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Quaternary Newsletters are issued in February, June and November. Closing dates for submission of copy for the relevant numbers are 1st February, 1st June and 1st November. Contributions, comprising reviews, notices of forthcoming meetings, news of personal and joint research projects, etc. are invited. They should be sent to the Secretary of the Quaternary Research Association, Dr. J.A. Catt, Pedology Department, Rothamsted Experimental Station, Harpenden, Herts., AL5 2JQ, England.

THE BRITISH GLACIAL-INTERGLACIAL SEQUENCE

Following the inclusion of Dr. A. J. Sutcliffe's article entitled "A Hazard in the Interpretation of Glacial-Interglacial Sequences" in Quaternary Newsletter No. 17 (November, 1975), the following note was received from Professor R. G. West:

Dr. Sutcliffe is quite right to comment on the hazards of interpretation of glacial/interglacial sequences. He asks what can be done to eliminate a situation which can lead to wildly different interpretations of the same sequences. The answer is more fieldwork and better knowledge of litho-stratigraphy and bio-stratigraphy. There is no necessity to follow any rigid scheme of stages or climatic phases. The reconstruction of local sequences should be followed by suggestions of correlations with stages already known. It is indeed likely that the "Geological Society's" sequence will prove in time to be simplified, but until good evidence is brought forward for the existence of stages not included in the "simple sequence", we can only refer to what stages are already firmly known. Thus the table put forward by the Geological Society in 1973 is explicitly "based on information supplied to the Quaternary Era Sub-committee up to January 1971 with some later additions". Let us hope that this table does not assume the rigidity which came to possess Penck and Bruckner's alpine terms.

In conclusion, may I ask Dr. Sutcliffe for the mammalian evidence that indicates the existence of stages not already identified ?

REPLY FROM ANTONY J. SUTCLIFFE

Professor West has asked me to state the mammalian evidence for the existence of more than one post-Hoxnian warm stages in the British Pleistocene. It is that there are too many distinct mammalian assemblages regarded as Ipswichian to include in one interglacial.

The idea that there may have been more than one post-Swanscombe warm period is not new. For example, Zeuner (1954) claimed two temperate phases, separated by a cool phase, which he equated with the Main (+18m) and Late (+7.5m) Monastirian high sea levels, both of which he included in the "Last Interglacial". This was based largely on sea level studies, though Zeuner did not overlook the mammalian evidence. Of special importance were his studies of the rich hippopotamus-bearing deposits at Brentford (supposedly Upper Flood-plain Terrace of the Thames), which he correlated with the Late Monastirian warm phase. However, at that time Zeuner did not have available to him the wealth of palaeobotanical evidence that we now have (e.g. Ilford and Trafalgar Square), and he was not able to relate his conclusions to this evidence. The palaeobotanical data that has become available in the last twenty years is a matter of enormous good fortune to those of us who are not palaeobotanists but are constantly looking for a stratigraphic yardstick to which our own specialised Pleistocene studies can be related. However, there is a growing tendency for workers in various fields outside palaeobotany to accept that the so-called Ipswichian represents a single climatic episode, and to make their own studies fit into this. As the mammalian evidence suggests that the Ipswichian is over-full, it seems timely to reconsider Zeuner's earlier conclusion that the Last Interglacial was not a simple event.

Before calling out for more interglacials or interstadials, we must first consider how many mammalian assemblages it is reasonable to fit into a single interglacial. The Ipswichian is divided palaeobotanically into four zones (Turner and West, 1968), which are: I. Birch and pine; II. Mixed oak forest; III. Oak, hornbeam and silver fir; IV. Pine and birch. A substantial temporal change of mammals, such as mammoths in zones I and IV and hippopotamus in zone II, would be expected and quite acceptable. Regional differences would also be likely; for example, conditions in south-west England would probably have favoured warmth-loving mammals more than those further north. However, the following comments are based only on observations in southern England and Wales, which is a small area with little room for any large geographic variation of fauna.

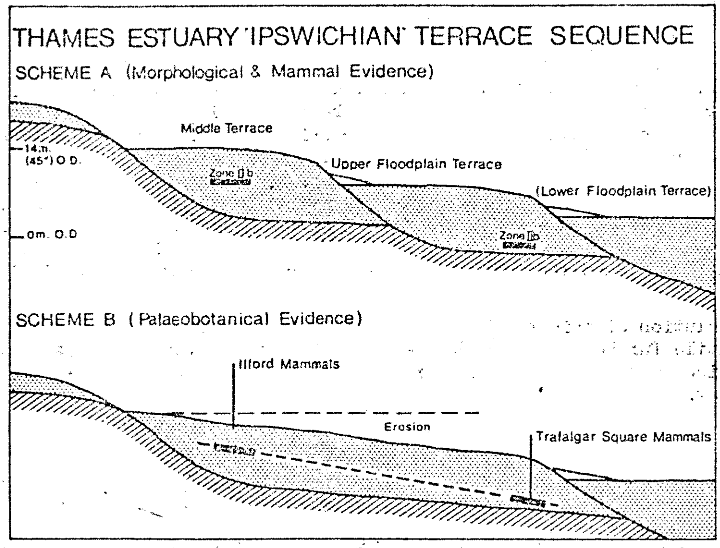
1. <u>The Thames Estuary: Ilford, Aveley and Trafalgar Square</u>

The most important area for studying Ipswichian mammalian faunas is probably the Thames Estuary, where commercial excavations for sand and gravel have revealed several sites with mammalian, plant, mollusc and insect remains associated together. In this area the main interglacial deposits are estuarine terraces, which have approximately horizontal aggradation surfaces and terminate abruptly at the heads of the contemporary estuaries. Zeuner identified two different terraces, which would now be regarded as Ipswichian; these were the one marked on geological maps as "Taplow" (a term best abandoned for the estuary, as Taplow is in the upper part of the river and is not estuarine - Middle or Ilford Terrace would be better), which he equated with the Main Monastirian sea-level, and the Upper Flood-plain Terrace, which he equated with the Late Monastirian sea-level. On altimetric grounds these two seemed to be quite distinct and different in age.

The subsequent discovery and study of plant remains from various localities in these terraces now allows Zeuner's interpretation to be re-appraised. Especially important sites with plant remains are Ilford (West, 1964), Aveley (West, 1969) and Trafalgar Square (Franks, 1960), which were assigned to the following Ipswichian pollen zones:

Pollen Zone			Flora	Ilford	Aveley	Trafalgar Square
LAST GLACIATION						
IPSWICHIAN INTERGLACIAL	h-i	IV	Pine, birch			
	g	III	Oak, hornbeam, silver fir		Mammoth ↑	
	f	IIb	Mixed oak forest		Straight tusked elephant ↕	
	e	IIa				
	d	Ib	Birch, pine			
	c	Ia				
"PENULTIMATE" GLACIATION						

To some of those who had studied the terraces and mammalian faunas of the Thames Estuary, these results were surprising. Ilford and Aveley seemed to be parts of a higher terrace (Taplow on geological maps), and Trafalgar Square part of a lower terrace (the Upper Flood-plain) which includes also Zeuner's



Brentford site. However, only one climatic fluctuation with the climatic optimum of Ipswichian zone IIb represented at all three sites, can be recognised from the pollen evidence. Was Zeuner wrong in attributing two phases to the Last Interglacial, the so-called "Taplow" and "Flood-plain" terraces of the Thames Estuary really being only one terrace, or are the floral remains from two separate terraces so similar that they cannot be distinguished on palaeobotanical evidence ? The two possible explanations are illustrated in the figure above.

At Trafalgar Square zone IIb contains remains of hippopotamus, straight-tusked elephant, a rhinoceros (probably Dicerorhinus hemitoechus), fallow deer, red deer, giant ox, bison, lion and other animals; no mammoth nor horse remains occur. This is a faunal assemblage which occurs commonly in British cave deposits in localities as widely spread as Joint Mitnor Cave, Devon (Sutcliffe, 1960) and Kirkdale Cave, Yorkshire. The Ilford-Aveley fauna is entirely different. At Ilford most of the elephant remains are of an early form of mammoth with affinities to the Middle Pleistocene Mammuthus trogontherii, though straight-tusked elephant is also present. Two species of rhinoceros are present, D. hemitoechus and D. kirchbergensis; the latter is also common in the preceding Hoxnian Interglacial. There is an abundance of horse, but both hippopotamus and fallow deer are absent. At Aveley, straight-tusked elephant in zone IIb is replaced by mammoth in zone III. The faunal assemblages of Aveley and Ilford on the one hand and of Trafalgar Square on the other are so different that it is difficult to believe they are contemporary, but it is possible they represent different parts of the same interglacial, or are different interglacials.

