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THE RECENT HISTORY OF NORTHERN LYNX, (*Lynx lynx* Linné) IN THE BRITISH ISLES

By R.D.S. Jenkinson

Recent studies of the history of vertebrate faunas during the Pleistocene and Flandrian periods within the British Isles (Yalden 1982, Stuart 1982) have included little information on occurrences of the northern lynx (*Lynx lynx.L)* in the British Isles. A study by Guggisberg (1975) has suggested that the northern lynx became extinct in Britain during the last cold stage.

This powerfully built, medium sized cat has enjoyed a vast European distribution during the Flandrian period in which the species has shown a marked preference for old high-timbered forests and particularly those with dense undergrowth (Guggisberg 1975).

The intensification of forestry based industries coupled with uncontrolled hunting are widely recognised as significant factors accounting for the modern decline in northern lynx population.

Its status in fossil vertebrate faunas within the British Isles has received little attention since the work of Dawkins (1866) and Jackson (1931), who noted the species occurrence within deposits which would now be dated to the late Quaternary. The apparent temporal distribution of this woodland species within deposits of this age, characterised by their shrub and tundra vegetation is intriguing. The contradictory nature of the fossil evidence and modern distribution of this species can be reconciled in two ways: firstly the lynx population presently living in tundra may have adapted to woodland biomes during early Flandrian. The second possibility is that the temporal distribution of lynx is confined to woodland biomes and that their apparent occurrence in the late Quaternary vertebrate fauna is the result of a misunderstanding of the fossil evidence. This study reviews the fossil evidence for northern lynx from fifteen British localities in order to define its recent temporal and spatial distribution, and to test the hypothesis that such a distribution is linked to the development of Flandrian woodland biomes.

Fossil Evidence

A major drawback for any consideration of fossil and sub-fossil lynx in Britain is that many specimens have been recovered from caves where early excavations and subsequent lack of detailed reporting impedes a clear understanding of the stratigraphic relationship between many faunal assemblages. This problem is aggravated by the frequent lack of independent dating evidence.

The fifteen fossil occurrences of northern lynx discussed in this study can be considered in respect to associated faunal and artefactual assemblages from which they were recovered, aided in some instances by independent dating evidence.

Table 1 sets out the vertebrate faunas recovered from localities with evidence for lynx. These are listed according to reported age, the Devensian localities being dated upon the basis of apparent associations with the Pleistocene Mammalia: hyaena *(Crocuta crocuta)*, lion *(Felis leo)*, and woolly rhinoceros *(Coelodonta antiquitatis)*. It is highly probable that 'mixing' with earlier Devensian fossil material has taken place at some of these localities. Remains from Banwell Cave, for instance, are thought to have been washed into the cave and therefore are not *in situ* (Davies,1926), whilst those remains from Langwith Cave, Derbyshire, are derived from a poorly excavated site (Mullins 1913). Northern lynx remains from the sites of Aveline's Hole (Davies,*et al* 1922) and Victoria Cave, Yorkshire (Jackson,1938) are seemingly more reliably dated in that they were recovered from horizons containing Later Upper Palaeolithic artefact assemblages, a technology which is indicated by radiocarbon dating to be confined to Late Devensian pollen zones 11-111 of Godwin (1975).

Of the remaining fossil localities, where there is no association with Early and Mid Devensian vertebrates or palaeolithic artefact assemblages, *post quem* dates are indicated by elements of the vertebrate fauna. Vertebrates at Lynx Cave, Staffordshire (Jackson,1962), Kinsey Cave, Yorkshire (Jackson,1932), and Inchnadamph, Sutherland (Peach & Horne 1917), include *Rangifer tarandus*, a Devensian species, that is known from radiocarbon dating to have survived at Dead Man's Cave (Mellars,1969) and Gough's Cave (Jacobi,1980) into the Younger Dryas (i.e. Godwin 1975, pollen zone III?). Similarly, *Equus* sp. recorded from Moughton Fell Cave, Yorkshire (Jackson,1931) and Robin Hood's Cave, Derbyshire (Laing,1889), amongst vertebrate faunas which include northern lynx and lack earlier Pleistocene species suggests an early Flandrian *post quem* date for horizons at these localities. The available evidence suggests that horse survived the Devensian and lingered into pollen zone IV (Godwin,1975), the Pre-Boreal (Bramwell,1973, Wiijngaarden-Bakker, 1974). The vertebrate fauna from Neale's Cave, Devonshire is dated by Neale and Sutcliffe (in Jackson,1962) to the Mesolithic. Vertebrate remains from Steetley Cave, Yorkshire are independently dated by the presence of a mesolithic artefact and a zone VIIa-VIIb (Godwin,1975), pollen sequence (Jenkinson, *et al* in press).

		Erinaceus europaeus	*Sorex araneus*	*Talpa europaea*	*Crocuta crocuta*	*Felis sylvestris*	*Lynx lynx*	*Felis leo*	*Gulo gulo*	*Mustela putorius*	*Meles meles*	*Canis lupus*	*Vulpes vulpes*	*Ursus arctos*	*Lutra lutra*	*Coelodonta antiquitatis*	*Equus* sp.	*Sus scrofa*	*Cervus elaphus*	*Alces alces*	*Capreolus capreolus*	*Rangifer tarandus*	*Bos* sp	*Sciurus vulgaris*	*Clethrionomys glareolus*	*Arvicola terrestris*	*Lemmus lemmus*	*Dicrostonyx torquatus*	*Lepus* sp	*Ochotona pusilla*	*Falco tinnunculus*	*Lagopus mutus*	*Lagopus* sp	*Larus canus*	*Strix aluco*	*Columba palumbus*	*Turdus merula*	*Garrulus glandarius*	*Corvus corax*	*Corvus monedula*	*Rana / Bufo* sp
FLANDRIAN	KILGREANY CAVE						X																																		
	INCHNADAMFF						X								X			X				X																X			
	GOP CAVE						X																																		
	NEALE'S CAVE						X																																		
	STEETLEY CAVE	X	X	X		X	X				X		X					X	X		X		X	X	X										X	X	X	X			X
	ROBIN HOOD'S CAVE					X	X				X	X	X	X			X		X	X	X		X						X												
	YEW TREE CAVE						X					X	X					X			X																				
	LYNX CAVE (STAFFS)									X		X										X	X																		
	TEESDALE FISSURE						X				X	X	X					X	X				X																		
	KINSEY CAVE						X					X		X								X	X																		
	MOUGHTON FELL CAVE						X						X	X			X												X												
	LYNX CAVE (CLWYD) (Layer A)						X				X		X					X	X		X	X?	X?					X?	X								X				
	LYNX CAVE (CLWYD) (Layer C)						X						X								X		X			X															
	CALES DALE CAVE					X	X				X	X	X										X		X	X			X		X		X	X					X	X	X
LATE GLACIAL	VICTORIA CAVE						X				X		X	X					X																						
	AVELINE'S HOLE						X			X			X	X			X		X								X	X	X	X		X	X								
	LANGWITH CAVE	X	X	X		X	X			X	X	X	X	X	X		X	X	X		X	X	X	X	X	X	X	X	X			X	X		X	X	X				X
	BANWELL CAVE				X		X	X	X			X	X	X		X						X	X																		

Table I Fossil localities with vertebrate faunas which include Northern Lynx within the British Isles.

A near complete skull and mandible from Yew Tree Cave, Nottinghamshire (Ransom,1866) were the first specimens to be described from a British locality (Dawkins and Sandford , 1866). Precise dating of the vertebrate fauna from the site remains problematic but analysis of the preserved specimens from this excavation shows that the associated remains include those of *Canis lupus*, *Vulpes vulpes*, *Sus scrofa* and *Capreolus capreolus* (Jenkinson,1983). Notably absent from the vertebrate fauna is any trace of earlier Devensian species which are known in considerable quantities from nearby sites. The record of roe deer not known from local Devensian sequences and its occurrence with *Lynx lynx* establishes the fauna as one which cannot be demonstrated to be older than the Flandrian.

Further specimens were discovered by Laing (1889) in the rear of Robin Hood's Cave. The two mandibles, maxilla and radius, occurring beneath a flowstone in the western area of the cave, were originally described as *Felis brevirostris* (Croizet & Jobert 1828), by Stewart (in Laing 1889). The original specimens have unfortunately been lost since the excavations, but the detailed description given by Stewart indicates that, although large, they fall within the size range for modern *Lynx lynx* and are smaller than the size range reported by Kurten (1978) for *Lynx issiodorensis* (Croizet & Jobert, 1828).

The age of deposits containing a juvenile mandible of lynx from Kilgreany Cave, County Waterford have been subject to much discussion (Jackson, 1962, Savage, 1966), particularly as the occurrence of Pleistocene species at this site have important implications for our understanding of Midlandian colonisation of Ireland by vertebrates. Most of these authors conclude that the earliest demonstrable sequence within the cave is of Neolithic age but there remains a possibility that a Late Glacial/Early Post Glacial sequence existed (Jackson 1962).

It can be seen from this description of fossil occurrences of northern lynx, that with the exclusion of remains from Victoria Cave, each occurrence is either of established Flandrian age or is known from localities where both Devensian of Flandrian vertebrates are known.

The significance of this observation is that of the fifteen fossil occurrences of northern lynx in the British Isles, thirteen are from localities not demonstrably older than the Flandrian. Of the remaining four localities, three have suffered either geomorphological disturbance of deposits or are too poorly excavated to be confident of association between other elements of the vertebrate fauna or artefacts.

Conclusion

This analysis has shown that it cannot be demonstrated that northern lynx occurs in association with Early and Mid Devensian vertebrates on any site earlier than the Late Devensian (pollen zones 11-111). The evidence from Steetley Cave suggests a *post quem* date for northern lynx in Britain of Godwin's (1975) pollen zone VIIA during the Flandrian.

These observations have a number of implications for our understanding of the species colonisation by and subsequent extinction of this species within the British Isles. It is likely that the appearance of the species is associated with the development of regional temperate forest biotopes particularly during the Early Flandrian. The species apparent occurrence within late Devensian contexts and apparent associations with palaeolithic assemblages must be treated with suspicion and needs testing through the application of radiocarbon dating.

The colonisation of Britain by this species is complicated by the rise in sea level during the early Flandrian. This problem is particularly acute for its occurrence in Ireland which if associated with the development of temperate woodland must imply colonisation during the Littletonian, not conceivably before the Boreal and prior to the flooding of the land connection which is dated by Cullingford, Caseldine & Gotts (1980) to 7500 bp.

Radiocarbon dating of reindeer antler from Dead Man's Cave (Mellars, 1969; Jacobi, 1980), Gough's Cave (Jacobi 1980) and the vertebrate bone associated with horse remains from Dog Hole Fissure (Jenkinson, *et al* 1982) indicate that both of these species survived the Devensian and are a constituent of early Flandrian faunas.

The strong association of these species with northern lynx remains suggests that its temporal distribution is within the Early Flandrian and at maximum extends to Godwin's (1975) pollen zone VIIA.

The absence of northern lynx from localities with horizons younger than zone VIIA is suggestive in view of the widespread evidence for woodland clearance toward the end of the Atlantic. This phenomenon may be a major factor accounting for the extinction of this species in mainland Britain. At Steetley Cave, palaeobotanical studies indicate that a woodland biotope favoured by lynx is followed by a dramatic increase in *Gramineae* pollen, Godwin's (1975) pollen zone VIIb, and is therefore indicative of woodland clearance. Lynx extinction may therefore be due to woodland clearance by human groups initiated during the closing stages of the Mesolithic.

Although a relatively rare fossil, this study notes the importance of northern lynx as a constituent of Flandrian vertebrate faunas. Analysis of the fossil evidence suggests that the species colonisation of Britain has been relatively rapid and short-lived. The precise nature of such a temporally restricted distribution particularly in view of the importance of such phenomenon for palaeontological studies, requires further definition. A priority for further study of this species in Britain must be the application of absolute dating methods, to fossil material, particularly from Late Glacial contexts.

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R.D.S. Jenkinson, Cresswell Crags Visitors' Centre,
Welbeck, Worksop, Notts. S80 3LH.

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AN OCCURRENCE OF PIKE *(ESOX LUCIUS L.)* IN THE EARLY POST-GLACIAL AT SEA MERE, NORFOLK, AND THE ORIGIN OF BRITISH FRESHWATER FISHES

By K. D. Bennett

Remains of fish have only rarely been found in lake sediments, despite the examination of many thousands of cores from a wide variety of lakes. The only recent instances on record in the British Isles are the salmonid bones and scales reported by Pennington and Frost (1961), from the Devensian late-glacial of Esthwaite Water in the Lake District, and the trout *(Salmo trutta L.)* and rudd *(Scardinius erythropthalmus (L.)* bones found in the early post-glacial calcareous marl of a shallow lake in Cheshire (Johnson, Franks and Pollard, 1970; Stuart, 1974). Frey (1964) summarizes records of fish remains found in a variety of other situations. In North America, fish scales were found by Lagler and Vallentyne (1956) in a post-glacial lacustrine sequence, and Vallentyne (1960) subsequently investigated in detail the abundance of scales in lake sediments in Ontario. He found up to 16000 scales, and over 1000 skeletal remains per square metre of sediment surface in the upper 15cm of sediment of one lake. If fish remains occurred regularly at that frequency, they ought to be abundant in lake cores, but, possibly because conditions for preservation are rarely adequate, finds are rare. In one study (Casteel, Adam and Sims, 1977), sufficient remains of one fish species were found in a lake core to permit a detailed assessment of changes in the fish population over a long period of time. Records of fish from lake sequences can be dated accurately by pollen biostratigraphic correlations or radiocarbon dating of the sediment matrix and may thus be important for establishing the former distribution of freshwater species. This paper describes a find of fish bones in a lake sequence from the post-glacial of East Anglia, and discusses its significance in the light of the possible origin of the British freshwater fish fauna.

