oceanic circulation through various causes. The Quaternary does not have a monopoly of Ice Ages and many fascinating problems of glacial type facies interpretation confront those who are concentrating on the investigation of the earlier record. However, inevitably the Quaternary has to underpin as far as possible the analogues used in aiding the reconstruction of the more distant past. Quaternarists therefore have a responsibility to help pre-Quaternary workers and this Penrose Conference did much to bring together a wide spectrum of glacially orientated interests scattered across the geological record. The recognition of a commonality of approach and sharing of data will be one of the enduring memories of a thoroughly revitalising meeting. A new IGCP Project (260) on the 'Earth's Glacial Record' organised by Max Deynoux has just been launched (U.K. correspondent - Michael Hambrey at Cambridge) and will aim at integrating glacial facies to tectonic setting.

The prescribed summary of the recommendations for future work submitted to the G.S.A. will be available in Geology 15 (in press) and those interested in the details are referred to that source. It is pleasing to see that the cold non-glacial environments *per se*, such as those dominated by permafrost, are regarded as equally relevant to the facies approach and this is a timely warning that the current practice of totally separate research communities is unhealthy. A final thought concerns the future activities of the Q.R.A. If the association is serious in its constitutional aim of promoting research should it not be actively involved in promoting worksh ops of similar kind in order to lead research rather than to more passively facilitate it.

Reference

Walker, R.G. 1984. Facies Models (2nd ed.). 317 pp. Geoscience Canada Reprint Series, no. 1. Geol. Ass. of Canada, Toronto.

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LATE QUATERNARY ALLUVIAL FANS, DEBRIS CONES AND TALUS CONES IN THE GRAMPIAN HIGHLANDS, SCOTLAND

Vanessa Brazier

Ph.D. thesis, Department of Geography and Geology,
St. Andrews University, 1987

Alluvial fans, debris cones and rockfall talus cones are widespread in upland Britain, but remarkably little is known about their characteristics, development and significance. This research project has three main objectives:

1. to establish the morphological and surface sedimentary characteristics of alluvial fans, debris cones and talus cones in the Grampian Highlands of Scotland;

2. to identify the factors that have controlled their formation and distribution; and

3. to determine the timing, nature and rate of fan- and cone-forming processes.

On the basis of previous literature, an *a priori* model that describes a continuum of fan and cone morphological and surface sedimentary properties was devised. The applicability of this model was tested using data for six variables (long profile gradient, slope form, downslope changes in clast size, roundness and form, and a scale ratio of maximum clast size to total fan or cone length) obtained for fans and cones in the Grampian Highlands and the Lyngen Peninsula in Northern Norway. The results of these tests were then used to produce a modified model appropriate to fans and cones in upland Britain.

Using a combination of map, field and aerial photograph data, several environmental and morphometric controls on the distribution and type of fan and cone development were investigated. The dimensions of different types of fan and cone are shown to be determined by basin morphometry, lithology and glacial history. Discriminant analysis identified basin gradient, basin width and basin height as the principal catchment properties that influence the dominant type of fan- or cone-forming process.

Stratigraphic and radiocarbon evidence suggests that many debris cones are essentially paraglacial landforms that formed in the earlier part of the Flandrian. Many of these cones have subsequently been modified in the late Flandrian by fluvial processes, in some cases in response to anthropogenic interference. However, evidence from one site has also revealed that substantial debris cone aggradation has occurred since *c.* 300 BP, implying high rates of gully denudation in the recent past at this site. The volumes of other debris cones imply that as much as 1-3 m of surface lowering has occurred in gullies upslope since deglaciation.

Much lower values of surface lowering are associated with alluvial fan development, suggesting that, locally at least, denudation by fluvial processes has been less significant than denudation resulting from debris flow.

ASPECTS OF LATEGLACIAL AND POSTGLACIAL ENVIRONMENTS IN SOUTH-WEST WALES

A.P. Donald

Ph.D. Thesis, University of Wales (St. David's University College, Lampeter), 1987

The environmental history of south-west Wales during the Loch Lomond Stadial and Flandrian was investigated from peat and lacustrine sediments at five sites. Pollen analysis (including concentration techniques) was supplemented in the case of three sites by investigations of sediment chemistry, and five radiocarbon dates were obtained.

During the Loch Lomond Stadial, the flora contained certain arctic-alpine elements (e.g. Koenigia islandica, Saxifraga oppositifolia) that were probably close to their southern extent for that period. Stratigraphic evidence from a kettle-hole site demonstrates the prevalence of discontinuous permafrost conditions, and the erosion of skeletal soils is indicated by the sediment chemistry curves.

Discussion of the Flandrian environment is focussed on the main stages of vegetational succession up to the establishment of the mid-Flandrian forest. The end of the early Flandrian Juniperus phase cannot be explained by the conventional "shading out" mechanism in Pembrokeshire, although the normal pattern of succession by birch is found further inland. In Pembrokeshire a reversion to open habitat conditions may be related to a temporary climatic deterioration identified from recently published coleopteran curves. When Betula eventually arrived it had only a limited distribution on the west Pembrokeshire plateau, probably due to exposure.

No evidence was found for the previously postulated early arrival of Corylus in the south-west British Isles; instead a rapid, synchronous expansion at 9,000 BP is implied. Similarly there was no evidence for a particularly early arrival of Alnus in the area. Mixed alder-oak-elm forest became established in sheltered valley locations, but in the exposed west Pembrokeshire plateau elm was unable to compete.

THE FLANDRIAN VEGETATIONAL HISTORY AND ENVIRONMENTAL DEVELOPMENT OF THE BREDE AND PANNEL VALLEYS, EAST SUSSEX

M. Waller

Ph.D. Thesis, Polytechnic of North London, 1987

This study examines the Flandrian development, particularly the vegetational history, of two valleys in the East Sussex Weald, the Brede and Pannel. Lithostratigraphic surveys of these valleys and biostratigraphic investigations from a number of key sites, principally using the technique of pollen analysis, have been undertaken. Radiocarbon dates provide a chronological framework.

In the lower Brede valley pre-Flandrian colluvial deposits are overlain by estuarine sediments and a thin intermittent peat. Widespread peat formation began *c.* 6000 B.P., when alder fen woodland became established on the floodplain. Estuarine conditions returned after *c.* 1800 B.P. The sedimentary history of the Pannel appears to be similar, although the deposits at Pannel Bridge are unusual. Here 12.5 m of organic material has accumulated since the beginning of the Flandrian. Comparisons are made with other coastal localities in East Sussex in order to determine the importance of local, against regional processes, in the formation of these sequences.

At Pannel Bridge the pollen record extends back to 10000 B.P. when the vegetation was dominated by *Pinus*. Macrofossils remains of *Alnus glutinosa* were found indicating the presence of this species at the opening of the Flandrian. *Corylus* was the first of the deciduous taxa to expand (*c.* 9400 B.P.), followed by *Quercus* and *Ulmus* (*c.* 9000 B.P.). *Tilia* became an important component of the vegetation after *c.* 7000 B.P.

The nature of the mid-Flandrian forests has been examined in some detail in the Brede valley. At Old Place investigations were undertaken to elucidate the pattern of pollen distribution across the floodplain. Sites close to the valley sides contain particularly high frequencies of *Tilia* pollen, indicating *Tilia* was abundant in the adjacent slope woodland.