An explanation put forward to support only one temperate stage is that most of the Ilford mammalian remains were recovered over a century ago during excavations for brickearth, which were shallow and did not extend into the underlying gravels, which then had no commercial value. The organic deposit, described by West as zones I to IIb, underlies the brickearth, so it is possible that the Ilford mammalian fauna is later than zone II (perhaps zone III), and that the Trafalgar Square fauna might have been found in the basal part of the Ilford terrace had excavations there been carried deeper. This would suggest that the Ilford fauna represents a later stage than the Trafalgar Square fauna, but the Ilford mammoth is relatively primitive, so that an early date is more likely than a later one. Also, despite extensive commercial excavation of sand and gravel in the London area, a Trafalgar Square type fauna has never been found beneath an Ilford type fauna. A further difficulty with the single terrace interpretation is that the Upper Flood-plain Terrace is a good morphological feature.

The solution of this problem is clearly a matter of the greatest urgency, because little further progress can be made with Ipswichian stratigraphy until we can decide whether the "Taplow" and Upper Flood-plain Terraces are the same or different.

2. Tornewton Cave, Devon

The sequence of deposits excavated in Tornewton Cave (Sutcliffe and Zeuner, 1962) is very long and of great importance in Ipswichian studies. The main deposits were:

iv. "Diluvium" - Holocene molluscan remains indicate a post-glacial age.

iii. Reindeer Stratum - This deposit produced a few worked flints of Upper Palaeolithic type, a human incisor and remains of hyaena, wolf, fox, stoat, brown bear, horse, woolly rhinoceros, bovid, mole and hare. Reindeer suggests a cold stage interpreted as Devensian.

ii. Hyaena Stratum - Mammals represented include hippopotamus, fallow deer, red deer, hyaena, wolf, fox, cave lion, brown bear, narrow-nosed rhinoceros (Dicerorhinus hemitoechus), bovid and hare. This fauna, which represents an accumulation in a hyaena den, is similar to that of the interglacial Upper Flood-plain Terrace of the Thames.

i. Glutton Stratum - This deposit is an accumulation in a bear den. Mammals represented are brown bear, wolf, fox, cave lion, wolverine, horse, rhinoceros, reindeer, bovid and clawless otter (a new record for Britain). Reindeer and wolverine suggest cold climatic conditions.

This series is interpreted as representing a series of climatic fluctuations from cold to interglacial to cold to Holocene, during which time the cave had been used successively as a bear den, a hyaena den and a site of human activity. The cave is of special importance as it is the only British locality where an Ipswichian Interglacial deposit can be directly observed lying between deposits of two cold periods. Nothing identifiable as the Ilford fauna was found between the Hyaena Stratum and the Reindeer Stratum, yet this would be expected is the Ilford deposits are younger than those of Trafalgar Square.

Initially the mammalian faunas of the two cold horizons seem indistinguishable and they could be confused in isolation. However, the rodent faunas, which have been studied by Kowalski (Kowalski, 1967; Sutcliffe and Kowalski, 1976), are distinctly different. The lower cold deposit is characterised by Cricetus cricetus (hamster), cf. Allocricetus bursae, Lagurus lagurus (steppe lemming - another new record for the Upper Pleistocene of Britain) and Microtus nivalis (snow vole). All of these are absent from the upper cold deposit, where they are replaced by large quantities of Microtus gregalis (narrow skulled vole). This key for distinguishing faunas antedating and postdating the intervening hippopotamus stage is of great stratigraphic significance. Another site where Microtus nivalis occurs in deposits older than the hippopotamus stage is Water Hall Farm Gravel Pit near Hertford.

3. Crayford, Kent

The terrace deposits at Crayford and Erith near the south shore of the Thames are generally considered to be Ipswichian, though this has not been demonstrated on palaeobotanical grounds. There are two main deposits - mammaliferous gravels and brickearths, with at least one included land surface rising to a height intermediate between the Ilford and Trafalgar Square terrace levels. A Levallois industry regarded as interglacial is associated with the land surface, and the succession is capped by sludge deposits (Kennard, 1944). The mammalian fauna does not correspond with either Ilford or Trafalgar Square. The land and fresh-water molluscs are believed to indicate conditions warmer than the present, but the predominant rhinoceros is the woolly rhinoceros, and Dicerorhinus is rare. There is an abundance of horse (reminiscent of Ilford), and other animals include wolf, fox, brown bear, lion, ox and bison, red deer, giant deer, abundant mammoth, rare straight-tusked elephant, rare musk ox and rodents. The rodent fauna includes Microtus nivalis and Kowalski has shown that its closest affinities are with the pre-hippopotamus Glutton Stratum of Tornewton Cave, and not with the Devensian levels of that site. Gromov, who studied the ground squirrel remains from Crayford found that they belong to the earlier Spermophilus (Urocitellus) primigenius and not to S. (Colobotis) superciliosus, which is the Devensian form found at sites such as Ightham. There are some other peculiar features of the Crayford fauna. The wolf is quite small (the Hoxnian wolf was even smaller) and was described by Freudenberg (1914) as Canis neschersensis. Kennard claimed that the musk ox is not the present day form, but a new species which he named Ovibos spurrelli.

I do not argue that the last two names should be retained, but the entire Crayford assemblage seems very strange, and needs much more study. It is difficult to accept that it represents the end of the Ipswichian, as has so often been suggested, and it seems more logical to regard it as antedating the hippopotamus warm stage, probably slightly older than the Tornewton Glutton Stratum. The warm aspect of Crayford and the cold aspect of the Glutton Stratum at least indicate that these two deposits are not exactly contemporaneous.

4. Other Cave Deposits

The apparently horse-less hippopotamus - D. hemitoechus fauna of the Upper Floodplain Terrace of the Thames and the Hyaena Stratum at Tornewton Cave also occurs commonly in other British caves, such as Joint Mitnor Cave and Eastern Torrs Quarry Cave, Devon, Milton Hill and Durdham Down Caves, Somerset, Victoria Cave, Raygill Fissure and Kirkdale Cave in Yorkshire. All the evidence suggests that these hippopotamus deposits are quite late. That in Eastern Torrs Cave, for example, is a cave stream deposit interbedded with stalagmite layers little above the level of the present day R. Yealm, indicating little valley down-cutting since its deposition. Although these hippopotamus-bearing deposits are so common, faunal remains resembling those of Ilford are quite rare, the only example known to me being at Hutton Cave, Somerset. As caves are quickly destroyed by normal processes of erosion, Devensian or Holocene deposits are much more common than earlier ones, and the rarity of anything resembling Ilford in caves suggests that deposits of that period have been subject to more denudation than the more recent hippopotamus-bearing deposits.

5. The Old Sea Caves of Gower, South Wales

The sea caves of the Gower coast contain deposits with Ipswichian mammalian remains which have an important bearing on problems in the Thames Estuary. If the Ilford and Upper Flood-plain deposits are part of the same terrace (the height of which would have been controlled by sea-level in the estuary), then one would expect to find evidence somewhere of a substantial rise of sea-level in post-hippopotamus times; but if the Upper Flood-plain Terrace is later, one would expect only a final falling away of sea-level at the end of the Ipswichian.

The Gower sea caves offer great scope for studying this problem, as raised beach and ossiferous deposits are closely associated in them; their importance was recognised by Falconer (in Murchison, 1868) and George (1932). Since 1962, Professor C. Kidson, Dr. D.Q. Bowen, Dr. C. Stringer and I have investigated three of these sites, Minchin Hole (Sutcliffe and Bowen, 1973), Bacon Hole (Stringer, 1975) and Ravenscliff Cave. The interglacial mammalian remains from Bacon Hole comprise a better assemblage than those from Minchin Hole, where the raised beach sequence is so interesting. In general the interglacial mammalian fauna (based partly on Falconer's report and partly on recent discoveries) is similar to that of Trafalgar Square and the Hyaena Stratum in Tornewton Cave. There is an abundance of D. hemitoechus and straight-tusked elephant, and horse is missing from a large part of the sequence. There are differences, however; fallow deer has not yet been recorded, and hippopotamus was found only in Ravenscliff Cave by Falconer. Perhaps the latter difference can be explained by the proximity of Ravenscliff Cave to Three Cliffs Bay, where at the present day there is a meandering river which looks ideal for hippopotamus, whereas the other two caves are in high cliffs away from rivers.