Sea Mere is a freshwater lake of about 330m diameter situated near Hingham, Norfolk (National Grid Reference TG037012). It has two small inflowing streams and an outflow which eventually joins the River Yare and flows into the North Sea at Great Yarmouth. The lake basin contains a long sequence of late-glacial (Hunt and Birks, 1982) and post-glacial sediments, which were cored in November 1980 in order to obtain a series of samples for pollen analysis as part of a project investigating the early and mid post-glacial vegetational history of East Anglia. The cores were taken from open water, in the centre of the lake. The fish bones were recovered from a depth of 1509cm below the sediment surface (1109cm below the sediment/water interface). The sediments are calcareous lake muds, containing (per cm^3 of fresh sediment) about 0.12g of calcium carbonate, 0.10g of other inorganic material, and 0.07g of organic material.

The bones were identified by Dr. A.J. Stuart. They comprise several fragments of skull, including part of an upper jaw element with a number of teeth adhering. The numerous sharply-pointed teeth and characteristic bases for attachment are diagnostic for pike *Esox lucius* L. The material probably represents a single young individual.

The associated pollen diagram (Bennett, 1982) shows that the pike bones occur during a period when the forests around the lake contained predominantly *Corylus avellana*, with some *Betula*, *Quercus* and *Ulmus*. *Alnus glutinosa*, *Tilia cordata* and *Fraxinus excelsior* were absent. An early post-glacial age, probably within Fl IIb of West (1980), is thus indicated. The calcareous nature of the sediments mean that reliable radiocarbon dates cannot be obtained, but comparison of the pollen biostratigraphy of Sea Mere with the well-dated sequence at Hockham Mere (Bennett, 1982, 1983) suggests an age for the bones of about 8500BP. The aquatic flora of Sea Mere at this time included *Nymphaea alba*, *Potamogeton*, *Sparganium/Typha* and *Ceratophyllum*. Sea Mere was thus a still, calcareous lake with a marginal fringe of rooted aquatics. Such a lake would be a typical locality for pike today (Muus and Dahlstrøm, 1971; Wheeler, 1978).

This is the first fossil record of pike from the early post-glacial of the British Isles (see Stuart, 1974, 1982), and confirms this fish as a member of the native British fauna. Since pike is a stenohaline, primary freshwater fish (*sensu* Wheeler, 1977), its occurrence on an island requires some explanation. Wheeler (1977) argues that since the British primary freshwater fish require high temperatures for successful reproduction, they cannot possibly have survived the Devensian glaciation in this country, and must therefore have immigrated during the period of low sea-level at the beginning of the post-glacial when east coast rivers and some south coast rivers were connected to rivers of mainland Europe. Thus, the British primary freshwater fishes should be native only in the rivers bordering the North Sea and the English Channel. This is an adequate explanation for the occurrence of a pike at Sea Mere in the early post-glacial. However, another primary freshwater fish, rudd, has been recorded from the early post-glacial of Cheshire (Johnson, Franks and Pollard, 1970; Stuart, 1974), and pike itself has been recorded from Hoxnian deposits at Nechells, Birmingham, (Shotton and Osborne, 1965) and early Wolstonian deposits at Brandon, Warwickshire, (Osborne and Shotton, 1968), all from river systems on the west coast of Britain. It therefore appears that immigration into the east coast rivers during a period of low sea-level is not entirely adequate to explain the distribution of British freshwater fishes, either during the post-glacial or earlier interglacials. Thus the present day records of stenohaline fishes in western Britain need not all be the result of introductions by man, as suggested by Wheeler (1977). It has been suggested that freshwater fish may be able to spread between river systems by moving across headwater fens, especially during periods of high water level (e.g. Schindler, 1957). However, it seems unlikely that this could have occurred in Britain. Alternatively, the stenohaline fishes may have survived the Devensian glaciation by moving downstream into portions of rivers now covered by the post-glacial marine transgression. At altitudes of nearly 100m below Ordnance Datum, especially in the extreme southwest, the climate need not necessarily have been too severe. In this case, the ultimate origin of these fishes in Britain may have been much earlier in the Pleistocene, possibly before the English Channel formed.

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K.D. Bennett
Sub-department of Quaternary Research
Botany School
Downing Street
Cambridge CB2 3EA

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LATE-DEVENSIAN MARINE EROSION IN ST. ANDREWS BAY, EAST-CENTRAL SCOTLAND

M.A.E. Browne and J. Jarvis

About 50 km of marine geophysical surveys have been carried out in St. Andrews Bay in water depths of 3-25 metres. The presence of an extensive erosion surface is revealed that may be graded to a former sea level which reached 20 metres below O.D. at its lowest extent. The feature is thought to have been formed during the Loch Lomond Stadial.

Introduction

The present sparker survey was carried out using the same equipment and survey practice as that reported from Western-Invernesshire (Boulton et. al 1981). The quality of the records is good and permits resolution of sediment thicknesses and identification of the boundaries between sedimentary units to about 1 metre where these are well defined. The original records are at a vertical scale of approximately 1:50 and a horizontal scale of about 1:300 although the latter scale depends upon the speed of the boat. Only those records necessary to illustrate the text are included here (Fig.1).

Geophysical Data

In the North-East of the area (Figure 1a) bedrock is overlain by largely unconsolidated sediments about 50 metres thick, but elsewhere the average thickness is about 20 metres. The sediment cover thins towards the southern shoreline, where rock outcrops at the sea-bed 1 to 1.5km from the coast. The interpretation of the seismic textures of the sediments indicates that the lowest unit is till which occurs as isolated patches and ridges overlying a fairly regular bedrock surface although its apparent absence in some areas may be due to lack of resolution of the method. Over most of the area bedrock is covered by a seismically near transparent sedimentary unit. Institute of Geological Sciences geophysical and borehole surveys (Thomson and Eden 1977) in the lateral equivalent of this material have shown that this sedimentary unit (St. Abbs Beds) is similar to the Errol Beds Late-Devensian clays of the Tay Estuary (Paterson et al 1981) although in St. Andrews Bay the seismic unit may also include the Late-Devensian "Lower Forth Beds" (Thomson and Eden 1977). The arctic character of the faunas in the clays of the Errol and St. Abbs beds has long been known.

The seismically transparent sedimentary unit is truncated by a conspicuous erosion surface (Figure 1b). Into this surface are cut two well-defined features which can be identified as 'buried channels' with depths below the adjacent surfaces of 5m and 3m. Although to date these features have only been proved in one traverse, its quality and similarity to the features on records held by I.G.S. lead to the suggestion that the first (Figure 1a and 1b) is a former channel of a paleo-river Eden. The seismic textures associated with the surface indicate that it is covered by a layer of boulders or gravel that is thickest in the north-west of the area. The erosion surface itself slopes gently seawards and descends eastwards from about 17 metres below O.D. at the mouth of the Eden to about 22m below O.D. some 5 km from the coast. In water depths of 17m to 25m where the erosion surface might be expected to intersect

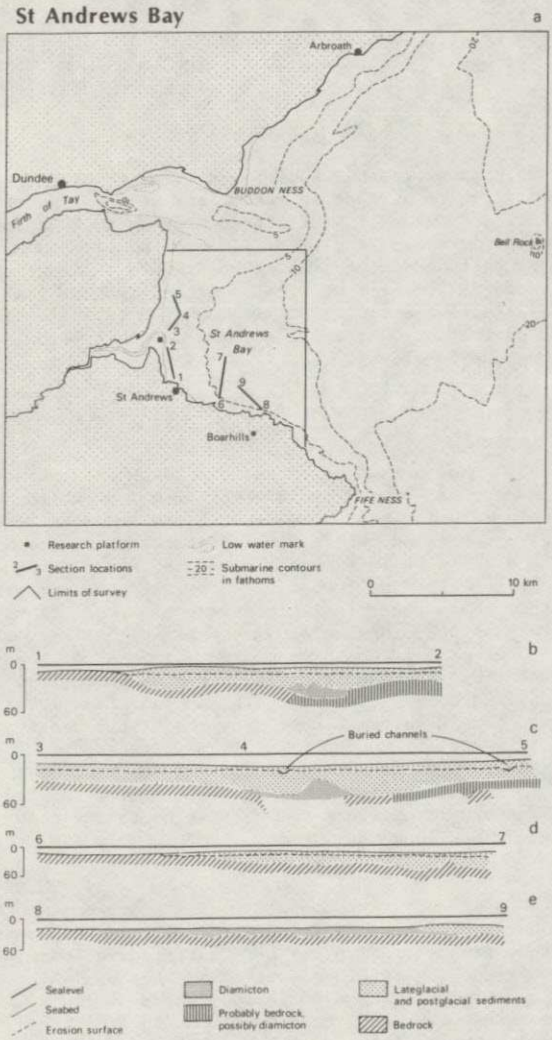

Fig.1. St. Andrews Bay - location map and lines of seismic profiles

the present seabed it becomes impossible to trace the feature because of the presence of a strong initial return from the seabed.

Boreholes onshore in the Tentsmuir area (Browne and Laxton in Laxton and Ross 1981) confirm the existence of this gravel deposit and its relationship to the underlying deposits of the Errol Beds. The gravel bed is locally over 3 metres thick and consists of individual clasts up to 20 cms across. In places the gravel rests on till NO484214 , the Errol Beds presumably having been removed by erosion. Although in the Tentsmuir area the lowest proven level of the base of the gravel is at 14.3m below O.D. NO487251 , the overlying Flandrian sequence was not bottomed at a depth of 18.9m below O.D. in one borehole NO503267 . Barnacle plates have been recorded at one locality in the gravels (Laxton and Ross 1981) but the deposit is not generally shelly.

North of Boarhills (NO5814) and seawards of the coastal rock platform on the basis of seismic textures (see Boulton et al 1981), the seabed consists of what is interpreted as planated till (Figure 1d). At its seaward limit this till surface steepens and dips beneath younger sediments. The upper surface of the till also appears to represent an erosion surface with a seawards limit at about 21m below O.D.

The texture of the sediments overlying the erosion surface in St. Andrews Bay is difficult to interpret because of the presence of the strong initial return. In shallow water, however, this layer which is up to 16 metres thick appears to be bedded and these sediments are interpreted as corresponding to the Middle and Upper Forth Beds, which comprise both Flandrian and recent sediment (Thomson and Eden 1977).

Onshore at Tentsmuir the overlying Flandrian sediments consist of two units of sand locally separated by a bed or layers of peat. The lower sand contains a macrofauna of intertidal aspect including *Macoma balthica* (Linné), *Mytilus edulis* Linné, *Cerastoderma edule* (Linné) and *Mactra coralline* (Linné) (D.K. Graham, I.G.S. pers comm). The microfauna is dominated by the foraminiferan *Elphidium clavatum* (Cushman) with subsidiary *Cibicides lobatulus* (Walker and Jacob) and *Ammonia batavus* (Hofker). *Miliolinella subrotunda* (Montagu) is only present near the base and indicates a fully marine salinity in this part of the succession (S.E. Barber, I.G.S. per comm). A cold water influence is suggested by the abundance of *Elphidinum clavatum* in an otherwise temperate assemblage. This sand deposit is locally overlain by a peat or peaty layers in sand (The Sub-Carse Peat?) at levels from as high as 2.2m above O.D. NO466211 to as low as 6.1m below O.D. NO479225 .

Discussion

Support for our view of the seismic survey data in terms of submerged erosion surfaces comes from previously published interpretations of sparker surveys and borehole records along the line of the Tay Road Bridge, where two buried channels have been identified at c. 41m below O.D. and 38m below O.D. in a location where the present estuary bed is at about 16m below O.D. (Buller and McManus 1971). If a similar relationship existed between sea-bed elevation and sea level at the time these channels were cut as exists today, their presence supports a former sea level of 20m to 25m below O.D., a level not dissimilar to that indicated by

Paterson et al (1981). The assumption of similarity between past and present channels is qualified since the floor of the buried channel represents the minimum elevation achieved during a period of erosion whereas the present channel will be subject to scour and fill. The data published in Buller and McManus (1971) indicates that the main channel is fairly stable at the road bridge and the base of the sweep zone of the channel is defined by Flandrian gravels which lie at about 18 metres below O.D. Accordingly the assumption of similarity is reasonable and the sea level estimate may be considered reliable. The correspondence between this estimate of sea level and those described earlier suggests that all these paleo-features are contemporaneous. Furthermore a borehole and cone penetrometer survey of Buddon Ness (Paterson 1981) revealed the presence of an erosion surface cut in the Errol Beds and sloping approximately south-eastwards from 5m below O.D. NO527326 to 20m below O.D. under the present channel of the Tay. The surface of the Errol Beds here is also marked by a resistant layer 1-2 metres thick of gravel and boulders from which well rounded clasts up to 20cms diameter have been recovered. It is, however, evident from the form of the erosion surface at Buddon Ness (Paterson 1981 Fig.4) that it may not define the axis of the buried channel of the Tay which appears to lie south of the I.G.S. survey.