Limited interference by man on the vegetation may have occurred prior to, and accompanying the 'elm decline'. However, there is no evidence to suggest major episodes of forest clearance prior to the declines in *Tilia* dated to *c.* 3700 B.P.

This study highlights some of the problems in interpreting pollen assemblages from deposits of rich-fen origin.

QN: review

Quaternary Glaciations in the Northern Hemisphere: IGCP Project 24, Final Report. 1987. (Eds. V. Sibrava, D.Q. Bowen & G.M. Richmond). Quaternary Science Reviews 5, 522 pp. Oxford: Pergamon.

An undertaking of no small ambition, this, to seek to summarise existing knowledge of the timing, extent and correlation of Quaternary glaciations in the Northern Hemisphere; and further, to relate this sequence to the oxygen isotope record, some three decades after the discovery of the latter had so effectively demolished the widely adopted, seemingly successful, quadriglacial stratigraphy. So, has this project succeeded? and can the development of continental ice-sheets be firmly correlated with changing isotopic concentrations within foraminiferal skeletons?

A warning, first. This book is almost entirely stratigraphic, and its heart lies in the 19 large correlation charts that come with it. The accompanying chapters serve largely to discuss the stratigraphic relations depicted. There is little in them of mechanisms or environments of deposition; nor are interglacials discussed, except in so much as they help to define glacial episodes. By and large, this does not make for easy or exciting reading. This book is a reference work, and as such is valuable. But if you want to read an account of the development of successive Quaternary glaciations in the Northern Hemisphere, my advice is to find another book.

Those are overall limitations; now to the structure. The Northern Hemisphere is divided into five sectors (the USA; Canada; Mexico; Europe; Eurasia). Each of which is treated somewhat differently; within these sectors, smaller regions, defined by a mixture of political and geographic boundaries, serve as the units of description. Altogether, 42 of these smaller regions are described.

16 chapters - and a single chart only (shared with Eurasia) describe Europe. The coverage is reasonably comprehensive, though a mixed bag as regards format and clarity. Some chapters show signs of having been put together hurriedly, with scattered passages of near-impenetrable syntax and untranslated tables or diagrams betraying a minimalist school of editing here. Also, the correlations and stratigraphic units in the chart do not always match those in the chapters, a feature which may perplex the reader a little.

To start on the most familiar territory ... The continually vexing question of the Wolstonian has meant that Britain has two accounts of its stratigraphy. That by Shotton (pro-Wolstonian) is short, clear, but infuriatingly referenced. That by Bowen *et al.* (largely anti-) covers the ground in much more detail. British Quaternary stratigraphy is not yet cut, dried and set in concrete, of course, and most Quaternary workers will find a bone or two to pick here. Picking but one, evidence for a Baventian ice-sheet adjacent to Britain's shores is decidedly weaker than the authors indicate.

The overall stratigraphic agreement between Britain and northern Europe seems to be reasonable, in an impressionistic kind of way, at least as far back as the Elsterian. Not that correlation is trouble-free. The three-fold division of the Eemian over much of the continent may be echoed in the "two-Ipswichian" problem in Britain. But, the continental three-fold Holsteinian, and the intra-Elsterian stadial, have less obvious expression in Britain. The lack of direct dating is of course, the main problem, and here the Polish (and Siberian) thermoluminescence dates going back more than 500 000 years are intriguing. Intriguing, but not yet wholly believable, as elsewhere thermoluminescence dates in excess of 100000 years are not considered trustworthy.

If "north European" stratigraphy shows room for improvement, then Alpine-type stratigraphy seems to be in some disarray. The Penck & Brückner Gunz-Mindel-Riss-Würm system is dead, or so we are told by Sibrava in his summing-up. However, this nomenclature remains in use, with varying degrees of qualification, in several "Alpine-type" regions (e.g. the Auvergne, the Pyrenees, the northern Alpine foreland of Switzerland). A more modern, critical view is given in Billard & Orombelli's description of the Penck & Bruckner type area, the French and Italian piedmont of the Alps and, more clearly in Kohl's account of Austria. Thus, the four main moraines/terraces are physical realities. They do not necessarily, though, reflect glacial/interglacial cycles (the type Mindel and Riss terraces, for example, are not separated by a warm period, but by a phase of tectonically-induced downcutting of the Rhone). Climatic changes are more clearly expressed in the soil profiles that overlie the terraces. On the evidence of this volume, though, some time will elapse before this more sophisticated view of Alpine-type glaciation will be universally applied.

The loess sequences of Europe are, on the whole, disappointingly treated, especially considering that, although they are not glacial deposits *per se*, they reflect the sequence of glacial episodes more faithfully than nearly all ice-contact sequences. Loess sequences obtain better shrift in Eurasia, particularly in the illuminating description by Liu *et al*. of Central China. The question of the extent of Chinese glaciations, meanwhile, is debated between Yafung *et al*. (restricted ice) and Sun & Wu (widespread ice). Yafung *et al*. appear clear winners; not all diamictons are, after all, tills. Russian glacial stratigraphy is clearly, non-dogmatically outlined by Velichko & Faustova for the western USSR, and rather less clearly by Arkhipov *et al*. for Siberia. Somewhat confusingly, Lower, Middle and Upper Pleistocene do not mean in Russia what they mean elsewhere.

In Europe and Eurasia, it is clear that many of the individual correlations are very tentative. So, by integrating a number of more or less uncertain frameworks, do we get a grand correlatory plan that just compounds errors, producing a synthesis too internally flawed to be useful? Or are many of the uncertainties "ironed out" during synthesis, with weaker correlations being supported by, or at least not detracting from, stronger evidence from adjacent regions? In Europe and Eurasia, the "best fit" so produced depicts the sequence of glaciations reasonably well, but mostly is not reliably enough dated to be compared critically with the oceanic record.

In North America, it seems one can go further. Partly through a longer record of glaciation (commonly to 2 MA) and partly through the sheer good fortune of having datable Quaternary volcanics intercalated with the glacigenic sediments, at least some of the more important questions highlighted by this volume seem to have obtained credible answers.

The section on the USA is the most impressive - if not the easiest - in the book, showing a formidable level of organisation and thoroughness. The USA is divided into 15 regions, each of which gets a near-identical treatment. For each region there is a chart showing the correlation of glacial deposits between different parts of that region, together with evidence of age such as magnetic polarity and radiometric dates. From the charts it is easy to obtain an overall appraisal of the extent and timing of glaciation. From the accompanying chapters, unfortunately, it is not; the very exhaustiveness of the stratigraphical nitpicking amid a riot of local nomenclature is in itself a deterrance. With this qualification, it is in itself a deterrance. With this qualification, it is impossible not to admire the efforts that have been made to overhaul U.S. glacial stratigraphy. Many of the classic terms have been discarded, particularly those relating to older glaciations - Nebraskan, Aftonian etc. The Sangamon is now not regarded as a fossil interglacial soil (which is thoroughly time-transgressive) but a chronostratigraphic unit equivalent to the oxygen isotope stage 5e (in Canada, though, it is regarded as equivalent to the whole of stage 5 - a little standardisation may be in order here).

As to dating, the small glaciated, volcanic area of Yellowstone National Park stands supreme. At least 10 major glacial epsodes have been recognised, and dated by K/Ar and fission-track methods on interleaved tuffs and lavas. Neighbouring regions in the western USA also include volcanics within the glacial stratigraphy, though rarely to the same extent. One presumes that in comparable, non-volcanic areas similar glacial complexity is present, but has just not been recognised.