An important feature of Ravenscliff Cave is its low situation. A two-metre rise of sea-level would allow storm waves to remove all deposits from the cave, yet Pleistocene deposits with remains of hippopotamus have been able to survive there until the present. This suggests that no great rise of sea-level occurred along the Gower coast after deposition of the interglacial deposits, so that a later rather than an earlier date is indicated for them. The horse-less stage may have been quite short, because Dr. Stringer has found remains of this animal in the basal deposits at Bacon Hole below the main interglacial horizon, which is without horse, and they have also been found in the upper remaining levels of Minchin Hole.

Conclusions

Mammalian and morphological evidence suggests that the earliest of the various sites attributed to the Ipswichian on palaeobotanical evidence is Ilford; this is characterised by a primitive mammoth and both species of Dicerorhinus. It was probably followed in time by Crayford, which is the most recent site with D. kirchbergensis, then by the Tornewton Cave Glutton Stratum cold period, then by a stage with abundant hippopotamus but no horse, and finally by Devensian and later deposits. If this sequence is ever proved, it will create problems in British Pleistocene studies, as it implies that floras of Ipswichian character occur at at least two distinct horizons within the sequence, represented first by Ilford and subsequently by Trafalgar Square. Sites I should like to include with Ilford are Aveley, Brunden, Stutton and possibly Lexden, which has a very primitive mammoth. Several of these sites and also Crayford have well-developed Levallois industries, suggesting that part of the Levallois, at least, is pre-hippopotamus.

As Dr. West points out, much more fieldwork needs to be done.

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WILLIAM PENGELLY CAVE STUDIES TRUST LTD.

Preliminary arrangements are in hand for extending the Pengelly Trust's London programme to include periodic one-day symposia. The first of these, on "Cave Studies in south-east England" will probably be in October; the second, on "The study of deposits with palaeontological and archaeological remains in old sea caves" will probably be in November, 1977. Further details of both meetings will be issued later.

SOME COMMENTS ON THE HISTORY OF THE ENGLISH CHANNEL

By C. Kidson and D.Q. Bowen

In recognising former widespread glaciation in southern England and the English Channel, Kellaway et al. (1975) have raised fundamental issues of interpretation of both sediments and morphology. In our view all the facts adduced in favour of glaciation are capable of alternative interpretation. Though they may seem to have some substance collectively, all can be dismissed when examined individually, for deposits may be ambiguous indicators of process and different processes may produce similar landforms.

Deposits

Various sized clasts, including large boulders, foreign to an area are not invariably indicators of former glaciation. The majority of deposits in which they lie in southern England are coastal, and their occurrence is related mainly to wave and tidal action. Not all the erracics are far-travelled. Of those at Selsey, Clement Reid (1892) commented "the first thing that strikes me from the list is the preponderance of erratics from known localities not more than 20 miles from Selsey"; of thirty-three described, only three were not local. Many are sarsens, up to 2.4 x 0.6 x 0.6 m in size (Prestwich, 1892), which are derived from Tertiary outcrops. Similarly, of the erratics from Chesil Beach, "all the types of rock identified can be correlated with sites in the south-west of England" (Carr and Blackley, 1969). Many come from the Triassic Quartzite at Budleigh Salterton, others from the Dawlish Breccia (Baden-Powell, 1930). Although Kellaway et al. quote Arkell's (1947) data on the Chesil erratics, they fail to point out that he believed "ordinary processes of shore migration by wave action are capable of introducing all the Permo-Triassic pebbles", and that barrier-like headlands such as Beer Head do not represent insuperable obstacles, as "they are but transient details of a coastline which is always changing as it retreats before the sea". Other material such as the flints prominent in Atlantic Cornish beaches, or at Slapton in Devon, is nearly always of durable lithology, and is long-term residual debris, reworked time and again during Cenozoic transgressions and regressions.

Characteristically, the undoubted 'giant erratics' on the south coast of England occur along or just above the shore. They are thus more realistically accounted for by floating rather than glacier ice - a process still operative in high latitudes (e.g. off Newfoundland, hundreds of kilometres south of the parent ice mass). An English Channel glacier would have left evidence of a more widespread trespass on adjacent land areas. Reid commented that "no sign of furrows ploughed into the (Bracklesham) clay at Selsey occur", and "the conclusion seemed irresistible that they (the erratic blocks and their associated pits) afforded clear evidence of the agency of floating ice". The complete absence of foreign material above the highest raised beaches is, in our opinion, conclusive support for the views of Reid and Prestwich. However, we recognise that there are still residual problems relating to the emplacement of the genuine far-travelled 'giant erratics'.

Much far-travelled material not found in beaches has been introduced as ballast or as material from offshore wrecks; in East Anglia, for example, sunken colliers provide cobbles of coal on the beaches. Along the English Channel large amounts of granite, Portland and Purbeck stone were transported, not all successfully, for the rebuilding of London after the Great Fire. Also, stone quarried at Caen and elsewhere in Normandy and Britanny was transported for the building of hundreds of Norman churches and cathedrals in England. It was with good reason that Reid (1892) wrote: "There has always been some uncertainty as to which of the far-transported blocks found on the Sussex coast were genuine erratics, and which had been brought in ballast, or had been derived from wrecks".

We believe that the Slindon raised beach, reinterpreted by Kellaway et al. as fluvio-glacial, has been used as circumstantial evidence for glaciation in exactly the same way and with as little justification as were the Burtle Beds of Somerset (Kellaway, 1971) prior to demonstration of their marine origin by Kidson et al. (1974). We see no good reason for rejecting the conclusions of at least seven distinguished workers on the gravel terraces of the Hampshire basin, that these are fluviatile and derived from a superabundant local source. Any fluvio-glacial interpretation rests on the supposed ice margin at Selsey and the notional Lake Solent; there is evidence for neither. We also reject as unsatisfactory evidence "foreign" stones incorporated into walls, stones reputed to have existed, and calcareous fragments which might have been used in agricultural practice. None of the evidence based on deposits affords proof of former glaciation.

Geomorphology

To infer process from form alone is a notorious source of potential error well known to any geomorphologist. Yet all the morphological features Kellaway et al. adduce in support of glaciation lack supporting data from sediments. In fact, the landforms are, in our opinion, more readily attributed to marine erosion and tidal scour, or to open channel subaerial erosion at times of low sea-level.

Submerged cliff-lines are conventionally accepted as marine features (Donovan and Stride, 1975); indeed, it is difficult to see how they assist any concept of glaciation unless identified as slopes against which alleged ice margins lay. However, there is no evidence for reconstructed ice margins such as those shown by Kellaway et al. (Fig. 3); they are purely conjectural, and as such it is unfortunate that they convey an impression of accuracy on a map, particularly for those not immediately familiar with the area or the literature on it.

Fosses or deeps indicate neither glacial nor fluvio-glacial erosion. In the case of the Hurd Deep, a process of tidal scour has been suggested as the formative mechanism (Hamilton and Smith, 1972). There can be no doubt of the efficacy of such a process, for Donovan (1973) cites examples of tidal scour fashioning deep basins (up to 11km wide and 417m deep) in the Far East, Caribbean, and off West Africa and India. Linear depressions on the sea floor are cited by Kellaway et al. as subglacial tunnel valleys, despite a basic dissimilarity to the Danish tunnel valleys and other subglacial channels, for example in Scotland (Sissons, 1963). Some merely continue on-shore streams, and lead into deeps. However, others have 'closed' ends or reversed profiles, though these features do not prove sub-glacial stream erosion, because open channel stream erosion can fashion rock basins (Schumm and Shepherd, 1973). Nor do they discount possible effects of tidal scour. With large supplies of meltwater from deglaciation of the North and Irish seas available to the English Channel, including overspill from proglacial lakes (Woldstedt, 1965), it is profitable to draw an analogy with the channelled scablands of Washington (Bretz, 1969). These valleys with basins up to 60m deep were fashioned by open channel flow from proglacial lakes. Similarly at Wissant north-west France) gravels have been attributed to a similar origin, involving catastrophic flooding in the manner of Bretz's model (Roep et al., 1975).

Enough illustration of the dangers of inferring process from form have been presented, and it will be readily apparent that the areas of "low relief" similarly presented by Kellaway et al. in support of their views cannot conceivably be regarded as indicators of glacial erosion.

All the facts adduced in favour of glaciation are therefore capable of alternative interpretation. None of them is an unequivocal glacial indicator, and in this sense there is no evidence for glaciation. Above all, the complete absence of stratigraphical evidence must negate all the expectations of Kellaway et al. The chronological elaboration of the data in which they indulge only distorts their interpretation further. As for Lamb's suggestion (in discussion of Kellaway et al., 1975) that there was a "glaciation in the English Channel area also in the last glaciation", well . . . really . . !!