The 'buried channels' of the Eden evident in the results of the present survey are considered to be intertidal in origin as the adjacent surfaces slope at too low a gradient to confine the flow to a channel in the seabed. An intertidal origin for the surface is also compatible with the onshore data at Tentsmuir on the basis of the overlying fossil assemblages. However, this refers to a somewhat higher elevation than in St. Andrews Bay.

Areas of planated rock surfaces are also present to the east of St. Andrews within 1 kilometre of the coast (Figure 1e). These surfaces slope from about 7m below O.D. to about 15m below O.D. before steepening and passing below unconsolidated sediments and clearly lie altutidinally above the erosion surface cut into Late-Devensian sediments. In Sissons' (1976; p.121) reconstruction of Lateglacial shorelines in south-east Scotland the only shoreline shown below that of the present-day is the 'Main Lateglacial Shoreline', which he believed to have formed during the Loch Lomond Stadial (c. 11000-10000B.P.). The projected elevation of this shoreline at St. Andrews is about 10m below O.D. (Fig.2) which agrees with the elevation of the planated rock surfaces in the Bay but is too high for the elevation of the erosion surface cut in the unconsolidated sediments.

In the Forth estuary at Grangemouth and in the area of the Edinburgh Sewage Works the planation of unconsolidated sediments that form the platform of the 'Main Lateglacial Shoreline' extends over a considerable altitudinal range, over 12 metres at the former and 9 metres at the latter (Sissons 1971). This planation is in addition to the supposed erosion of bedrock which Sissons identifies in the Forth which has been interpreted in terms of stable and slowly changing rates of sea level (Sissons 1981). The 'Main Lateglacial Shoreline' itself forms the break of slope at the landward limit of the planated surface. This shoreline does not represent the minimum level associated with the regression that accompanied the Loch Lomond Stadial since we suggest that the planation is intertidal rather than subtidal. Sissons (1969) also accepts the possibility that sea-level fell to a level of at least 6m below O.D. in the Grangemouth area which is well below the elevation of the 'Main Late-glacial Shoreline' in the area.

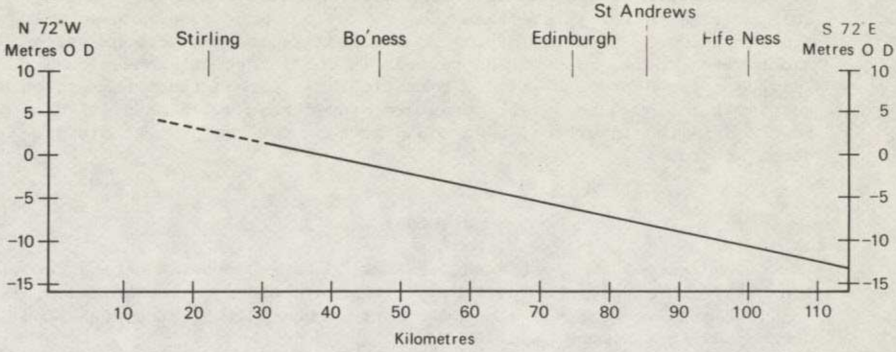

Fig.2 The Main Lateglacial Shoreline in southeast Scotland (after Sissons, 1976)

The data from St. Andrews Bay can be fitted into a Sissons' type model for Late-Devensian erosion in the Forth in which sea level could have stabilised at about 10m below O.D. while accomplishing bedrock erosion before falling to lower levels and causing further planation of Late-Devensian deposits. However, there is no conclusive link between these two erosive features and the distinct possibility exists of a much older phase of marine abrasion being responsible for the creation of the bedrock surface. The survival of the bedrock feature throughout the Devensian glaciation is not considered a serious problem since the bedrock floor of St. Andrews Bay does not indicate severe glacial erosion. This model would predict that the divergence between the planated bedrock surface and the Late-Devensian planated marine sediments noted at St. Andrews will increase eastwards and it will become more difficult to accommodate the increased vertical and horizontal erosion in a single phase of marine activity.

The mode of formation of the erosion surface and its relationship to changing sea levels has not been fully explained and needs investigation. The character of the surface in St. Andrews Bay as in the Firth of Forth and Beauly Firth consists of gravels distributed as a relatively thin layer over a wide area (Sissons 1976, 1981). However, our borehole and Sparker interpretations suggest that the layer in St. Andrews Bay is locally at least 2 metres thick. The origin of the gravels may be presumed to have been winnowed out from the underlying Errol beds and till as a result of wave activity in the intertidal zone although at the time of formation a periglacial climate probably prevailed (Sissons 1976) and cryonival processes in intertidal and supratidal zones may have contributed to the effectiveness of the erosive processes. The horizontal and vertical extent of the gravels however suggest that the surface is not comparable to the boulder pavements reported from high latitudes, (for example Hansom (1983)) which have been attributed to process associated with the grounding of sea ice.

Sissons (1981) suggests that a slow transgression of the sea was responsible for the feature in the Beauly Firth. It seems possible that erosion during the preceeding regression was equally if not more important for the formation of the surface. This view gains some support from the micropalentology which can be interpreted as indicating the presence of fully marine salinity immediately above the surface suggesting a rapid transgression. Further, beach processes during a slow transgression might sweep coarse material shorewards in the intertidal zone without leaving a lag deposit whereas a formation associated with a regression of sea level followed by a rapid transgression during which material was not reworked in the intertidal zone could account for the present distribution of gravels.

Conclusions

An extensive erosion surface cut in Late-Devensian marine deposits and till, and overlain onshore by gravel and boulder grade sediments, is considered to represent a shore platform formed in the intertidal zone during the Loch Lomond Stadial.

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M.A.E. Browne
Institute of Geological Sciences,
Murchison House,
West Mains Road,
Edinburgh,
EH9 3LK.

J. Jarvis,
Department of Geography,
University of St. Andrews,
St. Andrews
KY16 9AL.

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TOLSTA HEAD : Further investigations of the interstadial deposit.

by J. Birnie

As a consequence of the Q.R.A. short field meeting in Lewis and Harris in June 1981, the author had the opportunity to study the interstadial deposits at Tolsta Head. Whilst overall the results of the pollen analysis are in general agreement with those of Von Weymarn and Edwards (1973) who previously described the deposit, and dated it to 27,333 ± 240 ^{14}C years BP, some additional details permit further palaeoenvironmental interpretation. The results of diatom, pollen and some macrofossil analyses are given here, and it is hoped that the results of any other analyses of the material, consequent upon that field meeting, will also find their way into the newsletter to further the discussion.

METHOD

The sediment was sampled in the field by Donald Sutherland (exhibiting amazing confidence in the remainder of the party who held the rope). A sequence of eleven bulk samples was obtained, each sample consisting of a 5 cm depth of sediment. These were subsampled for pollen and diatom analysis, and the remainder was used for plant macrofossil analysis (by Peter Hulme, Macaulay Institute for Soil Research, Aberdeen). The results of full macrofossil analysis are not yet available, but preliminary results, of relevance to the interpretation of the pollen record, are given here.

Samples for pollen and spore analysis were prepared by standard disaggregation, and solution of humic colloids with sodium hydroxide, followed by acetylation (Faegri and Iversen, 1975). Minerogenic material was then removed by physical methods, with separation in a heavy liquid of bromoform and ethanol taking off most of it, and treatment with sodium pryophosphate (Bates, Coxon and Gibbard, 1978) clearing any remaining clay. Both methods permit retention of the 'non-polleniferous' fraction to check for pollen loss during preparation. Tablets of *Lycopodium* spores were added to measured volumes of sample prior to preparation to permit the calculation of pollen concentration (Stockmarr, 1971). Samples were mounted in silicone oil and counted in traverse of 1mm spacing for units of whole or half slides, to a minimum of 200 grains except where very low pollen concentration or poor preservation made this impractical. The organic fraction was removed from samples for diatom analysis by treatment with hydrogen peroxide, and the remaining material was mounted in Naphrax.

RESULTS AND INTERPRETATION

Table 1 gives a summary of the results, together with the description of sediment stratigraphy noted by Sutherland and notes on plant macrofossil identification by Hulme. The 0.55 m of organic material at Tolsta is overlain by approximately 2 m of till and 1 m of frost-disturbed sand, gravel and cobble. It sits on 6 cm. of sand, on bedrock. All aspects of the stratigraphic analysis show that the upper and lower parts of the organic layer are quite distinct, with the sample from 30 - 35 cm being transitional. The iron staining and marked changes in diatom and pollen stratigraphy at this level suggest the possibility of a hiatus.

Sedimentary zone TH1 refers to the four samples below this level, TH2 to the six samples above.

The organic content of TH1 was relatively low, and diatoms were scarcely represented, however, recognisable pollen was present throughout, with excellent preservation and a peak concentration of over 60,000 grains per cm^3 at 45 - 50 cm. Gramineae comprised over 60% of the total in this zone, and Cyperaceae under 10%. A type of Ranunculaceae pollen grain, very similar to *Ranunculus fluitans*, was well represented between 40 and 50 cm. Macrofossil analysis showed that abundant seeds of a water-crowfoot (*Ranunculus* subg. *Batrachium)* were present at 40 - 45 cm, and recorded in all samples between 35 and 55 cm. As *R. fluitans* is one of the water-crowfoots, it is likely that this, or something similar, was at or near the site. *R. fluitans* is characteristic of moderate to swift stream flow on a medium to coarse mineral substrate, and can tolerate considerable floods (Haslam et al, 1975). Apart from Gramineae, terrestrial vegetation is only represented by 2-3% Compositae Liguliflorae grains, and single grains of Compositae Tubiflorae and *Salix*,* with *Artemisia*, Caryophyllaceae and ?*Koenigia* (mediocre preservation) in the upper part.

Two observations indicate the provenance of the sediment of TH1. Old palynomorphs were present in decreasing quantities throughout, from a peak level of 25% of the contemporary pollen in the 50 - 55 cm sample. These were mainly trilete spores, with a few saccate pollen grains. This suggests reworking of a till containing sedimentary material, the most likely source area being the Permo-Triassic to Tertiary sediments of the North Minch Basin (Binns et al. 1975). In addition grains of chlorite or hornblende were seen in the microscopic preparations, particularly in the sample 40 - 45 cm, suggesting a metamorphic origin and little weathering.

The sample at 30 - 35 cm, transitional between TH1 and TH2 had the lowest pollen and spore concentration of the whole deposit, with under 2000 grains per cm^3 sediment. The pollen count was low, and therefore not particularly reliable, but Gramineae dominated. The change in colour and low pollen content may be consequences of exposure to oxiding processes at some point.

TH2 comprised sediment with a higher organic content, although including sand lenses, as at 10 - 15 cm. The presence of considerable quantities of diatom frustules, domination of the pollen record by Cyperaceae instead of Gramineae, increased levels of Caryophyllaceae and *Salix* pollen, and the presence of macrofossils of *Salix herbacea* distinguished TH2 from the zone below. Single grains of *Armeria* occurred only in this zone. A peak of Ranunculaceae grains coincided with the sand lens. These latter grains differed from those in TH1, and macrofossil analysis revealed that small seeds of *Ranunculus* subg.*Ranunculus*

*Footnote: Poor preservation precluded specific identification, as was also the case in earlier work (pers. commun. Edwards, 1983).

TABLE 1

SEDIMENT	STRATIGRAPHY	DIATOM	STRATIGRAPHY
Sample depth from top of organic bed (in cm.)	Visible stratigraphy (from D. Sutherland)	Variety/ Abundance	Dominant types*
0 - 5	predom. organic, with sand lenses	5/ few	*Pinnularia*, *Eunotia* and many fragments
5 - 10		15/ abundant	*Epithemia*, *Fragilaria* *Cymbella*
10 - 15	sand lens with angular debris	9/ frequent	*Epithemia*, *Cymbella* *Nitzschia angustata*
15 - 20	predom. organic, with sand lenses	17/ abundant	*Nitzschia ang.* (95%) *Tabellaria*, *Melosira/Cyclotella* *Eunotia*
20 - 25		18/ abundant	*Nitzschia ang.* (97%) *Tabellaria*, *Melosira/Cyclotella*
25 - 30		2/ few	occ. *Pinnularia* and *Melosira/Cyclotella*, fragments
30 - 35		0	
	iron staining		
35 - 40	fawn fine sand	0	
40 - 45		0	
45 - 50	grey, slightly organic fine sand	few	1 *Eunotia*
50 - 55		0	
55 - 61	iron stained, well sorted medium sand	not examined	
61 -	bedrock (gneiss)		

* Full details of diatom species and varieties are not given here

POLLEN Concentration	STRATIGRAPHY Dominant types		MACROFOSSILS (prelim. notes from P. Hulme)	ZONES (in text)
low	*Salix* Gramineae + herbs		leaf fragments cf *Salix herbacea*	
medium	Cyperaceae *Nymphaea*, Gramineae			
?	Gramineae Ranunculaceae	*Salix*, Caryophyllaceae, *Ameria* constants	small seeds of *Ranunculus* subg. *Ranunculus*	TH2
high	Cyperaceae Gramineae, *Salix*		*S. herb* ?	
medium	Cyperaceae Gramineae, *Salix*		*S. herb* ?	
medium	Cyperaceae Gramineae		*S. herb* ?	
low	Gramineae			transition
low	Gramineae + herbs			
medium	Gramineae, Ranunculaceae Compositae	old palynomorphs constant	abundant seeds of *Ranunculus* subg. *Batrachium*	TH1
high	Gramineae Ranunculaceae Compositae			
medium	Gramineae old palynomorphs			

were concentrated in the 10 - 15 cm sample, with some in the samples between 0 and 10 cm. These seeds are likely to represent semi-aquatic or shallow water plants (pers. comm. P. Hulme), of which, on the basis of the present British flora, *R. flammula* is the most probable.