Areas such as Yellowstone provide the crucial evidence for Richmond & Fullerton, in two lucid and authoritative discussions of the US sequence, to compare the oceanic and continental records. They state unequivocally that there is a good correlation between the two for at least the last 10 glacial episodes. And, there are indications of a comparable correlation in earlier parts of the record; for example, an absence of glacial conditions between 1 MA and 1.5 MA is indicated both by the isotopic record, and by the lack of glacial deposits within that time bracket onland. The correlations only work using dates of the Brunhes/Matuyama magnetic reversal within the oceanic sequence that have been arrived at by calculations from orbital parameters. This date (788 ka) is a little older than estimates based on radiometric dating. Thus, the continental record, far from being too fragmentary to be useful, provides an apparent confirmation that changes in the earth's orbital parameters are the primary cause of climatic change (well-publicised television programmes about the climatic effects of volcanic eruptions notwithstanding). Yet more subtlety: the dating of Wisconsin (=Devensian) glaciations indicates that changes in orbital parameters, ice-sheet volume and oceanic isotope ratios are not synchronous. Rather, ice-sheet maxima seem to lag behind orbital maxima by some 1000-2000 years, and the corresponding change in oxygen isotope values does not appear in ocean waters until another 1000-3000 years have elapsed. These are conclusions of no small significance, and make for the most absorbing reading in the volume.

Quaternary Glaciations is a useful and important compilation, though uneven in style and freighted with an order of magnitude or two too much detail to give an easily assimilable view of its subject. A mine of information, but to be used selectively, and preferably where there is a lot of floor space on which to spread out the charts.

Lying behind this vast collation exercise appears to be the editors' wish to promote the use of the oceanic isotope stage system as a framework for continental Quaternary stratigraphy. It has been established that the two are related, and, particularly in the USA, some stratigraphic terminology is already defined on this basis. It is perhaps premature to go much further. In practice, most local stratigraphies will need to be much more reliably dated and correlated before attempts to assign an oxygen isotope stage number become anything other than an irrelevance. There may be a light at the end of the tunnel, but for some time yet it is likely to be coming from a lamp held by someone pointing up the brickwork.

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Keyworth.

QN: abstracts

ABSTRACTS OF PAPERS PRESENTED AT THE Q.R.A./M.S.G. MEETING IN KEYWORTH AND NOTTINGHAM, JANUARY 1988

SEDIMENTATION PATTERNS ON GLACIATED CONTINENTAL SHELVES - IMPLICATIONS FOR ONSHORE/OFFSHORE CORRELATIONS

Pleistocene glaciomarine deposits exposed along the British coastline provide important clues as to the nature of offshore facies and depositional sequences. Interpretation of these large depositional systems is only as good as current understanding of sedimentation pattern across glacially-influenced continental margins. The longest and most accessible record of offshore ice-distal glaciomarine sedimentation on continental shelves and slopes is preserved within the Yakataga Formation of Southern Alaska which is an excellent analog for facies sequences and their large scale geometries seen offshore on seismic traverses across the British continental shelf. Glaciomarine sedimentation in Alaska began in the late Miocene (6 Ma) and continues to the present, with a total aggregate thickness of over 5 km of shelf and slope facies exposed along coastal mountains. The formation records the deposition of glacially-derived mud and ice-rafted debris, forming blanket-like units of diamict, together with large-scale downslope resedimentation events. Changing relative sea-level, identified from foraminiferal biofacies, is a major control on sedimentation patterns. Low sea-level stands are recorded by erosion surfaces associated with boulder lags and coquinas; the extension of surging partially-floating ice masses to the shelf edge at times of lowered sea-level is recorded by striated boulder pavements.

In contrast, Pleistocene glaciomarine sequences exposed onshore in Britain, e.g. the margins of the Irish and North Sea basins, were deposited in more ice-proximal shallow water settings around retreating tidewater ice margins. High relative sea-levels appear to result from glacio-isostatic submergence at and beyond the periphery of the British ice sheet; sea-level, not climate, may have been the major control on ice sheet behaviour and sedimentation patterns across these basins. Ice proximal facies are dominated by sediment gravity flow deposits and subaqueous outwash reworked by marine currents and have commonly been glacitectonized. Distal glaciomarine deposits, beyond accepted ice limits, are mapped as belonging to older, more extensive glaciations (e.g. southwest England). Detailed facies studies of raised glaciomarine sequences in eastern Ireland and the recognition of correlative distal facies on offshire seismic profiles have enabled an event stratigraphy to be recognised, based on rapid sea-level change. The approach could be profitably applied and tested elsewhere around the British continental shelf.

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CALCAREOUS NANNOFOSSIL BIOCHRONOLOGY OF QUATERNARY SEDIMENTS FROM SOUTHERN BRITAIN AND THEIR INTEGRATION WITH THE DEEP SEA RECORD

Recent estuarine sediments from the coast of Southern England contain moderately diverse indigenous coccolith assemblages that are comparable with those found offshore in the Celtic Sea and English Channel. The behaviour of tidal basins as 'sinks' for marine silt was also probably common-place during interglacial periods, when sea-level standings were high. Investigations of interglacial deposits from the Steyne Wood Clay (Bembridge, Isle of Wight) and Boxgrove have shown that they are of comparable age. The occurrence of Pseudoemiliania lacunosa (extinction datum 0.45 Ma, - middle of oxygen isotope stage 12), coupled with positive magnetic polarity suggests deposition between 0.45 and 0.7 Ma. (i.e. probably within interglacial cycles 13, 15, or 17).

Calcareous nannofossil and planktonic foraminifera have also been used to date the St. Erth Beds, Cornwall (1.9 - 2.1 Ma). Warm-water assemblages indicate deposition from a subtropical water-mass (18-24 ^{o}C.) which bathed the Celtic coasts of northwest Europe.

Calcareous nannofossils are regarded as having outstanding potential as the biostratigraphic link between the oceanic and continental records.

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N.E.R.C. EXPERT GROUP REVIEW OF QUATERNARY SCIENCE

The following Report is reproduced in full because of its potential interest to many Q.R.A. members. It is published with permission of the Director of Earth Sciences of N.E.R.C.

Foreword to Quaternary Expert Group Review Report by Professor J.C. Briden

This is one of two expert reviews that I commissioned in 1987 to report on areas of earth science research which I was persuaded were not functioning in ideal fashion in the U.K.

It is the duty of the Natural Environment Research Council in the UK to do everything it can to optimise research in the environmental sciences for which it is responsible. It is not enough for the Council simply to receive proposals from university and polytechnic researchers and from Research Council Institutes, and then seek to deploy the money and resources at its disposal as best it can. To do so would run too great a risk that important gaps might develop and, specifically, that important new ideas might not be taken up and exploited as they should.

It would be foolhardy for the Council, whether the Council members or officers, to believe that it can generate all the best ideas itself. Council has long recognised this, and has attempted to secure academic, industrial and governmental participation in the process. The Directors of Science in NERC are extending these efforts. We are attempting to pick up ideas at an early stage from all these experts, acting invidually, in their learned societies and in the various committees on which they sit. Then, as part of our planning process, we take advice on which of these ideas to study further with a view to promoting new activity. At that early stage the eventual form of any new activity may not be clear; it could involve NERC investment, it might need us to change our practices, or it might be that we produce evidence that stimulates others to take up the case.