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THE IGCP PROJECT ON SEA-LEVEL MOVEMENTS DURING THE LAST 15,000 YEARS

By M. J. Tooley

In 1974 the board of the International Geological Correlation Programme (IGCP) approved a key project entitled "Sea-level movements during the last 15,000 years". A preliminary working group was convened and met for the first time in September 1974 in The Netherlands, when the scope, implementation and administrative framework of the project were considered.

The primary objective is to establish a graph of the trend of mean sea-level during the last de-glacial hemicycle and continuing to the present. It was proposed to use sea-level curves from many localities where the index points were unequivocally related to former positions of sea-level. Differences in the amplitude of the sea-level curves and sea-level histories will be used to draw conclusions about the strength and elasticity of the outer layers of the earth. It is hoped that the graphy showing the trend of mean sea-level will enable the prediction of future sea-level movements, particularly in heavily-populated low-lying coastal regions, where a relative rise of sea-level poses serious problems for human settlement, agriculture and industrial activity. In the developed world, such regions include areas flanking the southern North Sea basin and the English Channel, and in the developing world Nigeria, Bangladesh, Malaysia, Indonesia, Brazil, Uruguay, and the states of the Arabian Gulf.

The implementation of the programme is over eight years, 1974-1982. It is proposed to screen and compile existing data, committing it to computer storage, to determine key areas of the globe where sea-level studies are well advanced, and to identify areas with deficient data, and to return data at national and international levels on a standard pro-forma. This will serve as the basis for mathematical modelling and the development of predictive models. The training of foreign personnel in field techniques, analytical methods and interpretation, and advice and supervision by acknowledged experts in the field of sea-level studies are regarded as high priorities by the working group for the successful implementation of the programme of work.

The project is administered and co-ordinated by an international working group led by Dr. A. L. Bloom of Cornell University, who has already published a synopsis of the objectives of the project. The members of the working group are in the process of being appointed by their IGCP national committees. By June 1975 the working group comprised fifteen members, and in October I was nominated as the UK representative. This note gives the background to the sea-level project, indicates the nature and extent of support in other countries, and suggests a co-ordinated approach to sea-level studies in the UK, stressing the need for development of a methodology.

Several countries have already allocated both funds and personnel to help realise the project, and laboratories in two countries have offered radiocarbon dating facilities as their contribution. In The Netherlands, Belgium, Germany (FR) and New Zealand, the Sea-level Movements Project is part of official government projects in progress, and is financed directly from government funds. Elsewhere work on the project is on an ad hoc basis in university departments and institutions, and is a research programme assisted by institutional or central government funds. However, it is intended than national representatives should assess the degree of national interest, stimulate participation, and wherever possible co-ordinate research relevant to the project.

In the United Kingdom research on sea-levels has been sporadic and confined geographically; it has laid stress on a small number of mutually exclusive techniques. Effort has been concentrated for short periods on a few areas, such as the southern Fenlands and the Somerset Levels, and modern techniques have not been applied subsequently to these areas. In default, promising areas have not been treated to detailed systematic analysis, even though that promise was indicated in the 19th and early 20th century literature; these areas include the south coast of England, the coasts of North Wales and Anglesey, the coasts of north-east and north-west Scotland and the Shetlands, the coasts of north-east England, the Lincolnshire marshes, and the northern Fenlands. Many of these areas are critical for sea-level studies, either because they lie in zones where elevated beach features give way to buried tidal flat and lagoonal deposits, or because subsidence poses a threat to settlements.

Techniques applied to sea-level studies include sedimentological, stratigraphic, pollen, diatom, foraminiferal and malacological analyses, and often include some type of plane surveying. The only technique common to all sea-level studies is radiocarbon dating, but rarely are the dates corroborated by referring the local pollen assemblage zones at the sampling site to regional pollen assemblage zones, and through them to the chronozones, as recommended by West (1970). Furthermore, data used to establish sea-level movements are often inadequate, for they are derived as secondary data in a primary study of vegetational history or coastal archaeology. Therefore there are often difficulties in interpretation, and correlation becomes hazardous.

It is suggested that a meaningful contribution to the sea-level project could be made by British workers in the following areas:

1. By screening available radiocarbon dates for their research areas, and justifying the remainder on a local sea-level curve.
2. By standardising the methods of data return, so that correlations may be established.
3. By establishing the provenance of dated material in relation to former tidal positions, estimating mean tidal positions, and calculating mean sea-levels.
4. Estimating the altitudinal variation of samples since burial, caused by primary and secondary consolidation.
5. Estimating the magnitude of the hydro-isostatic effect during transgressive and regressive episodes.
6. Establishing marine transgression sequences for small geographical areas that are homogeneous, as a basis for the subdivision of coastal lithologic units, and the correlation of time and altitudinal boundaries.
7. Exploring the relationship between marine transgression/regression sequences during the last 15,000 years and climatic changes.
8. Establish the history of coastal sand dune systems and their stability/instability cycles in relation to sea-level movements and climatic changes.
9. Identify the more important parameters that affect the distribution of sediment types and plant communities in coastal zones, to help interpret coastal palaeo-environments.

I should welcome comments on the scope of the sea-level project and on the contributions that could be made by the UK towards the realisation of the aims of the IGCP Sea-level Movements Project. They should be sent to Dr. M.J. Tooley, Geography Department, University of Durham, Science Laboratories, South Road, Durham City, DH1 3LE.

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THE QUATERNARY OF THE CONTINENTAL SHELF AROUND THE BRITISH ISLES

The following summaries are of papers read at the joint meeting of the Challenger Society, the Marine Studies Group of the Geological Society of London and the Quaternary Research Association held at Burlington House, London on October 22nd 1975, but not included in previous Newsletters (Nos. 16 and 17).

Glacial and Post-glacial Sedimentation in the Malin Sea

By M.R.Dobson and D.Evans

Geophysical and sampling surveys by University College Aberystwyth as well as shallow drilling and coring by the Institute of Geological Sciences have extended our knowledge of glacial and post-glacial deposits in the Malin Sea. The sediments are considered in terms of the form formations Binns et al. (1974) recognised in the Sea of the Hebrides.

The till of Formation 1 is widely distributed and is thought to be wholly Devensian in the east, although older tills may be present west of Malin Head. North of the projected line of the Great Glen Fault, the deeply eroded Mesozoic basin is covered by over 100m of sediments, of which the lower acoustically transparent deposits are here recognised as Formation 2, and may be laterally equivalent to the boulder clay. The upper thinner sequence is interpreted as Formation 3, a sub-horizontally bedded deposit which is widespread both west and east of Malin Head. Formation 3 reaches its maximum developement of 150m in the Sound of Jura where it lies directly on bedrock. Tidal effects have influenced the present distribution of Formation 3, and Formation 4 (modern sediments) is wholly controlled by recent conditions.

Recent Whitethorn boreholes have shown that Formation 3 consists largely of soft to firm clays, unlike the sandy muds of Formation 3 in the Hebrides. Work continues on the Quaternary of this area, both at Aberystwyth and the Institute of Geological Sciences.

Quaternary Features in the South-Western Approaches to Britain

By D.Hamilton

The main features of the Quaternary in this area are (a) an extensive even sea-floor in the western English Channel, (b) channel systems cut into the sea-floor, and (c) depositional features such as ridges. These topics have long been debated; for example, Hull's (1912) postulation of integrated river systems, and Sandford's (1929) discussion of the eastward movement of ice up the English Channel. Kellaway et al. (1975) present evidence for extensive ice erosion, transport and deposition in the area.

The origin of the extensive even surface in the western English Channel is complex, and cannot be ascribed to a simple process of glacial erosion, as do Kellaway et al. The largest of the channel and palaeovalley systems in the area is the Hurd Deep (Hamilton and Smith, 1971). Though no immediate continuation of the channel could be detected at its present south-western end, further to the west Auffret et al. (1971) have mapped a completely infilled channel. This is part of an integrated drainage system that is distinct from the closed depressions in the mid and eastern English Channel. Continuous seismic records in the Celtic Sea reveal a large infilled channel system flowing south-westward from the Bristol Channel and St. George's Channel. These are complex features due to fluvial, glacial and tidal erosion, together with the effects of sea-level changes.

The system of NE - SW ridges and banks in the western Celtic Sea are composed of Quaternary sediments resting on Tertiary rocks. The Flandrian transgression caused extensive reworking of sediments, leading to the development of an extensive graded bed over much of the Celtic Sea and parts of the English Channel.