The diatom record of TH2 indicated freshwater conditions throughout. As the site is at 60 m asl at present this leads to the not very startling conclusion that interstadial sea level was not sufficiently high to affect the site. It also suggests that the *Armeria* present was not necessarily representative of coastal habitats as now, but simply indicative of open ground conditions. The majority of diatoms indicated alkaline conditions, the acidophils *Eunotia spp.* and *Pinnularia spp.* always being in the minority except in samples where very few valves were present. Here they are likely to represent the more resistant remains of a population of inwashed diatoms, possibly originally growing within the locally-acid environment of Sphagnum-type mosses. The abundance of valves in the samples between 5 and 25 cm showed that diatoms were present at the site of deposition, within the pool or lake. *Nitzschia angustata var. acuta* was overwhelmingly dominant initially, probably indicating an abundance of epipelic habitats (Round, 1973), in more or less still water (Hawarth, 1976). Significant quantities of a small centric diatom show that a plankton may have been developed on the lake. The period of *Nitzschia* domination was succeeded by *Epithemia* and *Cymbella* species (including *E. argus* and *C. aspera)*, epiphytic forms probably reflecting the appearance of higher plants at or near the site providing suitable habitats. Indeed these coincided with the pollen record of the aquatic *Ranunculus* at 10 - 15 cm and *Nymphaea* at 5 - 10 cm. The *Ranunculus* and the fairly robust forms of *Cymbella* characterised the sandy sediment of 10 - 15 cm. reflecting an environment of relatively swift water flow, whereas the increasing organic content, the presence of *Nymphaea*, and the peak of the diatom *Fragilaria leptostauron* all indicated quiet water conditions at 5 - 10 cm. There was no evidence of plankton, and *Nitzschia angustata* was much reduced in this part of the record, showing a decline of epipelic habitats. This could be a consequence of poorer light conditions, perhaps because of higher plant presence. In other words the diatom sequence may represent a fairly standard succession in which abundant pioneer epipelic forms die out as higher plants colonise, changing light conditions and the nature of the substrata. However, there is no evidence for changes in water chemistry, with alkaline conditions throughout.

Similar diatom spectra have been recorded from both Late- and Post-glacial material from the Shetland Islands, with the presence of open ground in the catchment and consequently the inwash of minerogenic material into the lake being the common factor (Birnie, 1981). Only one minor constituent of the diatom record has a characteristically northern or arctic distribution at the present time *(Eunotia praemonas)*; other such types (as described by Cleve Euler, 1951-55) including *Cyclotella antiqua*, *Didymosphenia geminata* and *Pinnularia biceps*, occur in Late-glacial material from Shetland but were absent from Tolsta. Therefore the diatom flora cannot be said to directly indicate low temperatures, but the direct response of diatom assemblages to temperature is as yet imperfectly understood (Hawarth, 1976). What may be more important is the indication of continued alkalinity and minerogenic inwash, which, together with the evidence of *Salix herbacea* and open-ground herbs, may indicate catchment soils disturbed by solifluction. The disturbance appears to be at a minimum at the 5 - 10 cm sample level, when *Nymphaea* pollen was present.

The virtual absence of old palynomorphs in TH2, and the records of olivine in the microscopic preparations rather than the chlorite/ hornblende crystals of TH1, suggests a change in the sediment source. The olivine would be consistent with an origin in the area of the Tertiary dyke, noted by Edwards (1979) to be a likely source for base-rich sediments in the Tolsta deposit.

DISCUSSION

The main additions to existing knowledge about the Tolsta Head interstadial deposit are: the discovery of old palynomorphs, which indicates old organic material is present; the suggestion that the *Salix* pollen is likely to represent *S. herbacea* rather than shrubs; the contrast between the lower and upper sedimentary record of the environment; and the contribution of the diatom record.

The presence of 'old' organic matter is of particular concern in the interpretation of the ^{14}C analysis. However, only the lowest sample, in which contamination may reach 25%, would be likely to substantially affect the date. In a postglacial context, Nambudiri et al (1980) believed that this proportion of pre-Quaternary microfossils could indicate an error of around 1000 years. Fortunately the material originally submitted for ^{14}C analysis from Tolsta came from the topmost 15 cm of the organic bed (Edwards, 1979) where contamination with old palynomorphs is less than 1%. For this date, therefore, the contribution of 'old' carbon may be considered insignificant. Any attempts to date material from lower in the profile should be treated with caution.

The presence, and identity, of the old palynomorphs at Tolsta, and perhaps at other interstadial and lateglacial sites may provide an interesting clue to the nature, and hence origin, of the preceding till cover.

Interpretation of the pollen record as indicating *Salix herbacea* rather than *Salix* shrubs leads to some modification of the conclusions reached by Edwards (von Weymarn and Edwards, 1973; Edwards, 1979) as there is now evidence for continued instability, probably solifluction, throughout the period represented. Increasing *Salix* pollen and *S. herbacea* macrofossils in the uppermost sample, together with the decrease in *Nymphaea*, and the reduction of the diatom population in association with a coarser mineral input, suggest that there is also some evidence for deteriorating climate prior to deposition of the overlying till, and the deposit is not necessarily truncated as originally suggested. The main problem in this is the uncertainty of the status of *Juniperus*. Edwards identified nearly 15% *Juniperus* pollen grains in his topmost sample. This author admits to less experience in identifying *Juniperus*, but was unable to confidently assign more than single grains in any one sample to this category. This discrepancy may be a consequence of sampling accident (the Juniper-rich layer having been missed) or preparation technique, although extensive searches through discarded minerogenic material from the 0 - 5 cm. sample did not reveal Juniper grains.

The difference between the palaeoenvironmental indications of TH1 and TH2 was not remarked upon in the original analysis, perhaps because samples from TH1 were relatively few. The sandy sediment and presence of *Ranunculus fluitans* suggest swifter and possibly more varied flow conditions at the site for TH1 than in TH2. The characteristics of TH2 sediment indicate more stable conditions, for aquatic if not terrestrial life, with only occasional inundation. While direct climatic indicators are absent, such a sequence would be typical of a small depositionary basin becoming increasingly remote from glacial or snowbank effect on the hydrology. Both the change in the hydrological regime and in the provenance of the sediment between TH1 and TH2 could be explained by the disappearance of glacial control. Slower minerogenic sediment accumulation would then be likely in TH2, but this could not be expected to show in the figures for pollen concentration (or, for that matter, in any measure of loss-on-ignition) because of the increased contribution of diatom frustules to the volume of inorganic material.

The diatoms of TH2 show that fresh, alkaline, clear and still-water conditions were attained at the site for sufficiently long for succession from epipelic and planktonic communities to higher plants with epiphytic communities to develop. In common with the *Nymphaea*, the diatoms do not necessarily indicate temperatures any lower than those of the present. It is possible that diatoms are able to colonise and respond to climatic change more quickly than terrestrial higher plants, and that temperatures were close to those of the present day. In this context any analysis of the Coleoptera would be of considerable interest. In the meantime the temperature record must remain enigmatic, but an environment of decreasing glacial or rival influence is strongly suggested.

J. Birnie
Department of Geography
University of Aberdeen
Old Aberdeen AB9 2UF
Scotland

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REPORT ON A QUATERNARY RESEARCH ASSOCIATION FIELD EXCURSION TO ISLAY AND JURA, SCOTTISH INNER HEBRIDES

24th - 28th May 1983

By A.G. Dawson

Introduction

In recent years there have been major advances in our understanding of Late Quaternary environmental changes in western Scotland. These have been outlined in a series of important papers by Sissons, (1981, 1982, 1983). In particular, Sissons (1983 p.167) has suggested that the last ice-sheet in western Scotland would have normally lain through the Inner Hebrides where considerable parts of it would have been land-based and therefore relatively stable. Sissons (1982, 1983) has also proposed that the relatively stable margin of the ice-sheet approximately corresponds with the eastern limit of high rock platform fragments in western Scotland. In these respects the islands of Islay and Jura in the south-west Scottish Hebrides are of considerable geomorphological interest.

The field party assembled at the Bridgend Hotel, Islay on 24th May 1983. The author especially welcomed Dr. Brian McCann, MacMaster University, Ontario, Canada and recognised the contribution of his early work on the raised shorelines of western Scotland (McCann, 1961, 1964). The first day of the excursion was concerned primarily with ice-sheet limits and patterns of raised shoreline displacement in central and western Islay. During day two, the raised shorelines of western Jura were investigated while on day three, ice marginal landforms and raised shore-lines in north-east Islay were examined. The field excursion was concluded on day four after study of certain glacial and periglacial landforms in southern Jura. Most of the geomorphological evidence is presented in the Quaternary Research Association Field Guide for Islay and Jura and copies of this are available from the Q.R.A. Secretary.

Day 1 : Central and western Islay

The field excursion commenced with a visit to a gravel pit on the north shore of Loch Indaal (NR 287635). The exposures show coarse gravels with foreset bedding underlain by contorted sediments and over-lain by raised beach gravels that form part of a shoreline at 22.8 m. It was suggested that the coarse gravels were derived from a former ice mass located over the head of Loch Indaal and were deposited in standing water in the central Islay basin. It was also proposed that the overlying raised beach forms part of a high Lateglacial shoreline that was produced during a period when eastern and northern Islay and Jura remained covered by ice. The possibility was also expressed by John Smith that the seaward edge of the gravel pit, which coincides with the cliffline of the Main Postglacial Shoreline, was located only a short distance from a former ice màrgin in Loch Indaal.

Slightly farther east at West Carrabus farm (NR 308637) evidence was presented for a drop in the Lateglacial marine limit associated with the formation of the central Islay moraine. South of West Carrabus farm, a raised shingle ridge whose crest is at 24 m occurs adjacent to a large area of outwash gravels that decline in altitude westward from 28 m to 21.5 m where they merge with a raised beach at the latter altitude. A raised beach at 21.5-23 m is also eroded along the southern edge of the outwash gravels. As a result outwash deposition and the formation of thd 24 m beach ridge are considered to have occurred when sea-level was at c. 21 m. Members of the party commented upon the difficulty involved in accounting for the presence of the shingle ridge since it was apparently formed after the outwash yet is not likely to have been produced in such close proximity to the inferred ice margin and hence limited fetch conditions. Between West Carrabus farm and Bowmore along the head of Loch Indaal the highest raised beach is at 9.6 m and the highest beach ridge crest is at 12.6 m. A drop in the marine limit of c. 12 m is therefore indicated. John Smith and Murray Gray suggested that high (c. 21 m) raised beach fragments may occur east of the proposed limit. Unfortunately, time did not permit the examination of other raised shorelines at the head of Loch Indaal and hence the problem was not resolved.

The party proceeded to the summit of Borichill Mor (NR 312648) from where the central Islay moraine and associated outwash terraces are clearly visible. The moraine complex is composed of an extensive area of hummocky moraine, c. 500 - 700 m wide that extends south-west - north-east for c. 8 km. The area of hummocky moraine is succeeded westwards by large areas of fluvioglacial outwash that occupy the area between the Gleann Mor river and Craigens fram (NR 297672).