In 1987 two areas were identified for review, namely "Quaternary Science", and "Chemical and Physical Properties of Geological Materials". For each of them a small group of experts was assembled. The result in each case is a report which will serve in the first instance as a discussion document. This year both reports make recommendations for action some of which have been endorsed already by the Earth Sciences Committee of NERC for implementation as soon as possible. It may be that other aspects will be capable of support at a later date.

For the Review of Quaternary Science NERC is indebted to:

Professor D.Q. Bowen (Chairman), Royal Holloway and Bedford New College, University of London
Professor G.S. Boulton, Edinburgh University
Dr. N.G.T. Fannin, British Geological Survey, Edinburgh
Mr. J. Rose, Birkbeck College, University of London
Dr. N.J. Shackleton, Cambridge University
Dr. A. Street-Perrott, Oxford University
Professor R.G. West, Cambridge University

and to my NERC colleague Edmund Nickless who acted as Secretary to the group. I would like to extend my personal thanks to all of them for the time and thought that they devoted to the review over the summer of 1987.

For immediate action on this report, the Earth Sciences Committee has proposed to NERC Council a Special Topic Programme on one specific theme, namely "Palaeoclimate of the last Glacial/Interglacial Cycle", although at the time of writing I cannot be certain that it will be possible to fund this immediately.

More generally, the report is timely in two important respects. It will be drawn to the attention of the UGC in its process of restructuring University earth sciences, and also to the attention of the British Geological Survey at a time when the scope and programme of the future BGS are being developed with NERC, with commissioning departments, and beneficiaries of geological survey work.

In these various ways, and perhaps others too, we hope that this document will prove to be seminal to advances in UK Earth Sciences. It is published now for discussion, and I particularly invite comment from all interested parties. For example, does the evaluation of Quaternary Science fully and properly reflect the situation as you see it? Are there further recommendations which you would like to see added? If so, what are the arguments for and against?

It is vitally important that those with an interest in this matter realise that you have an opportunity to comment. I emphasise that 'interest' should extend well beyond those which are active in or benefit from the sector of science under review - because support for one area in some ways may influence or detract from support from other areas. Our goal should be to make the right new initiatives, to the right extent, against a clear background perspective of the earth sciences as a whole.

Professor J.C. Briden
Director of Earth Sciences,
NERC
November, 1987

NERC EXPERT GROUP REVIEW OF QUATERNARY SCIENCE

Contents

1. SUMMARY OF CONCLUSIONS

(a) NERC should include the Quaternary as part of its core programme.

(b) NERC should encourage the development of major collaborative programmes designed to address fundamental theoretical problems in Quaternary Science, which would help focus the efforts of the British community (sections 5 and 6).

(c) A series of strategic scientific objectives should be developed for the Quaternary of Britain and the adjacent continental shelves. These should be adopted as objectives by BGS who should play a major role in orchestrating the programme.

(d) Several other government scientific institutions should be involved in formulating objectives in Quaternary Science (viz. British Antarctic Survey; Institute of Oceanographic Sciences; Meteorological Office; Freshwater Biological Association).

(e) NERC should review the equipment provision for Quaternary Science to establish that an adequate range of analytical facilities are available and that access is assured.

(f) Multi-disciplinary centres of University Quaternary research should be maintained and improved. This point should be made strongly to the UGC in their current review of Earth Science.

(g) It is important that current British efforts in environmental modelling, and the data collection required to improve models, should be sustained and developed.

(h) International collaborative exercises to undertake some of the difficult and complex exercises of data collection and modelling should be strongly supported by NERC.

(i) Efforts should be made to develop teaching in Quaternary Science in British Universities, particularly in Geology Departments.

2. DEFINITION OF THE FIELD

There are special reasons why Quaternary Science should be distinguished from Mesozoic or Palaeozoic Science and make it appropriate for review:-

(a) The operation of the Earth's surface environment (physical, chemical, biological processes in the atmosphere, hydrosphere and cryosphere) requires a time dimension (a geological dimension) in order to understand time-dependent surface processes and their interactions. The ready availability of appropriate sequences, and the high-resolving power that available dating techniques afford, makes the geological record of late Tertiary and Quaternary time an ideal test-bed for such process studies. It is perhaps better to think in terms of studies of the late Cenozoic rather than of the Quaternary *per se*, and in this report, Quaternary Science is used merely as shorthand for the longer period.

(b) A study of recent geological time forms the necessary framework by which the modern Earth environment is best understood. Its deposits cover most of the surface on which we live and have the most immediate impact on human affairs. The Quaternary also provides the necessary evidence for the natural variability of the environmental system which must form a baseline for monitoring and understanding anthropogenic effects on the environment. There are also many applied-scientific objectives which require a projection into the future of the behaviour of the natural system. Such predictions are available either by extrapolating past trends into the future or by theoretical predictions tested against the evolution of the system in the past.

(c) Because of the ready availability of data which reflect the evolution of biological, meteorological, oceanographical, glaciological, geological, zoological, and chemical systems, the Quaternary is necessarily inter-disciplinary. It is best, therefore, defined by reference to its objectives (2a and b) rather than by any list of necessary components.

3. THE CURRENT INTERNATIONAL RESEARCH AGENDA

Much Quaternary research in the last decade falls into one of two categories; that which contributes at some level towards large scale international attempts to understand the operation of the Earth's environmental system (eg. CLIMAP; COHMAP; IGBP; and the Global Change Programme), and studies of particular processes for which the Quaternary forms a test bed.

(a) LARGE SCALE ENVIRONMENTAL CHANGE

In the 1970s it was demonstrated that the major environmental changes on Earth on a scale of 10^3-10^5 years were forced by predictable earth orbital variations modulated by interactions within the Earth's environmental system (hydrosphere-cryosphere -atmosphere). This theoretical development and the empirical base on which it rests has played the same unifying role in our understanding of the Earth's surface environment and its geological products as plate tectonic theory has for our understanding of Earth's structural evolution. The importance of establishing the processes which connect external forcing to the response of the environmental system has defined a structure and agenda for research (Fig. 1).

The overall objective is the development of full coupled models of the environmental system which will permit us to assess the processes connecting the response of the system both to changes in the external solar input, and to internal perturbations (level 6, Fig. 1). This is underpinned by:-

(i) A hierarchy of models (4-6, Fig. 1) requiring sound mathematical, physical, chemical and biological theory, and substantial computing resources.

(ii) Development of a chronological framework (2, Fig. 1) within which the temporal fluctuations of important environmental parameters can be determined (3, Fig. 1).

(iii) A strategic programme of fieldwork and sampling (1, Fig. 1).