Effects of the Pleistocene Glaciations in the Southern Bight of the North Sea

By E. Oele and R. Kirby

Two areas in the Southern Bight have been investigated - the Netherlands continental shelf area, which is being mapped on a routine basis by the Geological Survey, and an area around the Sandettie Bank at the entrance to the Dover Strait, with was studied by a special joint Anglo-Dutch survey. These two areas span a hinge which runs north-westwards from the mouth of the Westerscheldt. To the north a fairly continuous sequence of Pleistocene deposits occurs in the subsiding North Sea Basin, which lies across the Netherlands continental shelf. South of the hinge in the Sandettie area the Pleistocene deposits are discontinuous, attenuated, and represent only the upper part of the Pleistocene resting on a stable high-level Tertiary platform.

The Lower Pleistocene is poorly known, but from the Middle Pleistocene (Elster) onwards the deposits are more accessible. Elster glaciers reached the north part of the Netherlands shelf and land area, and deposited tills which now lie beneath the Holsteinian Interglacial deposits. Elsterian fluvio-glacial sands and lacustro-glacial meltwater clays are widely distributed in the north part of the North Sea. At their maximum the Elster glaciers reached and east-west line just south of the Frisian Isles and extending eastwards into Germany. British work suggests that the main East Anglian glaciation was Elsterian rather then Saalian (Bristow and Cox, 1973). The same workers considered the conflicting evidence for the age of the various interglacials, and in their view Eemian = Hoxnian and Hoxnian = Holsteinian. The date of the main East Anglian glaciation and the link with the continental Elster glaciers is still uncertain, therefore.

The southern limit of Holsteinian deposits runs east-west from the Dutch coast to the latitude of Hunstanton on the English coast. This line probably represents an ancient coastline, and marine Holsteinian deposits occur widely to the north. The orientation of this coastline contrasts with the younger Eemian and Holocene coastlines, which parallel the present continental coast. At this time there was no link with the Atlantic via the Dover Strait.

The Saalian glaciation is well known from the large amount of work onshore in The Netherlands, which has now been extended offshore. It was the most extensive glaciation in The Netherlands, reaching as far south as Nijmegen in the second of its five phases. The north west-south east trend of the ice fronts found onshore has now been shown to continue offshore. The glaciers had a profound effect upon the topography, resulting in various erosional, depositional and tectonic features. A sequence of lodgement tills was deposited, each of which is associated with a series of linear basins produced by ice lobes and reaching 8km in width and to -100m M.S.L. Around the margins of these basins are deformed ice-pushed Holsteinian deposits, which prove the Saalian age for the glaciation. The height of the ice-pushed ridges in the North Sea and western Netherlands is much less than in the central part of the country, and it may be that the glaciers were thinner or less competent westwards. Chalky boulder clay, similar to that found in East Anglia, is associated with linear basins and folded lacustro-glacial deposits (like the Saalian features in The Netherlands) on the Dogger Bank. If the true age of these features and their relation to the East Anglian succession are determined, they will form a useful link with the continental Pleistocene succession.

In the British continental shelf area Destombes et al. (1975) have speculated that a late Saalian ice tongue extended from the latitude of north Norfolk into the Dover Strait. However, the Netherlands evidence, that the ice fronts ran north-westwards, that the ice-pushed ridges decrease in amplitude westwards, and that they were retreating progressively north-eastwards in the late Saalian, does not seem to support this theory. Also, in the Sandettie area there is no evidence of transcurrent tunnel valleys, boulder clay or ice-pushed ridges to support the presence of such an ice tongue. However, there are several erosional basins of pre-Eemian age but unknown origin in this area. They are part of a series of similar asymmetric basins lying at approximately -30m M.S.L., which extend into Belgium where they occur at -10m. The extent of the Saalian glaciation on the English coast depends on the age of the Chalky Boulder Clay, which is still disputed. Southwards, in the Dover Strait, Kellaway et al. (1975) postulate a large Saalian ice tongue extending up the English Channel from the west.

A widespread marine inundation in the Eemian reached approximately to the line of the present continental coast, and marine Eemian sands blanket the whole area north of 51°30'N. To the south, the asymmetric basins in the Sandettie area and in Belgium and possibly the large transcurrent valley in the Dover Strait are filled with Eemian sediments. In the Sandettie area the deposits are about 9m of sands with an extensive cold water marine micro- and macro-fauna.

The Weichselian ice front did not reach The Netherlands, but ran north-south through central Denmark. It reached the English coast in north Norfolk, but several recent workers, including Kellaway et al. (1975), suggest that the North Sea was open northwards to the Atlantic. Only fluvio-periglacial and aeolian sands occur in the eastern part of the Netherlands continental shelf, but interstadial peats with an age of 45,090 years BP (Brørup Interstadial) have also been found. In the south-west of the Netherlands shelf area freshwater lake deposits with many vertical frost cracks form the Brown Bank Beds. In the Sandettie area the Weichselian deposits are confined to the asymmetric basins, but their original extent is unknown; they form a sand/clay sequence up to 4m thick. At one site a Weichselian sand with a freshwater molluscan fauna is overlain by a Late Weichselian clay.

In the Netherlands shelf area the lowest Holocene deposit is a very extensive transgressive peat ranging from pre-Boreal in the north (at -44m) to Boreal in the south (at -22m). Peats of similar age occur in the Sandettie area. Off the Netherlands coast the peat is covered by marine brackish tidal flat deposits, which are Early Boreal in the north, Boreal in the south and Atlantic in the coastal area. In the Sandettie Bank asymmetrical basin an early Flandrian sequence up to 5m thick occurs, and contains a boreal marine shelly fauna. Pollen dates ranging from Pre-Boreal Zone I to Boreal IIa, and Atlantic to Sub-Boreal Zones III and IV have been obtained from these deposits. Above the early Holocene deposits are the mobile sands forming much of the present sea bed. In the Sandettie area these sediments seem to be post-8,000 BP, and contain locally-derived *Nummulites*, which are quite distinct from those in the eastern Channel. These sediments also contain the Mediterranean foraminifera *Angulus pygmaeus*, which is derived from the south.

The major area of uncertainty at present is in correlation with the East Anglian Pleistocene stratigraphy. The doubt about whether the main glaciation is Elsterian or Saalian may be resolved if the well-established stratigraphy of The Netherlands could be extended by mapping westwards across the UK shelf. The presence of chalky boulder clay on the Dogger Bank with a range of other datable features is encouraging, but the succession presumably thins rapidly westwards. The problem of the age and origin of the mobile sand in the southern North Sea basin still presents difficulties.

Evidence for transgression and regression around the British Isles in the Pleistocene

By R.G. West

Fluctuations of relative land/sea-level result from glacio-eustatic causes, from isostatic movements in response to changing load, and from basement subsidence (as in the southern part of the North Sea basin). Evidence for low sea-levels comes from submerged topographic features and from the occurrence of fresh-water sediments at depth in coastal and off-shore regions. These latter are known from the English Channel and the Bristol Channel, for example at depths of c. -36m O.D., with radiocarbon ages of 9 to 10,000 years. It can be assumed that similar low sea-levels occurred in the older periods of glaciation as in the glacierisation of the Late Devensian.

Evidence for high sea-levels comes from the occurrence of marine sediments and beaches above present features of the same origin. Where these are fossiliferous they can sometimes be dated, but usually correlations are difficult in the absence of good bio-stratigraphic evidence. Such raised marine features can be the result of former high interglacial sea-levels (eustatic origin), as with sediments in the Nar Valley, Ingress Vale, Clacton, Portsdown-Slindon, Selsey and elsewhere, or they can be the result of warping and subsidence, as in the varying disposition of the Red Crag in south-east England, or they can be the result of isostatic uplift, as with the raised beaches of Scotland.

Rates of transgression are best documented in the Flandrian, where in the early part the rate reached some 7m/1000 years. A similar sort of rise probably took place at the beginning of each interglacial. Though there is evidence for regression in the later parts of the interglacials, rates are not known, though the palaeotemperature curve for the oceans indicates slower rates of regression than of transgression. Estimates of rates of regression will be important for the unravelling of river terrace histories.

There are three major provinces of relative land/sea-level change in the British Isles. In the south-east warping and subsidence played an important part in the Lower Pleistocene, with evidence for repeated transgression and regression from eustatic causes in the Middle and Upper Pleistocene. In the south-west there is again evidence for repeated transgression and regression in the Middle and Upper Pleistocene, but the long term movements of the area since the Pliocene are not so well known. In the north isostatic recovery since the Late Devensian glacierisation has been the major factor in producing raised marine sediments. The rock-cut features of this area may be much older. These north-south variations are thought to be reflected in the recent secular variation of sea-level demonstrated from tide-gauge evidence, with uplift in the north and down-warping in the south-east.