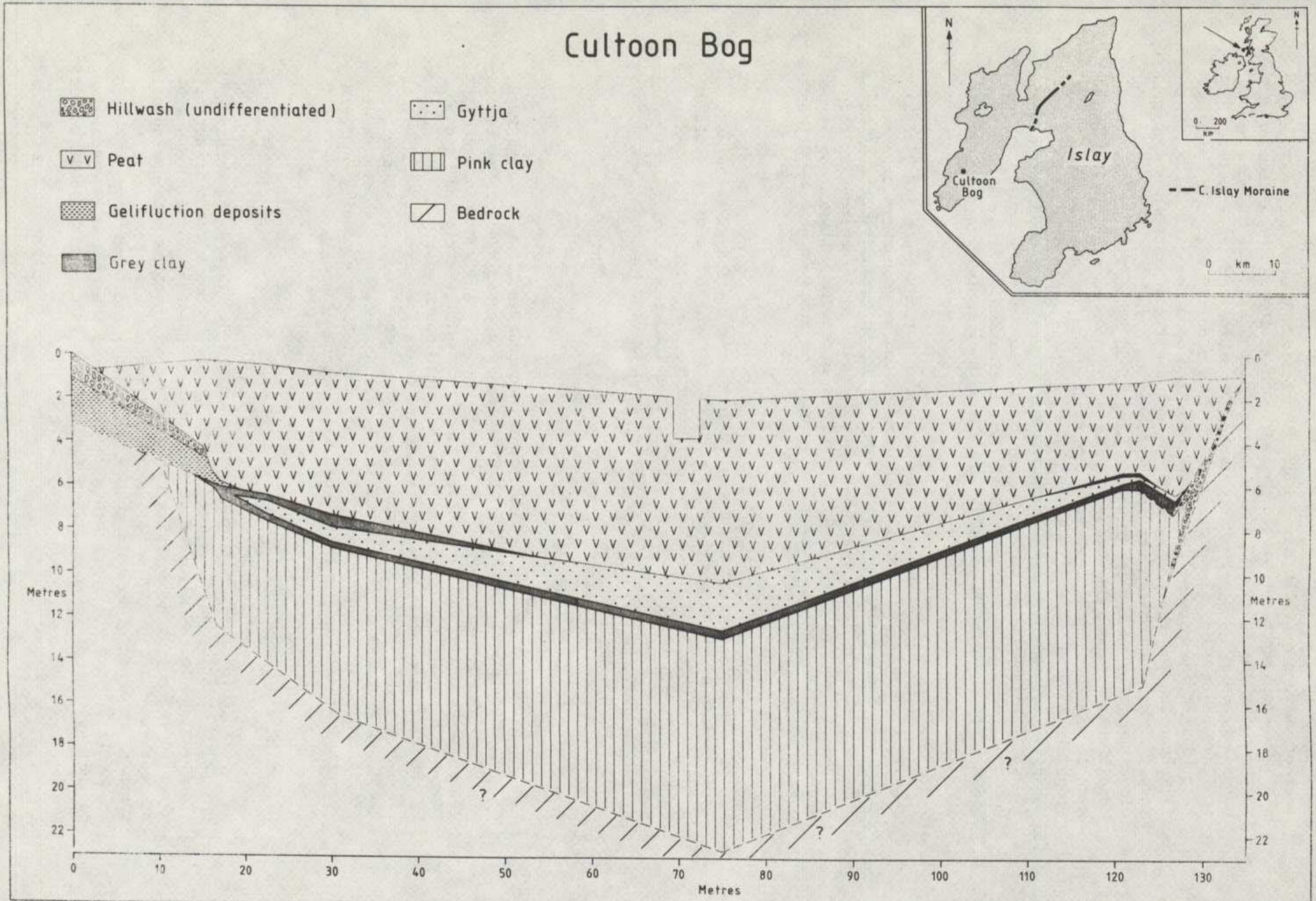
The remainder of Day 1 involved the examination of features located west of the central Islay moraine. Each of the sites visited produced considerable discussion and provided more questions than answers. In the following section, each site is described and the principal problems are outlined. The solutions to many of these problems await the results of future research.

1. Shelly till site (NR 282703)

Exposures of shelly till occur in stream sections at Leck Gruinart farm on the western shore of Loch Gruinart (Peacock, 1974). The till is red/brown in colour (Munsell 7.5 YR 4/4) and contains numerous fragments of the thin-shelled *Palliolum groenlandicum*. Till fabric analysis suggests a former ice movement from the south-south-west; a view supported by the inclusion of Bowmore sandstone and quartzite erratics within the till. Sissons (1983) has commented on the almost complete absence from the Inner Hebrides of records of shelly till associated with ice-sheet glaciation. The party agreed that this may reflect a paucity of field research rather than a genuine regional absence of shelly till.

2. Machir Bay (NR 2163)

In this area a red/brown till (Munsell 7.5 YR 4/4) containing quartzite erratics is widespread in the coastal zone. The thickest till accumulations (c. 30 m) occur at Kilchoman (NR 214635) and extend southwards where they occur as thick banks lodged against the high gneiss cliffs of south-west Islay. The till accumulations are also present farther south at the head of Kilchiaran Bay (NR 204602) and Lossit Bay (NR 182562). At Machir Bay two shell fragments were found in the till. However, it is unclear whether ice moving westwards across Islay was responsible for


Cultoon Bog
Hillwash (undifferentiated)
Peat
Gelifluction deposits
Grey clay
Gyttja
Pink clay
Bedrock
N
Cultoon Bog
Islay
C. Islay Moraine
0 km 10
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km
Metres
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Fig. 1.

till deposition in the lee of the western coastal cliffs or if the till is associated with ice that formerly occupied the North Channel area between Islay and Northern Ireland. The age of the till is particularly important since at Lossit, deposition of the till was responsible for the formation of a former lake at Cultoon (see below).

3. The Loch Gorm area (NR 2366)

Prior to the formation of central Islay moraine, widespread ice stagnation took place in the Loch Gorm area. Fluvioglacial outwash deposits related to stagnating ice descend in altitude westwards towards Machir Bay where they are locally eroded in the Machir Bay/Kilchoman till. Within the central area of the Loch Gorm depression outwash terrace fragments are absent. Synge and Stephens (1966) argued that the distribution of outwash gravels in this area could be used to define a former ice margin. General support for this view was expressed by the field party. However, the inferred ice margin is not associated with a drop in the Lateglacial marine limit since the raised shoreline fragments occur at uniform altitudes (18.4 - 21.5 m) throughout the area.

4. Cultoon Bog (NR 198567)

Cultoon Bog is a large basin that occupies a former valley the seaward end of which is occupied by Lossit Bay till (see above). The basin is remarkable for the great thickness (> 22 m) of unconsolidated sediments enclosed within it. At present the lithostratigraphy is known from 25 boreholes (Fig. 1) and is typically characterised by an upper grey clay, gyttja, lower grey clay, pink clay sequence beneath the peat. The most surprising aspect of the stratigraphy is the great thickness of pink clay; in nearly every borehole the base of the pink clay has not been reached. The ages of the sedimentary units are not known although one may speculate that lake sedimentation was operative during the Late-Devensian when central and eastern Islay remained ice-covered. A core of pink clay was sampled and examined in the field.

6. Kentraw gravel pit (NR 273629)

The basal unit of Kentraw gravel pit consists of c. 2.5 m of current-bedded sands and is unconformably overlain by up to 6 m of coarse outwash gravels. The gravel surface declines in altitude to the north-west from 12 m to 8.9 m. The outwash gravels are succeeded landward by a well-defined shingle ridge whose crest is at 18.8 m. The curvature of the ridge indicates that it was produced by waves travelling from the south-east. The absence of beach gravels overlying the outwash implies that shingle ridge formation preceded outwash deposition. However, this explanation requires that outwash deposition was associated with a former sea-level at or below c. 9 m. Although such an explanation is in accord with the drop in the marine limit associated with the central Islay moraine, the position of the Kentraw outwash lies c. 3 km west of the inferred ice margin. The entire field party remain puzzled by the field relations in the area.

7. Central Islay clays (NR 269650)

Day 1 was concluded by a visit to a clay pit c. 800 m north of

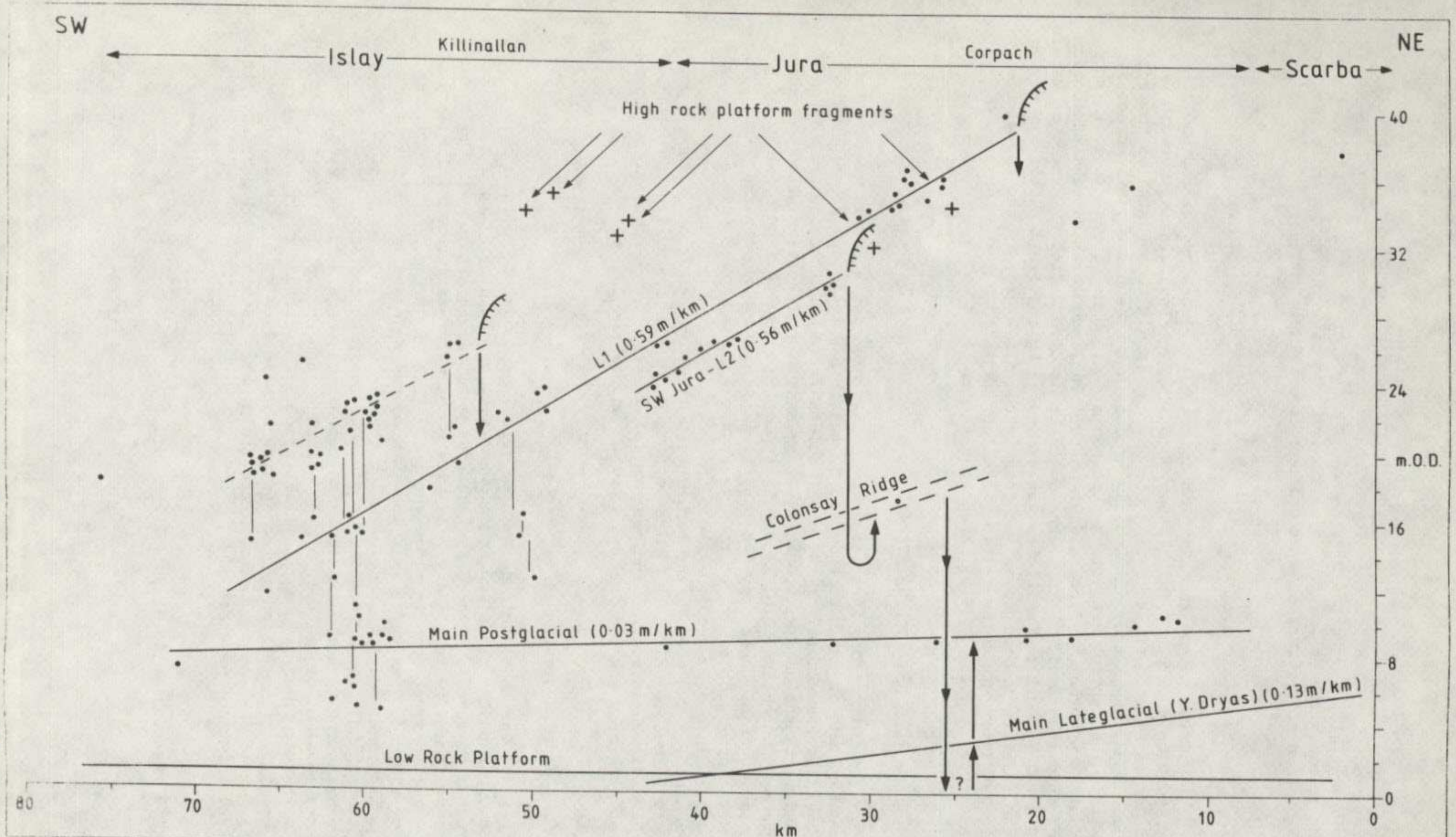

Fig.2 Height-distance diagram and shoreline sequence for Islay, Jura and Scarba, Scottish Inner Hebrides. Terrace fragment altitudes are shown by dots. The parallel dashed lines tentatively represent the approximate sea-level associated with the formation of the Colonsay Ridge (see text).

Foreland House (NR 269650). The surface of the clay forms a flat terrace at 21.5 m, is c. 600 m in length and is dissected by several gullies. The clay is c. 6 m thick and, with the exception of a thin gravel-rich basal layer, is stoneless. Microscopic examination of the clay indicates the presence of halite crystals and thus suggests a marine origin. The age of the deposit and the former sea level to which the clays are related remain unknown. The geomorphological discussions continued after dinner in the Bridgend Hotel Bar and an ample supply of malt whisky stimulated lively debate.

Day 2 : Western Jura

The morning commenced with a boat trip from Pt. Askaig to Ruantallain, west Jura. During the boat trip, the party observed the thick accumulations of till that characterise most of the terrain west of the Paps of Jura. At the western foot of Beinn and Oir, one of the Paps, a 3.5 km linear suite of parallel boulder belts descends seaward from 450 m to 30 m where it is truncated by a fragment of Lateglacial shoreline L2 (Dawson, 1979a). The boulder complex is composed of up to 4 parallel lines of angular quartzite debris, each line rarely greater than 27 m wide and 2.5 m high. The feature is interpreted as a medial moraine supplied by frost-shattered debris from the Beinn an Oir nunatak. The debris was transported seaward by an active ice mass that flowed to the west and northwest between the Paps of Jura and into the Firth of Lorn. The presence of raised shoreline L2 in southwest Jura indicates that this area was deglaciated slightly later than the adjacent coastlines of northeast Islay and northwest Jura.