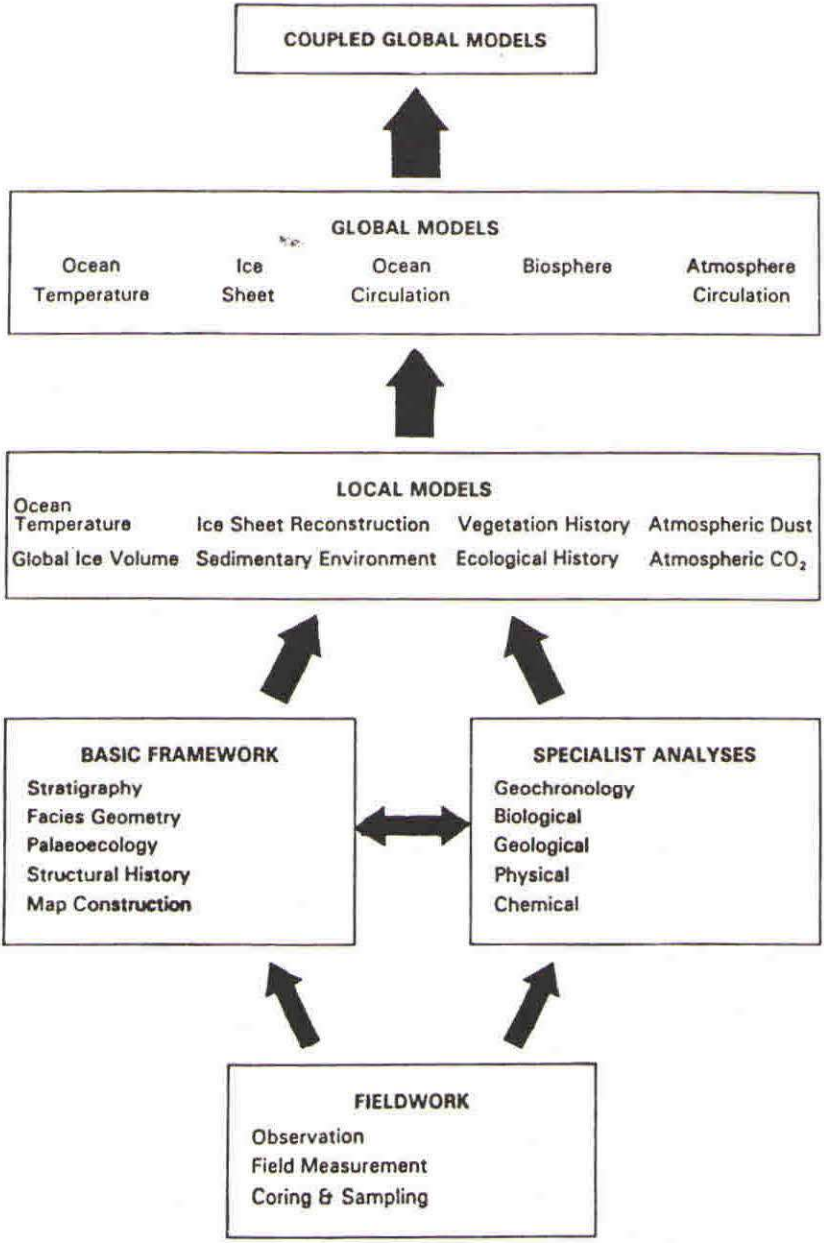
COUPLED GLOBAL MODELS
GLOBAL MODELS
Ocean Temperature
Ice Sheet
Ocean Circulation
Biosphere
Atmosphere Circulation
LOCAL MODELS
Ocean Temperature
Ice Sheet Reconstruction
Vegetation History
Atmospheric Dust
Global Ice Volume
Sedimentary Environment
Ecological History
Atmospheric CO_2
BASIC FRAMEWORK
Stratigraphy
Facies Geometry
Palaeoecology
Structural History
Map Construction
SPECIALIST ANALYSES
Geochronology
Biological
Geological
Physical
Chemical
FIELDWORK
Observation
Field Measurement
Coring & Sampling

Figure 1.

(b) PROCESS STUDIES

There have been particular advances in our knowledge of process and geological product in the following areas in which the Quaternary stratigraphic record has acted as a test bed:-

- Climatic change
- Palaeoceanography
- Ice sheet glaciology
- Chemical and isotopic cycling through the hydrosphere/cryosphere
- Sedimentary geochemistry
- Population dynamics of fauna and flora
- Process models of sedimentary systems
- Neotectonics

Although these studies are important in their own right, many contributed to the large scale effort illustrated in Figure 1 and involve the same logical structure (levels 1-4).

4. SIGNIFICANT RECENT DEVELOPMENT

We have classified these according to the level of the hierarchy (Fig. 1) to which they contribute:-

(a) LEVEL 1 - DATA COLLECTION

(i) Hydraulic Piston Corer.
(ii) High resolution digital seismic systems coupled with powerful seismic processing routines.
(iii) Automated sea floor mapping techniques.
(iv) High resolution satellite remote sensing appropriate to studies of geoid/ellipse changes (neotectonics), oceanographical, glaciological and meteorological phenomena; and increasingly efficient image analysis hardware and software for surface mapping.
(v) Correlation of acoustic and reflective properties of earth materials with other physical properties.

(b) LEVEL 2 - ELUCIDATION OF A TEMPORAL AND CORRELATIVE FRAMEWORK

(i) New geochronological tools: e.g. accelerator mass spectrometry 14-C techniques, T/L dating, ESR dating, 230-Th dating, amino acid epimerization, improvements in the palaeomagnetic record.
(ii) Seismic stratigraphy.

(c) LEVEL 3 - DATA ANALYSIS

(i) Extension of the 18-O ocean record back through time and recognition from this record that the amplitude of climatic response increases at 2.5 Ma and again between 0.9 and 0.6Ma, without any associated change in the pattern of external forcing.
(ii) CO_2 records from the oceans and ice sheets which demand a model of the carbon cycle and the role of CO_2 fluctuations in the system's response to orbital forcing.

(iii) Atmospheric dust record from ice sheets and oceans.
(iv) Elucidation of stratigraphic and facies sequences on continental margins from seismic and borehole data.
(v) Palaeohydrology inferred from changing lake levels.
(vi) Reconstructions of regional relative sea level changes and global eustatic changes.
(vii) Increasingly precise glacial geological evidence of past ice sheet fluctuation.

(d) LEVEL 4 - THEORY DEVELOPMENT AND LOCAL MODELS

(i) Numerical palaeoecology yielding quantitative proxy climatic and oceanographic reconstructions.
(ii) Chemical and mass flux theories which utilise the growing data set reflecting change in the ocean/ice sheet/atmosphere/terrestrial water system.
(iii) Role of deforming subglacial bed in glacier dynamics.

(e) LEVEL 5 - GLOBAL MODELS

(i) Initial development of ocean temperature models.
(ii) Time dependent, thermo-mechanically coupled ice sheet models.
(iii) Initial development of biosphere models.
(iv) High resolution general circulation models of the atmosphere.

(f) LEVEL 6

(i) Relatively simple, artificially coupled ice sheets/atmosphere models.
(ii) Ocean/atmosphere models in which only the superficial layers of the ocean are coupled.

5. ANTICIPATED DEVELOPMENTS

In the research agenda illustrated in Figure 1, we distinguish two major components, data-collection, analysis and interpretation (1-3) and the development of increasingly complex and general models (4-6):

(a) DATA-COLLECTION, ANALYSIS AND INTERPRETATION

(i) Highest possible time resolution in those parameters which reflect interactions of the global system in periods of rapid change:

response of the biosphere and its constitution
CO_2
18-O
sea level
ice sheet extent
hydrological balance as input to time-dependent models
(in particular periods of ice sheet build up and decay)
atmospheric dust balance.

(ii) Efforts to extend the range and improve the resolution of dating techniques (e.g. laser ionisation mass spectrometry).
(iii) Distinction between temperature and ice sheet effects in the deep oceans isotopic record.

(iv) Determination of global eustasy curve through the last glacial cycle.

(v) Dating large-scale tectonic uplift in relation to changes in climatic response.