QUATERNARY CLIMATES

A meeting of the Quaternary Research Association on this subject was held at Owens Park, Manchester University on January 3rd 1976. Summaries of some of the papers read are given below, and it is hoped that the remainder will be included in the Newsletter for June 1976 (No. 19).

Likely Causes of Climatic Change

By M.K.Miles

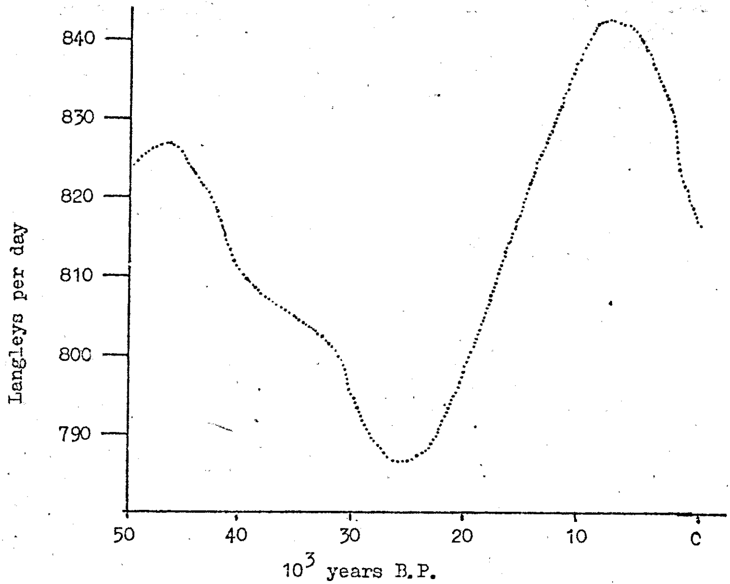
It is not difficult to conceive of various equilibrium temperatures differing by some 10°C for the earth-atmosphere system, but rather more difficult to assess the factors which could cause transitions from one to the other, as happened in the Quaternary. The possible primary causes may be listed as follows:

1. Changes in solar output

There is as yet no series of measurements of the solar constant taken from outside the earth's atmosphere. The corrections that have to be made to measurements from within the atmosphere make it impossible to conclude with confidence that there have been significant changes in the solar constant over about the last 100 years. This applies also to claims that the solar constant varies with the amount of sunspot activity.

2. Changes in Earth's Orbital Pattern

The effects first described by Milankovitch lead to the pattern of changes in the summer insolation at 60°N shown in the Figure on p. 17. The extreme differences amount to a fluctuation of about 7 %. Saltzmann and Vernekar (1971),



Mean Summer Insolation at 60°N (after Saltzman and Vernekar, 1971)
(1 Langley = 1 Cal/cm^2)

using a zonally averaged model with fixed ice-snow boundary, calculated that the mean summer hemisphere temperatures for those two extremes would differ by only 0.9°C, with very small changes in the zonal circulation and the intensity of the hydrological cycle. Allowing for consequent variations of the ice-snow area in high latitudes, a larger temperature range might be expected.

3. Changes in the composition of the atmosphere

The effects of water vapour and carbon dioxide are most important, because they affect the crucial long wave radiation budget. In their complete absence the equilibrium temperature at the earth's surface would fall some 10°C. Naturally produced changes in water vapour are not likely to be primary causes of climatic change; they enter as a strong positive feedback effect. However, it is thought possible that naturally occurring changes in carbon dioxide content may have been a primary cause during the Quaternary, though this could also operate as a positive feedback since the solubility of carbon dioxide in the ocean falls with increasing temperature.

The amount of carbon dioxide in most zones of the northern hemisphere has increased by some 10 % since the end of the 19th century. Calculations with radiation and convection models indicate that this is likely to have increased the global temperature by 0.2-0.3°C.

The ozone content of the stratosphere may be important because this gas absorbs very strongly in the ultraviolet part of the solar spectrum. However, it appears that fairly substantial changes in content are required to affect temperature in the lower troposphere.

The aerosol content of the atmosphere has varied in the past due to a varying incidence of volcanic eruptions, and there may also have been variations in the dust raised from desert areas by winds. The effect of this natural dust is probably to reduce the atmospheric albedo and so give cooling over all but fairly strongly reflecting surfaces, such as snow and ice. In a recent study of the effect of aerosols on climate, Kellogg et al. (1975) concluded that most aerosols lead to cooling with a surface albedo less than 0.36, but man-made aerosols only when the albedo is less than 0.08. If the incidence of volcanic activity has not been entirely random during the Quaternary, then the effect of volcanic dust may have been enough to produce the observed changes. Unless the dust content reached and stayed at values far larger than those determined by Lamb (1970), it would not be sufficient in itself to produce changes of 5-10°C.

4. Changes in the heat input from the sea.

These include changes in the heat input to the atmosphere arising from changes in the surface temperature of the sea, or in the intensity of evaporation arising from this, and changes in the vigour of the atmospheric circulation.

Because it covers such a large part of the earth's surface, and that mainly in lower latitudes where solar insolation is strong and reflectivity low, the sea absorbs a large part of the solar input. If, as Newell (1974) has postulated, there is the slightest imbalance in its heat budget this could mean substantial changes in its total heat content. For example, if an excess were to accumulate in the bottom layers, it could in time provide an adequate energy source for climatic changes of the size which occurred in the Quaternary. Newell draws attention to the effect a sea ice-sheet over the shelf areas of the Norwegian Sea and Weddell Sea (during a glacial period) would have on the radiative balance of the sea; the bottom water would warm up at the expense of the atmosphere in these high latitudes, and the conserved heat would eventually, through the oceanic circulation, appear in the surface layers, where it could gradually melt the ice and thus lead to a different radiative balance for the sea and a new phase in the cycle.

The events during the first 30 years of this century provide an illustration of a probable change of heat input from the sea. The north Atlantic winter circulation was more vigorous than in the decades before and after, and presumably more heat was taken up from the sea and more water vapour evaporated. This additional heat was then effective in raising temperatures in the Russian arctic, and caused a recession of the sea ice limits. Similarly the stronger trade winds in this period must have increased the rate of oceanic upwelling off the north-west coast of Africa.

5. Changes in the general circulation of the atmosphere

Could changes in the intensity of the general circulation so alter the distribution of heat and precipitation as to effect climatic change ? The warming of the arctic and increased rainfall in much of Europe and western Russia in the first 30 years of this century were probably associated with a period of more intense winter circulation. It is not known what caused this circulation change but, substantial though it was, its effect on the hemispheric mean temperature was an order of magnitude less than we are looking for. Whether it is a primary factor or an effect of the reduced amount of volcanic dust in the atmosphere after 1912 is not easy to say. Circulation changes affect the amount of dust raised from dry regions of the earth and may affect the radiation balance as described under 3, but again the effects seem likely to be an order of magnitude too low.

Conclusion

The effects of the likely primary causes of climatic change are not sufficiently well known to permit any firm conclusions. Factor 1 could conceivably be capable of leading to large climatic variations but there is no firm evidence that it was operative during the Quaternary. It seems, however, that the other factors are not sufficient to produce changes of over 10°C directly, but together with feedback effects each of the factors 2, 3 and 4 might be sufficient. Factor 5 is less certain; it may not be a primary factor, and would seem to require the presence of stored heat in the sea to produce the required effect.

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Approaches to the reconstruction of Quaternary Climates from Palaeobotanical Data: A Review

By H.J.B.Birks

The importance of the Quaternary pollen analytical record as a source of palaeoclimatic information was discussed in terms of the time span and resolution of the available record. The 'indicator species' approach, in which the modern distributions of particular species are compared with contemporary climatic patterns, seems limited in view of recent experimental studies on the climatic tolerances of selected species with contrasting distributions. Other studies have involved the distribution and performance of a few selected species in relation to two or three ecologically important climatic variables, and multivariate approaches, in which transfer functions are used to relate modern poolen assemblages to modern climate, and are then applied to fossil pollen data to derive quantitative estimates of past climate. Various refinements to the last approach were considered, and their advantages and disadvantages discussed.