After landing at Ruantallain, the party observed the first of many spectular unvegetated raised shingle spreads that dominate this area of coastline (Dawson, 1979b). A high rock platform is also present in this area but the feature is not as clear as in northeast Islay (see below). The frontal edge of the high rock platform between Ruantallain and Shian Bay forms the cliffline of the Main Lateglacial Shoreline (Main Rock Platform) which is a continuous feature along the coast of northwest Jura. There are only two locations in west Jura where Lateglacial raised beach deposits are separated from the underlying high rock platform by till. One of these is at Bhrein Port (NR 50688405) and the other is located c. 150 m farther north (NR 50948415) in a stream section where the inner edge of the high rock platform is choked by 0.7 m of creamy till that is in turn overlain by Lateglacial shingle accumulations. Several high Lateglacial coastal terrace fragments occur along this coastline, particularly in the area south of Shian Bay. These form part of shoreline L1 and are of the same age as the highest Lateglacial shoreline in northeast Islay (Fig. 2). Thus it was suggested that shoreline L1 was produced while southwest Jura and east Islay remained covered by ice. Seaward of this shoreline in the Ruantallain - Shian Bay area are extensive unvegetated shingle spreads that attain their finest development in the Loch Aoinidh Duibh area where a staircase of 55 beach ridges extends from c. 36 m to the frontal edge of the high rock platform where they are at c. 21 m. In this area, the relative fall in sea-level to c. 21 m appears to have been uninterrupted by major relative sea-level reversals although possible periods of relative sea-level stability are indicated at the 33.5 - 32.0 m and 28.6 - 27.8 m levels. Lateglacial shingle ridges below c. 21 m are only present immediately south of Shian Bay in an area where the surface of the high rock platform is anomalously low. This area is dominated by a large shingle ridge 480 m in length (the Colonsay ridge) the crest of which declines in altitude southwards from 20.3 m to 18.9 m (Fig. 2). McCann (1964) considered that this ridge represented a major halt in the retreat of the Lateglacial sea while the author suggested that the feature was a large shingle spit produced during a period of falling sea-level. The prevalent opinion favoured Brian McCann's view that the ridge may have been produced either during a Lateglacial marine transgression or during a prolonged halt in sea-level retreat. Donald Sutherland suggested that the feature may possibly correlate with shoreline CLG-2 associated with the Otter Ferry stage in mainland Argyll. Raised shoreline fragments associated with the c. 17 m sea-level to which the Colonsay ridge is related cannot be traced elsewhere in Jura since any shoreline features of similar age would have been later eroded during the Younger Dryas when the Main Lateglacial Shoreline was produced.

The Main Lateglacial Shoreline is a continuous feature between Ruantallain and Shian Bay and is generally 70 - 200 m wide and backed by a c. 20 m high cliff. It has been suggested elsewhere (Sissons, 1974; Gray, 1978; Dawson, 1979b) that this feature was produced by periglacial shore erosion during the Younger Dryas and without exception the field party concurred with this view. The party then returned by boat to Pt. Askaig. After dinner, most participants continued their evaluation of the Islay malt whiskies although a few were still observed drinking beer.

Day 3 : Northeast Islay

The day commenced with a boat trip from Pt. Askaig to Rhuvaal, northeast Islay. Some difficulty was experienced in landing due to a strong sea-swell. However, the party was soon ashore and after a mishap when an eminent geomorphologist almost disappeared in a quaking bog, the landforms were soon discussed. An intertidal rock platform up to 700 m wide extends along most of the coastline of northeast Islay. The platform locally exhibits ice-moulding and its generally flat surface contrasts markedly with the more irregular surface of the Main Lateglacial Shoreline of west Jura, Mull and mainland Argyll. The features were originally interpreted by W.B. Wright (1911) as a "preglacial plain of marine denudation" and have since been described as the Low Rock Platform (Dawson, 1980). Sissons (1983) has suggested that the platform fragments described by the author as belonging to the Low Rock Platform form part of a series of fragments at various altitudes produced during several interglacials. A high rock platform is also exceptionally well-developed in northeast Islay where it is up to 700 m wide and backed by a degraded cliff up to 70 m high. At Aonan nam Muc (NR 400785) the platform is overlain by the Coir Odhar moraine (cf. McCann, 1964, Synge and Stephens, 1966; Dawson, 1979b). This feature is composed of two north-facing arcuate ridges that are separated by an embayment. The outer edges of both moraine fragments are cliffed and in each case the cliff defines the inner edge of a high Lateglacial raised shoreline (L1) at 26.5 m. Landward of the moraine ridges, stratified and sand and gravel deposits are present. The surface of the deposits descends seaward from over 42 m to 30 m and is graded to the raised shoreline (L1). Members of the party agreed that the deposition of the sands and gravels occurred in association with the melting of the Coir Odhar ice and also at approximately the same time as the formation of shoreline L1.

Farther west the inner edge of the high rock platform is visible seaward of Mala Bholsa where it is at 32.7 m (NR 37747780). Sissons (1982) has proposed that most high rock platform fragments in west Scotland were produced by periglacial shore erosion during glacials. The origin of the north Islay feature is problemetic although an estimate for the length of time needed to produce it is instructive. Comparisons with the rates of rock erosion needed to produce the Main Lateglacial Shoreline in northwest Jura suggests that a minimum period of between 8000 and 28000 years is necessary to form the high rock platform. Thus in view of the instability of relative sea-level during glacials, the platform may represent the product of several periods of periglacial shore erosion, the last phase of which was responsible for the present form of the feature. Members of the party agreed with this interpretation.

The party returned by boat to Pt. Askaig on the third day of continuous sunshine. All of the participants were sunburnt and many commented on the truly spectacular landforms of the northeast Islay and west Jura coastlines - in particular the shingle spreads of west Jura. During the course of the evening, even the hardened beer-drinkers were observed sipping the occasional malt whisky. Later in the evening, many were distressed to learn that the hotel supply of Laphroiag malt had been consumed.

Day 4 : Southern Jura

The field excursion was concluded by a visit to a fossil lobate rock glacier at the foot of Beinn Shiantaidh, one of the Paps of Jura (Dawson, 1977). The debris accumulation occurs between 355 m and 400 m O.D. on the margin of an exposed col that separates Beinn Shiantaidh from the neighbouring summit Corra Bhein. The landform has a maximum length of 180 m, is 380 m wide and consists of angular quartzite boulders many of which exceed 0.5 m in diameter. The feature is considered to have been produced during the Loch Lomond Stadial, its formation having been assisted by a favourable east-north-east aspect and the susceptibility of quartzite to frost-riving. The field party agreed with this interpretation. Graham Holmes commented on the observation that the Paps of Jura may have protruded as nunataks above the last ice-sheet in Jura. Under such circumstances, the talus slopes, blockfields and boulder lobes that mantle many of the high quartzite ridges in Jura and north Islay may have been initially produced considerably earlier than during the Loch Lomond Stadial.

Acknowledgements

The author would like to thank Mr. D. Boyd (Islay Estates), Mr. A. MacFarlane (Port Ellen Diving Co.) and Mrs. A. Mottram (Bridgend Hotel) without whose help the field excursion would not have been possible. Gratitude is also expressed to S. Addleton for drawing the diagrams and to K.L. Bass for the use of some unpublished data.

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REPORT ON SYMPOSIUM ON QUATERNARY NON-MARINE MOLLUSCA, UNIVERSITY OF READING, 23 APRIL 1983

By D.T. Holyoak

This informal symposium was organised jointly by the Conchological Society of Great Britain and Ireland and the Quaternary Research Association. Increased interest in Quaternary land and freshwater molluscs was reflected by an attendance of over thirty, many of them being members of both the Conch. Soc. and the Q.R.A.

Thanks are due to the Chairmen, J.G. Evans and R.B.G. Williams, to I.M. Fenwick, D. Hill and M.B. Seddon for help with arrangements and to the Department of Typography and Graphic Communication (University of Reading) for use of their facilities.

Mollusc Analyses of Two Neolithic Sites on the Cotswolds

M. Bell, University of Bristol

Recently Alan Saville's excavation of a henge at Condicote and a long barrow at Hazleton have provided palaeoenvironmental evidence from the Cotswolds. Below the Hazleton barrow was a subsoil feature containing a small assemblage of shade-loving species including *Acicula fusca* and one example of *Vertigo alpestris*. This assemblage probably represents climax woodland significantly predating the monument. Unfortunately the upper horizons of the old land surface were devoid of Mollusca. Post-monument environmental evidence is provided by samples from the quarries, the secondary fill of which contained largely shade-loving species suggesting a degree of regeneration following the monument's construction. An overlying stabilization horizon probably represents a long hiatus when few molluscs were preserved, above this is colluvium with a restricted open country assemblage. The sequence of ecological changes in the Condicote henge ditch 11 km away is closely comparable, though here there are also shade-loving species in the primary fill and the secondary fill has a much larger shade-loving assemblage implying that the henge may actually have been constructed within woodland. Thus both sites have produced evidence of post-monument woodland regeneration suggesting perhaps that Neolithic sites on the Cotswolds may not have been constructed and used in such a uniformally cleared and tame landscape as archaeologists have tended to assume extrapolating from John Evans' work in Wessex.

Molluscan Biostratigraphy of Flandrian Slope Deposits in the South Downs

C. Ellis, Imperial College, London

The biostratigraphy of Postglacial dry valley infill deposits have been studied in Sussex, at Asham Quarry near Lewes and at the Devil's Dyke near Brighton. Sections at these sites show Late-glacial chalky solifluxion deposits overlain by a Postglacial soil that has been buried by colluvial deposits.

Analysis of the sediments has revealed that they contain molluscan assemblages representing biozone z of the Late-glacial and biozones d, e and f of the Postglacial. Particular attention has been paid to the biozones e and f that are attributed to man's influence on the environment. The base of biozone e is defined by the re-expansion of the grassland species as a result of forest clearance by man, and zone f by the appearance of *Helix aspersa*, an introduced Mediterranean species that became widespread in lowland Britain during the Romano-British period. In the later part of zone f the most recent immigrants, the "common" helicellids appear and expand, namely *Cernuella virgata*, *Candidula gigaxii* and lastly *Candidula intersecta*.

Application of Biological Statistics to Fossil Molluscan Data from Asham Quarry

D. Gordon, University of Bristol and C. Ellis,
Imperial College, London

Three biological statistical methods have been applied to the molluscan data from Late-glacial and Postglacial sediments at Asham Quarry, near Lewes. Two species composition parameters proposed by Hurlbert (1971, *Ecology* 52, 577-86) demonstrated low "diversity" in the relatively unstable open country environments of the Late-glacial (biozone z) and during vegetation clearance in the Postglacial (biozone e) and a high "diversity" in the stable woodland environment (biozone d). A marked decrease in diversity is demonstrated prior to the biozone change indicating that these measures are probably more sensitive to environmental change than conventional zoning criteria. Comparison with the absolute number of Mollusca allowed the differentiation of sedimentary from environmental change. These proposals were tested by comparison with a completely independent data set, the life expectancy data of the Juvenile stage of *Trichia hispida*, which also demonstrated the possibility of distinguishing small climatic fluctuations from random fluctuations due to sample error.

The Interpretation of Molluscan Assemblages from Archaeological Deposits

J.G. Evans, University College, Cardiff

Two points are made about molluscan analyses from archaeological deposits. One concerns the use of diversity indexes, the other the context of the assemblages.

Diversity indexes reduce much of the information in an assemblage to a single value, thus allowing easy assessment of a sequence and comparison of assemblages from different sites. Most useful is the Shannon-Wiener index which combines (a) a measure of evenness of the distribution of numbers among the species with (b) the number of species. The Brillouin index incorporates, additionally, the total number of specimens. Diversity indexes are only informative at the level of species diversity and must be used with more conventional ecological interpretations.

The context of molluscan assemblages, especially whether from ditches or extensive level areas, is crucial to their interpretation. Stable grassland may survive for long periods, even in the absence of grazing, if there are no sites for woody species to invade. On the other hand woodland often develops in ditches where breaks in the soil surface allow colonisation.

In the Avebury area of north Wiltshire regeneration of woodland in the later Neolithic took place, although some sites remained as grassland from earlier times. The grassland was tall and ungrazed, so both types of environment suggest a reduction in land utilisation by prehistoric groups. The diversity of the woodland faunas was as high as those of the Atlantic forests, but the total range of diversity in the later Neolithic was much greater.

Taphonomy of Mollusca in an Alpine River

L. Harris, University of Sheffield

A few pioneer studies in fluvial taphonomy have stressed the need to delineate the variables that control transport of organic remains in order to determine the means of accumulation of fossil assemblages. Experimental methods have been used as a means to identify factors that are significant in controlling shell transport by water. Using a recirculating flume attempts have been made to delineate these factors using a range of shell material.

Sediment transport equations suggest that shape, size and density are the most important factors controlling particle transport. Thus a range of shells have been classified into shape categories, and within these categories the average critical entrainment velocity for a number of shells has been determined, varying shell size, density and size of bed material. It is hoped to link critical entrainment velocity of shell particles to these factors in some quantitative way which would aid interpretation of fossil assemblages.

Initial results have shown that size and shape are both significantly correlated with critical entrainment velocity. Multiple regression analysis has shown that size and shape account for 42.7% of the variance in critical entrainment velocity. It is hoped to raise the level of "explanation" by including the variable density in the analysis. This work is at present continuing.

Are there Modern Arctic Analogues for the Mollusca of the Devensian?