(vi) Seismic mapping and deep-drilling to elucidate sedimentary sequences on continental shelves and slopes as a reflection of large-scale continental changes and of sea level change.

(vii) Hardware and software development to further resolve and map morphology and surface materials from satellite imagery.

(viii) Hardware and software to elucidate lithology from marine seismic reflection profiling.

(ix) Development of land seismic reflection profiling.

(b) THEORY AND MODELLING

The modelling objectives in Figure 1 are likely to set the major goals in Quaternary Sciene over the next few years. Most of the types of models in levels 4 and 5 already exist in different stages of sophistication. A considerable effort will continue to be made in improving the physical, chemical and biological basis of these models and their mathematical formulation. A major hurdle exists in making them properly time-dependent.

Few coupled models which pretend to any high degree of physical realism yet exist, but we have little doubt that these will be a major focus of research into the late 1990s.

Several specific current theoretical objectives are:-

(i) An explanation of the initiation and maintenance of the 100 ka global cycle established between 0.9 and 0.6 MA.

(ii) A theory explaining the fluctuation of atmospheric CO_2 during a glacial cycle.

6. THE UK EFFORT IN THE FIELD

British efforts in the Quaternary can be divided into two categories:-

(a) Stratigraphy, correlation and geomorphic history, leading to a generalised narrative of Quaternary events. This work is concentrated on the British mainland and the surrounding sea area, although some distinguished contributions have been and are made to research in polar and tropical areas.

(b) More highly focussed work concentrating on processes, the evolution of particular attributes of the environment through time, the development of palaeoenvironmental indicators and dating methods, and the development of theoretical models.

Areas in which Britain has a high international standing are of relatively highly focussed work by small groups:-

Palaeo-oceanography (in particular stable isotope work)
Ice sheet modelling and glacial sedimentation

Numerical palaeoecology based on palynology and Coleoptera
Palaeolimnology
Tropical palaeoenvironments
Secular palaeomagnetism
Mammalian evolution

Marine geological work on the UK continental shelf by BGS is of high quality and compares well with that of the best foreign groups, though it is rarely adequately exposed to an international audience.

The NERC radiocarbon laboratory also has a well established reputation.

It is particularly noticeable however that, in comparison with other developed countries, there is a lack of any nationally-defined strategic objectives which address the major agenda items illustrated by the upper part of the hierarchy in Figure 1. Elsewhere such objectives tend to be set:-

(i) by national research councils;
(ii) by consortia of scientists initiating major programmes through their research councils;
(iii) by national surveys.

We believe that it is important that British Quaternary scientists should be involved at all levels of the hierarchy shown in Figure 1, rather than merely the lower levels, and that attempts should be made to develop strategic programmes, based on our existing strengths, to achieve this. This would also have the advantage of entraining many Quaternary scientists currently involved in the important, though more routine, tasks of 5(a) many of which should fall within the remit of the Geological Survey, or at least be orchestrated by them, in more highly focussed scientific programmes.

The role of the British Geological Survey is particularly important. Its offshore division has been very effective, but the apparent absence of any strategy for the terrestrial Quaternary and the lack of application of modern concepts, successfully and usefully applied elsewhere, leaves us without good thematic Quaternary maps or as comprehensive a description of sedimentary sequences as should be available. Though BGS has the largest concentration of Quaternary workers in the UK it is weak in certain skill areas (e.g. some areas of palaeontology, recent sediments and soil mechanics). Their efforts are often highly diffused, and funded on a short term and insecure basis. The offshore effort is better co-ordinated but also has an insecure funding base. There is a great deal of scope within BGS for co-ordination and a better use of expertise and facilities if appropriate funding assurance can be provided. This is particularly important with the offshore effort where the existing unique combination of technical, operational and interpretative skills may be disbanded if 'science vote' underpinning of the work is not provided to ensure continuity. It would be little short of a tragedy if the personnel, equipment and methods developed by this unit over recent years did not continue to be deployed in addressing important scientific problems on the shelves and continental margins around Britain.

A considerable contrast with the Quaternary effort of most other countries is that the geological contribution to Quaternary Science in Britain is still relatively minor. It stems from its relative neglect in geology undergraduate courses. There is thus little enthusiasm for it amongst graduates, who are thus not drawn into Quaternary research; and consequently, there is little apparent need for academic geological posts in the field. Quaternary Science suffers from this, as does Geological Science, both on a scientific level and in failing to provide an adequate geological input to the developing fields of resource and environmental assessment. It is important that at least some University Geology departments take up this challenge. The current UGC Review of Earth Science could be an appropriate vehicle to encourage this trend.

7. DESIRABLE DEVELOPMENTS IN UK QUATERNARY SCIENCE

(a) ORGANISATION

There is a relatively large British Quaternary Science community, made up primarily of geographers and botanists, with a relatively smaller contribution by geologists, archaeologists, civil engineers, geophysicists and mathematicians. The range of available skills is such that, given a series of strategic objectives defined by collaborative initiatives between our more successful groups, we could anticipate a very substantial scientific return on investment and a substantial stimulus of the important scientific skills required by successful Quaternary science research.

We recommend two parallel routes by which this could be achieved:-

(i) Encourage the formulation of major collaborative programmes of research which would permit and stimulate UK scientists to address problems at all levels of the hierarchy shown in Figure 1. The benefits of such an approach can be seen in such NSF-sponsored programmes as CLIMAP, SPECMAP and COHMAP, and the French Climate Programme. At the highest levels of the hierarchy shown in Figure 1, such is the level of scientific skill required and the breadth of the information-gathering and analytical exercise, that international collaboration is required. It is important that NERC support such collaborative ventures, whether initiated here or abroad. The currently developing ESF programme to study changes in different parts of the environmental system at the last glacial/interglacial transition with high resolution dating, as the basis for developing time-dependent models, and the developing ESF Polar Science network may prove to be appropriate vehicles for major collaborative efforts by UK scientists.

(ii) The identification of a series of strategic scientific objectives for the Quaternary of Britain and the adjacent continental shelf. BGS should play a major role in this and could co-ordinate a national effort involving academic scientists. On the continental shelf, the data base acquired by the BGS continental shelf unit over recent years is an important scientific resource which could and should be exploited more effectively.

There are a number of other government scientific institutions whose collaboration in major Quaternary science programmes would help to achieve the ambitious objectives to which we believe we should aspire nationally:-

(i) British Antarctic Survey.
The Antarctic ice sheet and its surrounding oceans play an important role in the environmental system. The Quaternary history of the region should be an important BAS priority. BASs logistical organisation should be reviewed with the object of facilitating greater involvement of academic scientists in Antarctic research.

(ii) Institute of Oceanographic Sciences.
IOS should be encouraged to develop the Quaternary history of the oceans as a research priority. Their further involvement in temperature and circulation models of the ocean in the context of ocean/atmosphere/cryosphere interaction would be welcomed.

(iii) The Meteorological Office.
There is a substantial Meteorological Office effort in modelling modern climate, and some palaeoclimatic work has been done. The Met. Office should be encouraged to take a greater interest in modelling past climates. Their interests in atmospheric CO_2 and future climates would alone justify this. [The Meteorology Department at Reading University should also be approached in this regard].

(iv) Freshwater Biological Association.
There has been a very distinguished British contribution to palaeolimnology. Current reorganisation could adversely affect this. We should attempt to ensure that this capacity is sustained as many lakes retain a very high resolution record of environmental change and provide a detailed record essential in assessing the past terrestrial response and its extrapolation into the future.