The evidence of Quaternary climates from Soils

By E.A.FitzPatrick

Two main categories of soils should be considered - those at present at the surface, and those interstratified with Quaternary sediments. Many of the soils that occur at the earth's surface contain features that can be attributed to previous climatic conditions during the Quaternary. These include evidence of silicification, of clay translocation and of faecal material produced by earthworms. Because Pedology is a young science it is difficult to deal in detail with principles, but evidence for Quaternary climatic change can be discussed in general terms. During the Tertiary much of the earth's surface experienced a tropical or subtropical climate which produced deep and very strongly weathered soils. During the Quaternary some of these soils remained relatively unaffected, but others were subjected separately to aridity, pluvial conditions, glaciation and periglacial processes. Some soils show evidence of successive climatic changes, such as tropical weathering, followed by periglacial activity and now cool temperate conditions. The following examples illustrate some of these changes:

1. In many tropical arid and semi-arid areas there are mesas capped by a hard vesicular or concretionary material generally known as laterite. These laterite caps once formed the middle or lower horizon of tropical soil profiles, but are now exposed at the surface because of increased aridity, which has killed the vegetation and caused erosion of the top soil.

2. In western Nigeria the landscape is dominated by inselberge and long pediment slopes on which the soils have a marked discontinuity about 50-100cm below the surface. Below the discontinuity there is usually the distinctive mottled clay formed by in situ weathering; above the material is coarser with much gravel. The discontinuity is regarded as an erosion surface formed during an arid period, and the gravel has accumulated on it by differential erosion. At present conditions are more humid and the surface is fairly stable.

3. In parts of Australia the accumulation of silica is some deeply weathered soils suggests a change from humid to arid conditions. Although this process probably started in the Tertiary, it seems to have continued into the Quaternary.

4. The occurrence of massive calcite in some red Mediterranean soils suggests that the climate has become drier.

5. In central U.S.A. there is a succession of interglacial and interstadial soils interstratified between till or loess. The nature of these soils suggests that in most of the interglacial periods the climate was similar to the present, but during the Last Interglacial a red soil developed in some place and is indicative of warmer conditions. A similar suite of buried soils occurs in central Europe.

6. Near Canberra in Australia there is a succession of buried soils attributed to periods of erosion and deposition followed by periods of stability and weathering. This periodicity is ascribed to changes in climate from humid when the weathering occurred, to arid when erosion and deposition were active. The exact age of these periods is unknown, but they may correlate with glacials and interglacials. There are distinct differences between the various soils, suggesting that the climate in each period of stability was different.

7. Throughout central Europe and many parts of Britain there are remnants of the strongly weathered tropical soil cover, which have been affected by periglacial processes causing massive solifluction on slopes where podzols or brown forest soils are now developed in the old weathered and soliflucted material. In some areas the occurrence of an indurated layer is further evidence for the previous existence of permafrost; shattered stones may also have resulted from frost action.

Within soils it is therefore possible to find evidence for many of the climatic changes during the Quaternary.

QUATERNARY STUDIES AT OXFORD: A BRIEF REVIEW

By D.A.Roe

The main subjects considered in this review are geology, prehistoric archaeology, environmental studies including geography, botany and zoology, and certain aspects of physical anthropology and human biology, in so far as these are concerned with the Quaternary. At Oxford there is no Faculty or Department in which the relevant parts of all these subjects are united; on the contrary, courses and personnel are widely scattered, and are also surprisingly few. This review is based upon consultations with colleagues in other fields, but follows the writer's reading of the situation, and this may explain any undue bias in the direction of prehistoric archaeology.

Quaternary studies in one form or another have a long history at Oxford despite their slight representation in the university at the present time. Several outstanding figures in the early history of Quaternary studies held posts at Oxford or had other strong connections. Robert Plot was first keeper of the Ashmolean Museum in the late 17th century, but the early 19th century is perhaps a more realistic starting point, with William Buckland (1784-1856) and to a lesser extent John Kidd (1775-1851). Charles Lyell (1797-1875) was a pupil of Buckland. Buckland's successors in the Chair of Geology were John Phillips (1800-1874) and then Joseph Prestwich (1812-1896). W. Boyd Dawkins (1837-1929), another important figure in 19th century geology, not least in cave studies, read Natural Science at Jesus College, and in 1861 became the first holder of the Burdett-Coutts Scholarship in geology. John Evans (1823-1908) had links with Oxford, including an honorary fellowship at Brasenose in his last few years, and most of the great collection of Palaeolithic implements which he assembled during the critical years of debate on the antiquity of man has passed to the Ashmolean Museum through his son, Sir Arthur Evans. W.J.Sollas (1849-1936) was another distinguished Professor of Geology, and his book The Age of the Earth (Unwin, 1905) contains a chapter on Oxford's influence on the history of geology. Sir Edward Tylor (1832-1917) is remembered as an anthropologist, but to him anthropology comprehended the study of all aspects of the physical and cultural development of man from earliest times; he was also influential in the development of the teaching of human sciences in late 19th century Oxford, and indeed beyond it.

In the present century the dominant figures in Quaternary studies since Sollas have been K.S.Sandford (died 1972), D.F.W.Baden-Powell (died 1973) and W.J.Arkell (died 1958). The work of A.S.Barnes and Sir Francis Knowles on the technology of stone implements, including pioneer experimental studies, is also worth mentioning. In the School of Geography, R.P.Beckinsale has done notable work on the Pleistocene of the Lower Severn and the Cotswolds, and G.W.Dimbleby, now Professor of Human Environment at London University, graduated in Botany at Oxford and was University Lecturer in Forest Ecology for nearly 20 years up to 1964. There have also been major figures in other fields with a clear relationship to Quaternary studies - the late Sir Wilfred Le Gros Clark in Physical Anthropology is but one example.

Given the presence of such men as these over so long a period, it is not surprising that Oxford is rich in teaching collections relevant to the Quaternary. The Evans collection already mentioned is merely one part of a large store of Palaeolithic artifacts in the Ashmolean Museum. At the University Museum there is much material excavated by Buckland, Sollas and others, which is important to any student of the British Upper Palaeolithic; to this has been added the vast Llewellyn Treacher collection from Lower Palaeolithic sites in the middle Thames valley. As if these were not enough, the Palaeolithic artifacts in the Pitt-Rivers Museum comfortably exceed either of the other collections in quantity. Founded upon the original gift by General Pitt-Rivers in 1881, and added to by each successive curator, the Pitt-Rivers archaeological collections contain Palaeolithic ·aterial from many parts of the Old World, and the museum's ethnographic material .s one of the best collections in the world. Fine collections of later prehistoric material can be seen in the Ashmolean and Pitt Rivers Museums. Library facilities for Quaternary studies are also very good in Oxford, if all the University, Museum and Departmental Libraries are taken into account.

It is then a paradox that comparatively little is currently being made of .ll these resources. In archaeology, few workers during the last 50 years or so ·ave concerned themselves with earlier prehistoric studies, and these are still ·nly a tiny part of the undergraduate teaching. Since the time of Tylor, who ·nited disciplines that have subsequently drifted apart again, the archaeological ·trength of Oxford has lain in the study of the great civilisations of Rome, Greece, Egypt and south-west Asia, and secondarily in the archaeology of barbarian societies, including north-west Europe, contemporary with these civilisations. 'ith the exception of the sedimentological work of H.G.Reading, the current interests f the Geology Department seem to have turned away from the Quaternary. The same .s true of several other departments, such as Botany, Zoology, Soil Science and ·uman Biology, where Quaternary studies could prosper.

So far as present teaching at Oxford is concerned, various aspects of ·uaternary geology and geomorphology are taught to undergraduates in the School f Geography, mainly by A. Goudie and Marjorie Sweeting. Glaciology and glacial edimentology are well established at graduate level in this school, and there have ·een many successful research students in these topics over the years. Prehistoric ·rchaeology is taught to graduates in the Department of Ethnology and Prehistory ·or the one-year diploma and the new two-year B. Phil. degree in Prehistoric ·rchaeology; the teachers involved are B. Cunliffe (Professor of European ·rchaeology), H. Case and A. Sherratt (Department of Antiquities, Ashmolean Museum), . Inskeep (Pitt Rivers Museum), and D. Britton and D.A.Roe (University lecturers). ·ome prehistoric archaeology is also taught to graduate students for the diploma ·d B. Phil. in European Archaeology, under the direction of the Committee for ·chaeology, which also sponsors parallel courses in classical archaeology. ·ropean archaeology, for the purposes of the committee's courses, begins with the ·olithic and continues to the 8th century A.D. Although there is some overlap ·ith the course in Prehistoric Archaeology at the beginning of the period studied, ·he overall emphasis and approach are quite different. Sheppard Frere (Professor · the Archaeology of the Roman Provinces) and Sonia Hawkes teach this course ·ith several of those named above, but the links with orthodox Quaternary studies ·re tenuous. Some aspects of prehistoric archaeology can also be studied as option ·ubjects by students for the graduate diplomas in Ethnology and Human Biology.