D.T. Holyoak, University of Reading

Faunas of land and freshwater Mollusca similar to Devensian fossil assemblages from southern England have been sought at a number of locations in the Arctic. Study regions on two high-Arctic islands with continuous permafrost (Banks Island, N.W.T., Canada; Vest-Spitsbergen) both lacked land snails. Banks Island had two aquatic species, both of them living in habitats with unusually mild thermal regimes. No aquatic molluscs were found on Vest-Spitsbergen. Physical processes and some aspects of the floras in these two regions appear similar to those reconstructed for the Middle Devensian in England, so it is surprising that their molluscan faunas are markedly poorer. One possible explanation for this difference is the shortness of the arctic summer.

Richer land snail faunas were found in rocky coastal sites in arctic Norway, where sea-spray was a source of bases. A large form of *Pupilla muscorum* comparable to the English Devensian form occurred there, in markedly salty habitats. It was accompanied by a number of other land snails, locally including *Vallonia pulchella, Vitrina pellucida, Oxychilus alliarius, Clausilia bidentata, Balea perversa* and *Arianta arbustorum*, several of which do not occur in the Devensian deposits in England. Thus, no close match was found for the English Devensian faunas, suggesting perhaps that the environments examined do not closely match those of the Devensian.

Stoke Goldington (Buckinghamshire) - an Intra-Wolstonian Interglacial Site?

D.H. Keen, Coventry (Lanchester) Polytechnic

The site, which lies beneath a low terrace of the Great Ouse downstream of Newport Pagnell, was found by C. Young in 1981. The deposits fill a channel cut in the Upper Lias. They consist of basal gravels covered by 1.7 m of organic muds topped in turn by two suites of gravel which are divided by a silty clay layer. The organic muds have yielded Mollusca (D.H.K.), ostracods (J.E. Robinson), pollen (R.L. Jones), plant macros (J.H. Dickson), insects (G.R. Coope). The sedimentology and stratigraphy are being described by C. Young and C.P. Green.

The Molluscan sequence from the organic deposits can be zoned into three. At the base a zone dominated by *Valvata piscinalis* and *Bithynia tentaculata* but which also contains *Corbicula fluminalis, Pisidium amnicum* and *P. moitessieranum* also indicative of moving water. In this zone also are small numbers of land Mollusca largely of grassland type *(Pupilla muscorum)* but also the shade demanding taxa *Discus rotundatus, Azeca goodalli, Clausilia pumila* and *Cochlodina laminata.*

The bulk of the samples from the organic mud yield a fauna indicative of a clear pond. The Mollusca are dominated by *Gyraulus laevis* with the pond bivalves *Sphaerium corneum* and *Pisidium casertanum.*

The upper levels of the organic mud contain a more varied planorbid fauna dominated by *Anisus vortex, Armiger crista* and *Hippeutis complanatus* together with *Acroloxus lacustris.* This fauna probably marks the infill of the pond and increasing quantities of aquatic vegetation, a trend confirmed by the increase of the marsh species *Lymnaea truncatula, Oxyloma pfeifferi* and *Vallonia pulchella.*

As a whole the fauna contains 43 taxa. Such a number, and the individual species present, are clearly indicative of warm, probably interglacial conditions. The age of the fauna is unclear although evidence from insect remains suggests an age intermediate between the Hoxnian and Ipswichian.

The Postglacial History of Non-Marine Mollusca in The British Isles

R.C. Preece, University of Cambridge

In recent years much new information has been obtained on the Postglacial (Flandrian) history of non-marine Mollusca in the British Isles. Studies have focussed on three main types of deposit: (1) chalk muds and rubble (solifluxian debris) deposited during the Late-glacial period (13,000-10,000 BP) (2) tufaceous (spring-chalk) deposits spanning the period between 10,000-5,000 BP (3) slope washes resulting from human forest clearance episodes (after 5,000 BP). In many dry valleys in southern Britain it is possible to observe this tripartite stratigraphy in direct superposition. Detailed quantitative analyses of the Mollusca from such profiles led to the conclusion that after the Last (Devensian) Glaciation, land snails recolonized Britain in an ordered sequence. The consistency of this biostratigraphical sequence prompted the definition of a series of *molluscan assemblage zones*, analogous to pollen zones, which are recognizable over large areas of southern Britain. Radiocarbon dating has provided a means of assessing the synchroneity of these zones in different regions and attempts have also been made to correlate them with the standard Godwin pollen zonation. Certain regional differences have emerged both in the character of the zonal assemblages and in their dating. Such data throw considerable light on biogeographical history.

The Biostratigraphy of Flandrian Tufa Deposits in The Cotswold and Mendip Hills

M.J. Willing, University of Sussex

Detailed biostratigraphical study of tufaceous and associated deposits at sites in Kent, has enabled the establishment of a series of local molluscan biozones. The basic pattern of such zones has been recognised from similar deposits at isolated sites in other parts of England and Wales. However, little biostratigraphical work has been completed for sites in south western England, only one at Blashenwell being analysed in any detail.

A study was introduced of the mollusca (plus associated biota, ^{14}C dates of critical zone boundaries being given wherever possible) from -

(1) Deposits within the fairly restricted region of the Cotswold and Mendip Hills,

and (2) where such deposits were of sufficient extent laterally separated sections.

In order to show -

(1) That regional biozones could be isolated and how they compared with those from Kent,

and (2) that although facies variation existed it did not obscure the local picture.

Molluscan biozones resembling Z, E and F were only described from two sections but those similar to A, B, C and D could be seen clearly at all sites. The major differences from the Kent biozones being the much earlier appearance of *Leiostyla anglica* and the late arrival and expansion of *Vitrea crystallina*. A number of local variations were also described.

ABSTRACTS OF PAPERS TO BE PRESENTED AT THE Q.R.A. DISCUSSION MEETING IN BRIGHTON, JANUARY 6-7TH 1984

SOILS AND QUATERNARY LANDSCAPE EVOLUTION

Soils and paleosols: problems and definitions

I.M. Fenwick, University of Reading

Although soil scientists and stratigraphers have employed the term 'paleosol' for several decades it is evident that the criteria by which such a unit is identified are neither clear nor are they always employed. Central to an identification of paleosols is an understanding of soil formation and thus of what constitutes a soil. Either we can look at the internal characteristics of the material - the micromorphology, mineralogy and particle size distribution - or at the relationships between similar materials in the landscape - in the form of geographical associations. In recent years the latter approach has been advocated. This has led to practical difficulties in that rarely are laterally extensive paleosols observable.

If internal characteristics are to be used then, not only do we need to have a clear specification of what combinations are necessary for the recognition of a paleosol, but also we must be sure of the processes responsible for the creation of the various morphological features. This points to the need for work on modern analogues of our fossil soils.

Furthermore, the peculiarly paleosolic problem of post-formational changes must be addressed. Work on the decay of amino-acids in soil organic matter offers the prospect not only of progress in this direction but also of an addition to our range of dating techniques. However, dating of paleosols remains one of the most intractable problems. Interpretation of ^{14}C activity levels in soils has been shown to be an exceedingly complex business. The limitation of ^{14}C dating to <40 ka also offers problems, especially when concerned with interglacial soils. Accordingly, work is proceeding into the use of U series and Thermoluminescence dating of fossil soil materials.

The long-sought goal whereby paleosols could be used like plant and animal fossils to infer former environmental conditions must remain for some time yet an 'El Dorado'. Only when we have answered the many problems relating process to morphology and chemistry will the value of the treasure be revealed.

Composition in the identification of paleosols

D.A. Jenkins, University College of North Wales, Bangor

Soils are the product of processes determined by environmental factors - parent material, topography, climate, vegetation. Environmental changes are therefore reflected in pedogenic processes and thus in the constitution and fabric of soils: it is the latter whose detection can lead to the identification of paleosols. Although paleosols may be readily identified when a major environmental change leads to burial and a new parent material, they may also persist as relic features at depth when a new phase of pedogenesis is superimposed upon an existing profile.

Recognition of such features within the context of profiles of complex horizonation and possibly variable parent material then demands a knowledge of processes and products together with a delicacy of analysis which are not always available.

This paper will review aspects of composition and physical attributes by which paleosols might be recognised. Textural changes can result from pedogenesis (weathering, illuviation, etc.) but may also reflect original (eg. fluvioglacial) or subsequent (eg. aeolian) variations in parentage: fabric, for example preferred orientation, may record both parentage and pedogenesis. Mineralogy in terms of the instability of inherited minerals (eg. etching of silicates) and development of new minerals (eg. clay mineral assemblages) can be helpful, although the processes can be subtle and slow, even on the Quaternary time scale: in particular, attention has been paid to decalcification and to the possible significance of gibbsite and of haematite in reddened soils as indicators of past pedogenesis under different climatic regimes. A more obvious example is the biotic record of change in the form of such 'fossils' as pollen, phytoliths, spicules, diatoms, mollusca, etc., although the problems of differential preservation and adequate background data have only been satisfactorily established for pollen. There is therefore considerable potential in the use of composition in identifying paleosols, but equally a need to refine analytical techniques and for more detailed, integrated case histories.

The role of micromorphology in soil studies

Soil survey of England and Wales

P. Bullock, Harpenden

The chief soil forming processes operative during the Quaternary period in Britain are weathering, podzolisation, gleying, clay translocation, pedoturbation and rubification/ferruginisation. These have led to additions, removals, transfers and transformations of constituents in soils and the development of soil horizons and different soil types. Soils in the landscape are rarely the result of a single process but rather a number of processes, many of which produce features that are not evident to the naked eye.

Micromorphology has become a powerful tool with which to attempt to unravel the usually complex history of soil formation. It is probably the single most sensitive technique for studying various processes acting singly or in combination. It has been used effectively to study weathering of minerals and formation of new minerals. In the case of organic matter it can be used to follow stages in the transformation of plant remains and the new products that form. The most important application of micromorphology is, however, in the study of soil fabric. The fabric of a soil is the end product of the various processes that have operated through time in the formation of a particular soil. A considerable experience has been built up in the last 30 years of the interpretation of soil fabric in relation to soil forming processes and soil forming factors. Sufficient experience has been obtained now to attempt to characterise and interpret the microfabrics of the main diagnostic soil horizons. Several of these will be illustrated and discussed in relation to landform. Micromorphology has for long been mainly a descriptive and observational branch of soil science. It is now entering a more analytical phase and some examples of the potential of this will also be discussed.

Frost effects in soils

B. Van Vliet-Lanoe, Centre de Géomorphologie, Caen, France

Evidence of frost action in paleosols is very common in temperate regions; two types are considered.

First, it may be inherited from former disturbance of the parent material and can influence pedogenesis. A good example of this is the periglacial type of fragipan (former permafrost table) developed in loessic material. Inherited polygonal patterns, geliflucted ground mass with oriented porosity, suprapermafrost silt accumulations, are all elements important enough to influence profile development as lithological parameters.

Secondly, frost may have disturbed the pedological organisation of the profile on a macroscopic scale or on a microscopic scale. Disturbance is mainly associated with deep seasonal frost. It ranges from macroscopic cryoturbation (differential frost heave) and thrusting by frost creep, or even gelifluction, to microscopic disturbance.

Microscopic disturbances result mainly from textural heterogeneity: leached tongues of eluvial material projecting into the illuvial horizon are very sensitive to differential frost heave. In this case, a granular structure due to cryoturbation is seen in the tongue infilling, though the illuvial matrix is only affected by repeated ice lensing and develops, by mechanical processes, a platy to angular blocky structure, covered by silt-capped and bleached skeleton grains (podzol flour). This last feature has been generally considered by soil scientists to be the result of geochemical degradation although no traces of hydromorphy are visible. Clay coatings in pores are also disturbed at a microscopic scale by this mechanism but they are commonly unbleached.

Consolidated soil horizons react like weathered rocks when affected by frost creep or gelifluction. The occurrence of lumps of compacted or cemented material, like the Bs horizon of podzolic soils, leads to the development of very similar microfabrics to those existing in heads or in granitic gruss.

Application of these observations to the "present" lessivé soil of the loess belt of Western Europe, leads us to consider it as, in most cases, a Tardiglacial paleosol on which, during the Holocene, podzolic or acid brown soils developed. Similar conclusions apply to soils on granitic gruss in the French Central Massif.

These results are important for interpretation of so-called "temperate interglacial soils".

Development and significance of the paleo-argillic horizon concept

B.W. Avery, Harpenden

An argillic (Bt) horizon is defined in the U.S. Taxonomy (1975) as a diagnostic subsurface horizon in which silicate clay has accumulated by illuviation, as shown by the vertical distribution of clay-size particles coupled with recognition of translocated clay as macroscopic cutans or in thin sections.

Soils with argillic horizons (chiefly Alfisols and Ultisols in the U.S. system) are widely distributed from the boreal regions to the tropics in various parent materials that contain significant amounts of silicate clay, but are mainly restricted to relatively stable ground surfaces of pre-Flandrian age in areas with a seasonal soil-water deficit. They were first differentiated and mapped in the British Isles during the 1950's, when freely and imperfectly drained types were identified as kinds of brown earth *(sols lessivés* or grey-brown podzolic soils) and grey soil respectively. Concurrent pedological studies in the Chilterns and elsewhere suggested that two genetically distinct variants were represented, and these were eventually (1973) distinguished as argillic and paleo-argillic classes in the system since used by the Soil Survey of England and Wales. The former, with a brownish or grey and brown mottled 'ordinary argillic B horizon', are typically but not exclusively developed in originally calcareous Devensian deposits; the latter, with a strong brown to red or red-mottled 'paleo-argillic B horizon', are typically in 'older drift' or residuum from pre-Quaternary rocks and have complex or polycyclic profiles considered to incorporate the more or less disturbed remains of pre-Devensian interglacial soil formations.