There are some excellent individual facilities in Britain such as the Cambridge Stable Isotope Laboratory, Cambridge Thermoluminescence Laboratory, the NERC Radiocarbon Laboratory at East Kilbride, the Accelerator Carbon-14 Laboratory at Oxford, the Amino Acid Laboratory at Royal Holloway & Bedford New College. Techniques available at these laboratories should form a part of the basic tool-kit available to the community of scientists working on the Quaternary and Late Tertiary. They are analogous to many of the analytical tools that are widely available within British geology departments for the use of geochemists. A start has been made on multi-dating approaches and it is now desirable to formulate a strategy for general access to the several dating systems that are available. Access to accelerator mass spectrometry 14-C techniques is of very high priority.

The current UGC Earth Science Review may well lead to the development of centres which will help to focus the national effort in different areas of

Earth Science, to provide resource bases for other workers and to encourage collaboration. It is important that such centres of Quaternary Science effort should also develop. Substantial concentrations of Quaternary scientists now exist at Cambridge, Edinburgh, Royal Holloway & Bedford New College, Aberystwyth and Oxford.

(b) SCIENTIFIC OBJECTIVES

Within the scientific context set out in sections 2, 3 and 4, and with regard to those fields in which we have some international standing, major scientific objectives might be:-

(i) The development of a hydrosphere/atmosphere/cryosphere data gathering and modelling group to address itself to questions of the response of the system to orbital forcing.

(ii) Utilisation and development of the existing BGS data base from the continental shelf around Britain which could furnish a very important record of change on continental areas through the Quaternary.

(iii) The Quaternary evolution of continental margins, the outer shelf and upper and middle slope.

(iv) The history of the Antarctic ice sheet, particularly during the last glacial cycle, a major unknown jigsaw piece in our picture of global change.

(v) Further developments in quantitative palaeoecology.

(vi) The mapping of Quaternary geology on a very large, up to continental, scale from satellite imagery.

(vii) The development of a glacial, geological map of Britain and establishment of the pattern and tempo of the last deglaciation in Britain is long overdue. Such a project should be orchestrated by BGS in collaboration with appropriate academic groups and involving modern satellite imaging techniques.

(viii) High resolution reconstruction of the environmental system at periods of rapid change, particularly at glacial/interglacial and interglacial/glacial transitions.

(ix) The further development of high resolution dating methods, particularly those which extend beyond the range of 14-C methods, to cover at least the last glacial/interglacial cycle. It is also important that the bio- and lithostratigraphic basis, particularly for the Quaternary of Britain, should be continually improved. BGS should play a pivotal role in this.

Though we are clearly advocating some steering of the British Quaternary Science research effort, we stress that NERC should continue to support outstanding individuals who come forward with good proposals, wherever they come from.

8. ECONOMIC AND SOCIAL RELEVANCE

The materials of the Earth's surface play an important role in human economic and social activity and are predominantly products of Quaternary processes. There has thus been an increasing demand for those with knowledge of interdisciplinary Quaternary Science, particularly when allied to traditional disciplinary skills. The particular areas of economic and social relevance are:-

(a) Resources. Evaluation of natural resources such as sand and gravel are most efficiently carried out using sedimentary models produced by Quaternary Scientists, and evaluation of hydrogeological reservoirs and surface water regimes can depend heavily on their historical content.

(b) Site investigation for engineering works. Much civil engineering and engineering geology practice is concerned with Quaternary deposits and is or should be based on theoretical and empirical approaches developed by Quaternary scientists to their processes of emplacement, three-dimensional geometry and properties. Examples include slope stability; foundation problems; road, rail and pipeline routing, etc. (Six examples of major civil engineering failures in UK during the last 20 years are directly attributed by Professor J. Hutchinson of the Civil Engineering Department of Imperial College to a lack of appreciation of important features of Quaternary sediments. The cost of these failures alone is estimated at £50m. The overall cost of failures of this type in the UK is probably very much higher than this figure.)

(c) Natural background of environmental change. Establishing the effects of industrial and agricultural pollution in the environment is of great economic and social concern. Determination of the natural background of variability and its cause is thus of high priority (e.g. acid rain, CO_2, etc.).

(d) Pollution. Many pollutant pathways in the environment are best elucidated through study of the way in which pollutants are locked into sedimentary sequences (e.g. heavy metals in marine sediments, fertiliser products in Broad sediments, atmospheric pollutants in the ice cores).

(e) Future change. We are now aware that climate and environment are dynamic, and can change naturally on a very short timescale. The future of climate and associated environmental changes are of great importance (viz. ICSE Global Change Programme). It is an important aspect of the major current programmes in Europe (including the DoE) on the problems of waste disposal. It is critical in assessing many future economic and social trends, and in hazard assessment, even on a 10-year timescale. The theoretical and empirical base for future prediction comes from the extrapolation of past trends, and manipulation of interactive climate/environment models.

(f) Hazards. Assessment of hazards requires a Quaternary time dimension which provides a basis for the magnitude and frequency of hazardous events (storms, floods, tectonic hazards, etc.) and the natural trends which change these magnitudes and frequencies (e.g. sea level rise, changes in global climate circulation).

9. CONCLUSIONS AND RECOMMENDATIONS

(a) NERC should include the Quaternary as part of its core programme.

(b) NERC should encourage the development of major collaborative programmes designed to address fundamental theoretical problems in Quaternary Science, which would help focus the efforts of the British community (sections 5 and 6).

(c) A series of strategic scientific objectives should be developed for the Quaternary of Britain and the adjacent continental shelves. These should be adopted as objectives by BGS who should play a major role in orchestrating the programme.

(d) Several other government scientific institutions should be involved in formulating objectives in Quaternary Science (viz. British Antarctic Survey; Institute of Oceanographic Sciences; Meteorological Office; Freshwater Biological Association).

(e) NERC should review the equipment provision for Quaternary Science to establish that an adequate range of analytical facilities is available and that access is assured.

(f) Multi-disciplinary centres of University Quaternary Research should be maintained and improved. This point should be made strongly to the UGC in their current review of Earth Science.

(g) It is important that current British efforts in environmental modelling, and the data collection required to improve models, should be sustained and developed.

(h) International collaborative exercises to undertake some of the difficult and complex exercises of data collection and modelling should be strongly supported by NERC.

(i) Efforts should be made to develop teaching in Quaternary Science in British Universities, particularly in Geology Departments.

QN: notices

ANNOUNCEMENT OF NEW IGCP PROJECT: PROJECT 260 EARTH'S GLACIAL RECORD

This project aims to draw together the expertise of those interested in modern and ancient glacial processes, and their representation in the geological record.

A major objective is to relate glacial facies to tectonic setting. This is particularly relevant to understanding pre-Pleistocene sequences, but it is essential that recent developments in understanding glacial sedimentological processes, especially in the marine environment are incorporated. The project will also involve studies of palaeomagnetism and biology of glacial sediments, and will continue to chronicle the glacial record through time. The fundamental question to be answered by the project is "Why did glaciation happen?".

In order to gauge the degree of UK interest in this and related fields, readers are invited to submit a summary of their research to the National Correspondent (from whom further particulars may be obtained): Dr. Michael J. Hambrey, (IGCP-260), Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ. This information will be used to compile reports for the IGCP National Committee at the Royal Society and the IGCP-260 Project Leader, Dr. M. Deynoux (Strasbourg), in the hope that research in this field may be stimulated.