Primatology and Human Evolution are taught as options for the diploma in Human Biology, and both Human Evolution and Human Ecology are studied at undergraduate level in the Honours School of Human Sciences. Undergraduates in the Honours School of Natural Science may also study some Quaternary subjects at a very general level if they choose Zoology, Botany or Geology, or offer Anthropology as a supplementary subject. Of these, it is the Anthropology option that is the most relevant, though the phrasing of the following extract from the syllabus may not inspire the highest confidence:

> The zoological position of man. Comparative osteology and odontology of the Primates. Human palaeontology, including the outline of Tertiary geology and a study of Palaeolithic and Neolithic culture sequences. (University of Oxford Examination Decrees and Regulations, 1975, p. 152).

One cannot but feel that if there were a better general awareness at Oxford of Quaternary studies and prehistoric archaeology, the term Quaternary would have been used as well as Tertiary, Mesolithic would have been specified between Palaeolithic and Neolithic, and neither the Geology nor the Archaeology would have been treated as a sub-discipline of Human Palaeontology.

Apart from the teaching, there are of course various graduate students doing research for the B. Litt. and D. Phil. degrees, whose topics are partly or even wholly concerned with Quaternary studies in Britain or abroad; almost all are within the Faculty of Anthropology and Geography. There is also the advanced study and research of the teaching staff, which also covers many parts of the world; as examples one can cite A. Goudie's current work in India and East Africa, that of Miss Sweeting in Indonesia, and that of R. Inskeep in South Africa.

Although the teaching collections and library resources at Oxford are so good, laboratory facilities have kept pace less well. Sollas found them inadequate when he was Professor/Geology, and would hardly think that there had been fifty year's worth of improvements since his day. Oxford has a unique asset in the Research Laboratory for Archaeology and the History of Art in Keble Road under the direction of Professor E.T.Hall, but again the comment must be made that its distinguished research output comparatively rarely touches the main stream of Quaternary studies. For example, the Laboratory's work on thermoluminescence dating and palaeomagnetics has so far been concerned mainly with their applications to later prehistory and the historic period. The School of Geography has a laboratory with specialist equipment for the study of Quaternary sediments, and many other facilities are available or potentially available in various other departments. However, in 1975 there was a splendid addition to Oxford's resources in this direction with the completion of the new Donald Baden-Powell Quaternary Research Centre, which will be open to inspection by members of the Q.R.A. attending the Oxford meeting in April 1976. The centre was established through the generous benefaction of £10,000 to the university from Francis Baden-Powell, Donald's son, who asked that the centre might bear his father's name and continue his interests. Donald himself left his library, field notes and collections of shells, Palaeolithic artifacts and geological specimens to the Pitt Rivers Museum. The university has used the money to fit out the whole first floor of 60 Banbury Road, a fine Victorian town house, as the centre, which comprises teaching and study rooms, a common room and a small laboratory. The centre forms part of the Department of Ethnology and Prehistory, as does the Pitt Rivers Museum; development plans for the Museum envisage new buildings for it immediately adjacent to the centre. Meanwhile, there is room at the centre to house the major portion of the Museum's palaeolithic and mesolithic collections. The Human Biology Department is shortly moving into the house next door on the south side; Social Anthropology premises already exist on the other side of Banbury Road, and if all plans and aspirations come to academic and financial fruition, there could eventually be a magnificent centre for all kinds of anthropological and archaeological studies on this site.

The centre starts life with a modest but useful range of laboratory equipment, including enough to prepare and analyse pollen samples and sediments, and it has outstanding microscopic equipment at present being used by L. Keeley for research on the microwear traces on British palaeolithic flint implements. More equipment can gradually be added as it is needed. At present there is no-one able to study the Baden-Powell shell collections, which should contain some valuable material, but no doubt this will be undertaken before too long. This review thus ends on an optimistic note, and the few who are actively concerned with Quaternary studies at Oxford may take the birth of the new centre as a sign that the glories of the past are not wholly forgotten. It will be apparent that the teaching and research described above is at present far too scattered amongst different faculties and departments to make much united progress; more is in fact going on than readily meets the eye. However, we hope that the efforts of the present may receive encouragement and that the future may see some long overdue expansion.

The author thanks many who have helped with the preparation of this article, including Professor C.F.C.Hawkes, J.M.Edmonds, D. Britton, R. Inskeep, A. Goudie and Marjorie Sweeting; however, they are not responsible in any way for the opinions expressed, nor for any factual errors there may be.

DISCUSSION MEETING OF THE ROYAL SOCIETY AND ROYAL IRISH ACADEMY ON CHANGING ENVIRONMENTAL CONDITIONS IN GREAT BRITAIN AND IRELAND DURING THE DEVENSIAN STAGE

A meeting organised jointly for the Royal Society and the Royal Irish Academy by G.F.Mitchell R.R.S. and R.G.West F.R.S. will be held on Thursday April 1st at 9:30 a.m. and Friday April 2nd at 9:30 a.m. at 6 Carlton House Terrace, London SW1Y 5AG on the subject of "The Changing environmental conditions in Great Britain and Ireland during the Devensian (Last) Cold Stage". An official invitation to the meeting should be sent to all Q.R.A. members in the near future, and those wishing to attend should inform the Executive Secretary of The Royal Society by March 25th, quoting the reference 92/PMR; a tear-off sheet will be sent with the invitation. Buffet lunch will be available at a cost of £1.08 (incl. V.A.T.), but should be ordered in advance. The meeting will close on April 2nd in time to allow members who will be attending the Annual Field Meeting at Oxford to arrive there in time for dinner in St. Edmund Hall. A summary of the programme is given below:

<u>Thursday April 1st</u>

9:30 Introductory remarks - Chairman: J.S.Sawyer, F.R.S.
9:35 F.W.Shotton F.R.S. The development of Devensian chronology
10:10 A.McIntyre. Around Britain and the North Atlantic
10:50 Discussion and coffee
11:20 G.de Q.Robin. Ice cores and climatic change
11:55 N.J.Shackleton. The ocean oxygen isotope record during the Last Cold Stage
12:30 Discussion and lunch
14:30 E. Watson. Great Britain during the Devensian Cold Stage - the periglacial environment (Cha rman: A.W.Woodland)
15:05 G.F.Mitchell. Ireland - the periglacial environment
15:40 Discussion and tea
16:50 F.M.Synge. Sea levels
17:25 Discussion

<u>Friday April 2nd</u>

9:30 Introductory remarks - Chairman: J.J.Moore
9:35 R.G.West F.R.S. Early and Middle Devensian flora and vegetation
10:10 W. Pennington. The Late Devensian flora and vegetation of Britain
10:45 Discussion and coffee
11:20 W.A.Watts. The Late Devensian flora of Ireland
11:55 A.J.Stuart. Vertebrates
12:30 Discussion and lunch
14:15 G.R.Coope. Fossil coleopteran assemblages as sensitive indicators of past climatic changes
15:00 General Discussion under chairmanship of Sir Harry Godwin F.R.S., including
H.H.Lamb: On climatic implications
L. Starkel: On mid-European comparisons
15:45 Tea, followed by general discussion; close 17:25.

CALENDAR OF MEETINGS

2nd March 1976	Liverpool Geological Society distinguished visitor's debate on "Glaciation in the Irish Sea Basin" by G.F. Mitchell and D.Q.Bowen. Geology Department, Liverpool University, 7:30 p.m.
1st-2nd April	Joint Discussion Meeting of the Royal Society and Royal Irish Academy, 6 Carlton House Terrace, London. The Changing Environmental Conditions in Great Britain and Ireland during the Devensian (Last) Cold Stage. For further details see p. 23 of this Newsletter.
2nd-6th April	Quaternary Research Association annual field meeting and Annual General Meeting, Oxford.
20th-24th May	Quaternary Research Association field meeting, Rhum. Further details given in circulars for November 1975 and February 1976.
22nd August - 2nd September	Quaternary Research Association study course, southern Norway. For further details and availability of vacancies, please write to the Hon. Secretary.
11th-12th September	Yorkshire Geological Society field meeting on glacial and periglacial deposits of Holderness and the Yorkshire Wolds. Further details from A.V.Hodgson (General Secretary, Y.G.S., 14 Durham Road, Middle Herrington, Sunderland SR3 3NR).
24th-26th September	Quaternary Research Association field meeting, north Norfolk. Further details given in Q.R.A. circular for February, 1976.
8th January 1977	Quaternary Research Association Discussion Meeting, Durham
1st-5th April	Quaternary Research Association annual field meeting and Annual General Meeting (1977), Bristol.

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