LECTURE ON LATEST RESULTS FROM BOXGROVE, WEST SUSSEX

Mark Roberts will give a Public Lecture on 'Latest results from the Middle Pleistocene site at Boxgrove, W. Sussex and its implications for Quaternary research' on Wednesday 9th March 1988 at 5.30 p.m. in the Lecture Theatre of the Institute of Archaeology, University of London, 31-34 Gordon Square, London WC1H OPY (telephone 01-387-7050).

THE NEOGENE OF THE KARAKORAM AND HIMALAYAS

A Conference will be held at the University of Leicester from 21st-23rd March 1988 to stimulate and interest those researchers working in the Neogene (including Quaternary) of the Karakoram, Himalayas and adjacent areas. Details are available from: Professor E. Derbyshire and Mr. L.A. Owen, (The Neogene of the Karakoram and Himalayas), Department of Geography, University of Leicester, Leicester LE1 7RH, U.K. (telephone 0533-523822).

OPEN DAYS AT THE BRITISH GEOLOGICAL SURVEY: MAY-OCTOBER 1988

For information on these events, described as 'splendid examples to the general public of geology in action' and as 'immensely valuable to the profession as a whole', please contact Dr. Brian J. Taylor at BGS, Keyworth (telephone 06077-6111 extension 3392). All are welcome.

OTTO-JAEKEL-SYMPOSIUM

A Symposium consisting of lectures and excursions in honour of Otto Jaekel (1863-1929) will be held at Greifswald, East Germany from 11th-14th May 1988. The programme considers various aspects of Mesozoic and Quaternary geology and palaeontology. Details from: Dr. R.-O. Niedermeyer, Ernst-Moritz-Arndt-Universitat Greifswald, Sektion Geologische Wissenschaften, JAEKEL-Symposium, Friedrich-Ludwig-Jahn-Strasse 17a, Greifswald 2200, German Democratic Republic.

AMERICAN QUATERNARY ASSOCIATION 10TH BIENNIAL CONFERENCE

The 10th Biennial Conference of AMQUA on 'Land-sea interactions in the North Atlantic Region between approximately 14,000 and 6,000 years ago' will be held at the University of Massachusetts, from 6th-8th June 1988, with excursions before and after. For further details contact: AMQUA Local Program Committee, Geology and Geography, University of Massachusetts, Amherst, Massachusetts, USA.

INQUA SHORELINES SUBCOMMISSION FOR NW. EUROPE

A Symposium and Field Excursion to Scotland will be held during 9th-15th September 1988. The Symposium will be held at Callander, Perthshire on 11th September and will consider 'Late Quaternary sea levels and crustal deformation'. For further details please contact: Dr. Alastair G. Dawson, Department of Geography, Coventry Polytechnic, Coventry CV1 5FB (telephone 0203-838556 or 0203-838565).

QUEBEC ASSOCIATION FOR QUATERNARY STUDIES (AQQUA)

The Sixth Congress of AQQUA will be held at Rimouski from 22nd-25th September 1988. The focus of the Congress is 'The Quaternary events in glaciated regions bordering on the North Atlantic Ocean'. Details from: Bernard Hetu, Departement des sciences humaines, Universite du Quebec à Rimouski, 300 avenue des Ursulines, Rimouski (Quebec), Canada G5L 3A1.

MARINE STUDIES GROUP OF THE GEOLOGICAL SOCIETY

A Meeting on 'Glacimarine Environments: Processes and Sediments' will be held at the Geological Society, Burlington House, Piccadilly, London on 16th-17th March 1989. The emphasis of this meeting will be on the controlling processes of glacimarine sedimentation. The meeting will be multidisciplinary in character. It is hoped to provide a forum for interchange of ideas and information between scientists working on contemporary glacimarine environments and geologists interpreting glacimarine sequences. The proceedings will be published as a Special Publication of the Society. All enquiries, including offers of papers and posters should be addressed to the convenors: Dr. J.D. Scourse, School of Ocean Sciences, University College of North Wales, MENAI BRIDGE, Gwynedd, LL59 5EY, U.K. (telephone 0248-351151 extensions 2872/6) <u>or</u> Dr. J.A. Dowdeswell, Department of Geography, University College of Wales, Llandinam Building, Penglais, ABERYSTWYTH, Dyfed, SY23 3DB, U.K. (telephone 0970-3111).

QUATERNARY ENGINEERING GEOLOGY

The 25th Annual Conference of the Engineering Group of the Geological Society is to be held at Heriot-Watt University, Edinburgh, from Sunday 10th to Thursday 14th September 1989. The Conference is to be held in association with the International Association of Engineering Geology and will cover all aspects of Engineering Geology relating to the Quaternary. For further information and details of the call for papers, contact: Dr. J.A. Little, Department of Civil Engineering, Heriot-Watt University, Riccarton, Edinburgh EH14 4AS, Scotland. (telephone 031-449-5111, extension 4413).

CALENDAR OF MEETINGS

(NOTE Q.R.A. Meetings are listed in the accompanying Circular)

9th March 1988	Lecture by Mark Roberts on 'Latest results from Boxgrove' at Institute of Archaeology, London (5.30 p.m.) (see notice above).
21st-23rd March 1988	Conference on The Neogene of the Karakoram and Himalayas, at University of Leicester (see notice above).
8th-11th April 1988	Symposium on the Geomorphology of Southern Africa, University of Transkei, Southern Africa (see Newsletter 50, p. 52)
11th-14th May 1988	Otto-Jaekel-Symposium at Greifswald, East Germany (see notice above).
13th-15th May 1988	Cave Archaeology Study Weekend at Creswell Crags, Nottinghamshire (see Newsletter 53, p. 42).
23rd-25th May 1988	Geological Association of Canada, Mineralogical Association of Canada, Canadian Association of Petroleum Geologists, Joint Meeting at St. John's, Newfoundland (see Newsletter 49, p. 48).
6th-8th June 1988	AMQUA 10th Biennial Conference, at Amherst, Massachusetts, U.S.A. (see notice above).
10th-15th July 1988	International Working Meeting on Soil Micromorphology, at San Antonio, Texas, U.S.A. (see Newsletter 51, p. 23).
9th-15th September 1988	INQUA Shorelines Subcommission for NW. Europe: Symposium and Field Excursion to Scotland (see notice above).
19th-23rd September 1988	International Symposium on Engineering Geology, at Athens, Greece (see Newsletter 51, p. 22).
22nd-25th September 1988	Quebec Association for Quaternary Studies, 6th Congress at Rimouski (see notice above).
2nd-6th October 1988	Field Meeting and Workshop on Glaciotectonics (WGGT/ INQUA) in Norfolk, U.K. (see Newsletter 53, p. 42).
16th-17th March 1989	Marine Studies Group of the Geological Society, meeting on Glacimarine Environments: Processes and Sediments, at Geological Society, London (see notice above).

9th-19th July 1989	28th International Geological Congress to be held at Washington, D.C., U.S.A. (see Newsletter 48, p. 44).
10th-14th September 1989	Geological Society/International Association of Engineering Geology Conference on "Quaternary Engineering Geology" at Heriot-Watt University, Edinburgh (see notice above).
25th-29th September 1989	Second Iberian Quaternary Meeting in Madrid, Spain (see Newsletter 53, p. 42).

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