After listing the differentiating criteria currently employed, this paper reviews identification problems they have engendered and discusses the distribution of paleo-argillic horizons in relation to Quaternary landscape evolution. It is concluded that interglacial soil horizons cannot as yet be positively identified in all situations, particularly by internal properties alone.

Soil development in Flandrian floodplains

Mark Hayward, University of Reading

Floodplain investigations can make an important contribution to our knowledge of Quaternary landscape evolution because they are stores of mineral and organic sediment which record environmental change. Sediment undergoes soil formation while it lies within the alluvial tract, and this pedogenesis may be intensified after terracing, while diagenesis ensues after burial. Before these later influences can be assessed, we require a better understanding of soil development in the floodplain environment.

Parent materials exert a strong influence on soil properties during the early stages of soil formation, through, for example, texture and detrital organic matter. However, biological homogenisation may obliterate sedimentary features. In addition, plant growth and decay, and faunal activity, help to produce a recognisable solum in which pedological structures replace the original stratification.

Continued aggradation adds fresh material to the floodplain surface. Later sediment may be subjected to different soil forming processes, being higher above the mean water table, and meanwhile earlier alluvium becomes isolated from the source of fresh organic matter. In the latter case the processes might be viewed as diagenetic rather than pedogenic, and soil features formed earlier are then paleosolic.

Bearing in mind the strong influence of parent materials, the time available for soil formation, and the intensity of the soil-forming processes, are important controls on the expression of pedological features. In the former respect, the amount of reworking of the alluvium is dependent on the geomorphological activity of the river.

These aspects are discussed in relation to soil layering, chemistry, structure and micromorphology, with reference to two case-studies. Implications are considered for Quaternary landscape evolution and paleopedology.

Soils and Quaternary Stratigraphy in the U.K.

J.A. Catt, Rothamsted Experimental Station

The routine mapping of surface soils and studies of their genesis, especially by petrographic methods (granulometry, mineralogy and micromorphology), have greatly expanded knowledge of Quaternary events in Britain. They have shown that thin deposits of Late Devensian loess are widespread in southern and eastern England, and that patches of older loess also occur in favourable situations. Plateau deposits over Chalk in southern England (the Clay-with-flints of geological maps) were found to be derived mainly from a thin veneer of basal Palaeogene sediment. This shows that the sub-Palaeogene surface is more widespread than was previously thought, and was probably exhumed mainly in the early Quaternary. Neogene peneplanation and Plio-Pleistocene marine transgressions had little influence in shaping the present Chalk landscape. The recognition of thin weathered outliers of Late Devensian till has shown that the ice margin reconstructed from supposed end moraines or marginal drainage channels is often inaccurate. In eastern coastal areas the Late Devensian glacial sequence was originally thought to include three lithologically distinct tills, but the uppermost of these (the Hessle) proved to be a Holocene weathering profile, in which oxidation of pyrite and siderite has caused slight reddening to 5m depth and some erratics have been destroyed near the surface.

Laterally extensive buried soils, such as the Valley Farm rubefied *sol lessivé*, can clarify stratigraphic relationships between Quaternary deposits, but they are less common in the U.K. than many other countries. Relict soils with evidence of pre-Devensian pedogenesis are much more common, and often contain micromorphological evidence of development during several Quaternary stages. Characteristic features resulting from soil development during individual interglacials cannot yet be distinguished, but intensity of rubefication, weathering of certain heavy minerals and some micromorphological features are useful for dating within broad limits.

Quaternary soils in the western United States: Use in dating deposits and neotectonic events, and in deciphering paleoclimate

Peter W. Birkeland, University of Colorado, U.S.A.

A wide variety of Quaternary soils have been studied in the western United States, from the alpine soils above treeline to the carbonate and salt-enriched soils of the semiarid and arid areas. Key properties of these soils can be used to assign approximate ages of tills, fluvial deposits and lacustrine deposits. In the more humid environments, the properties are mainly colour, clay accumulation, an index of profile development and rock weathering in the Bw or Bt horizons. Some alpine soils develop more rapidly than do soils at lower altitudes in warmer environments. For tills in the latter environments, soils about 20,000 years old have Bw horizons, 10YR hues, and unweathered clasts; in contrast, soils about 130,000 years old have Bt horizons, 7.5YR hues and weathered clasts. Soil-catenas on moraines of the above ages are characterized by cumulic A horizons at the footslope positions of the younger moraines, and thick well-developed Bt horizons at the footslope positions of the older moraines. These latter slopes may have been quite stable for some time. In the more arid regions, the stages of carbonate morphology in Bk and K horizons, as well as the total amount of carbonate in the soil, are most useful for dating. Both of these latter properties have rates of change that vary with region, and regional rates are reasonably well known. Data on regional clay accumulation are less well known, but that in some aridic soils is so rapid that Bt horizons form in the Holocene.

All of the above soil properties are useful to subdivide local successions and to cautiously suggest long-range correlation. Recent work suggests that some of the earlier correlations, based mainly on soils, have to be altered. Quaternary tectonics are common in parts of the western United States, but datable materials are not always present. The relationships between soil-stratigraphy and the faults or deformed geomorphic surfaces is useful in suggesting limiting ages for neotectonics.

Soils can also be used to suggest or reject marked changes in soil-moisture regime that probably is related to climatic change. Changes in soil-moisture regime are suggested by Bt horizons that are thicker than present moisture penetration, soluble salts in Bt horizons, and carbonate accumulation at two different depths in individual profiles. In other areas the soil chemistry (extracts of Al, Fe and P) and clay mineralogy can be used to suggest that past changes in soil-moisture regime may not have been too drastic.

The Valley Farm Paleosol : A Review

R.A. Kemp, Birkbeck College, University of London

In providing a revision of the Middle Pleistocene stratigraphy of southern East Anglia, Rose *et al.* (1976) introduced for the first time in the United Kingdom the concept of soils (namely the Valley Farm and Barham Paleosols) as stratigraphic units. The Valley Farm Paleosol is recognizable in the field by its red colour, evidence of pedogenic clay translocation and horizontal continuity. It is either buried beneath Anglian glacial or glaciofluvial sediments or exists at the present-day surface in a relict or exhumed form, where it may be mapped as a paleo-argillic soil horizon.

Initial objections concerning the pedogenic and paleoclimatic implications of the paleosol unit have been countered on the basis of standard pedological analyses. Present studies are concentrating on structural, mineralogical and micromorphological aspects and provide the first comprehensive description and pedological interpretation of the paleosol.

The Valley Farm Paleosol, which has been shown to be extensive over large parts of East Anglia, is developed in sand and gravel materials on terrace surfaces of the Proto-Thames. It was originally assigned to the Cromerian interglacial stage on the basis of its stratigraphical relationship to the Anglian sediments and the presumed Beestonian age of the Kesgrave Sand and Gravel parent material. However, it is now recognized that the paleosols on the highest terrace levels have developed over a longer time interval which probably extends from the Bramertonian to the end of the Cromerian.

Significant morphological and micromorphological differences between the buried paleosols on the highest and lowest terrace surfaces indicate the occurrence of a post-incisive chronosequence. Consequently, it appears that the Valley Farm Paleosol should be considered as a complex pedogenic unit representing a series of fossil land surfaces which have been exposed to temperate and cold climate pedogenic processes.

Reference

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The Barham Arctic Structure Soil in East Anglia, England

J. Rose, R.A. Kemp, C.A. Whiteman (Birkbeck College, University of London), P. Allen (City of London Polytechnic) and N. Owen (Mapping and Charting Establishment, R.E.)

The Barham Arctic Structure Soil was defined formally as a buried paleosol formed by periglacial processes during the Anglian glacial stage (Rose and Allen, 1977). It has been recognised throughout most parts of East Anglia and is developed in river and marine sands and gravels of Beestonian age and earlier, and in tidal and freshwater sediments of Cromerian age. It is buried beneath Lowestoft and Cromer Tills. Association with glacially derived wind-blown sediments shows that its formation continued until the area was overridden by Anglian ice.

The most common structures are involutions and wedges forming, respectively, patterns of sorted circles and nonsorted polygons. Both features incorporate adjacent soil material and wind-blown sand. Particularly fine sand wedges are developed showing vertical sand laminations. At a smaller scale are developed subhorizontally banded sand and silt concentrations, and at a microscale silt accumulations infil voids and cap the coarser aggregates, and clay skins formed by previous interglacial pedogenesis show signs of extensive disruption. Evidence for contemporary wind activity is provided in the form of polished flint pebbles, and beds of well sorted coversand and loess.

The association of these structures and sediments at a spatially continuous unconformity in the Pleistocene sediments indicates pedogenesis under severe permafrost conditions with mean annual temperatures at their most extreme below -12°C, a virtual absence of vegetation and extensive thermal contraction. The occurrence of both ice wedges and sand wedges is attributed to variations in mesoscale relief with the latter formed in well drained localities, but both reflecting extensive non-sorted patterned ground. Involutions are associated with moisture retentive parent material and reflect active layer processes in the form of frost boil development, and often incorporate coversand spreads. Thaw-season processes within the active layer are represented by the size differentiation layers and silt accumulations. The aeolian sediments suggest a northwesterly source and wind direction. Relationships of one structure to another suggests that thermal contraction and coversand accumulation is the final process before the landsurface was overridden by Anglian outwash and ice.

The Troutbeck Paleosol, Cumbria, England

John Boardman, Brighton Polytechnic

The Troutbeck Paleosol, developed in pre-Devensian glacigenic sediments, occurs at a number of localities in the Mosedale and Thornsgill Beck valleys, northeastern Cumbria. Irregular bedrock topography afforded protection for the sediments from glacial erosion. Relatively unweathered Devensian sediments overlie the paleosol and generally form the land surface.

The Troutbeck Paleosol consists of a zone of severe rock weathering which includes pedogenic features. At Caral Gully, the severely weathered zone extends to bedrock at a depth of 15m. Contact with overlying sediments is everywhere erosional: soil A horizons are not preserved and sheared blocks of the paleosol are incorporated into the Devensian till. At two sites the weathering decreases in intensity down the profile and relatively unweathered parent material overlies bedrock.

The paleosol may be recognised on the basis of:

1. colour: it is typically yellowish brown (10YR 5/6) having developed from dark grey (N 3/0) and dark bluish grey (10BG 4/1) parent material;
2. texture: it is characteristically developed in sandy gravel;
3. friable, rotted clasts of andesite and microgranite, up to 1m in length, are frequent: these are yellow brown throughout;
4. clay mineral alteration products: illite, kaolinite and vermiculite.
5. iron and manganese staining of clasts;
6. pedogenic features indicative of gleying and clay translocation.

Micromorphological evidence is of considerable value in investigation of the processes responsible for the development of the paleosol.

Formation of the paleosol must have occurred, in part at least, during the Ipswichian Interglacial. However, the scale of weathering suggests development over long periods of temperate conditions. Paleosol evidence for pre-Devensian landscape evolution is rare in northern Britain, particularly within the zone of Devensian glacial erosion.

Holocene Soils in a Semi-arid Environment: The Southern High Plains of Texas

Vance T. Holliday, Texas Tech University, U.S.A.

Recent investigations into the late Quaternary stratigraphic and pedologic history of the southern High Plains (northwest Texas) provide considerable data on the origins and geochronology of Holocene sediments and soils developed therein. The nature and rates of pedogenesis have been studied in a sequence of buried and unburied soils at the Lubbock Lake site, a well-stratified, well-dated, archeological locality. The parent materials are calcareous, eolian sand, all less than 5000 years old. Time is the most significant factor of soil formation. Field, micromorphological, and chemical data indicate that mollic horizons form within 100 years and calcic and argillic horizons form within 350 years. In 3500 years of pedogenesis Stage II calcic horizons form and there is as much as a 10% increase in pedogenic clay in the argillic horizon. Aerosolic additions of clay and carbonate are important local factors of soil formation, promoting the rapid pedogenesis.

Gile (1978) has studied Holocene geomorphic surfaces and associated soils in sequence of noncalcareous sand dunes in an upland setting northwest of Lubbock. Within 5000 years Bt horizons develop in the form of thin bands of pedogenic clay. Within about 10,000 years argillic horizons form. The principal factors of soil development are time and the sandy, noncalcareous nature of the parent material.

Over the past 10,000 years on the southern High Plains landscape stability prevails and soil formation occurs under climatic conditions similar to those of the present. Deposition of parent material takes place during times of departure from the current climate.

Reference

Gile, Leland H. (1979), Holocene Soils in Eolian Sediments of Bailey County, Texas. *Soil Science Society of America Journal*, 43(5), 994-1003.

Holocene soil development in Scotland

J.C.C. Romans and L. Robertson, Macaulay Institute, Aberdeen

The contemporary zonal sequence of soils in Scotland extends from sea level to over 1300 m, and includes brown forest soils, podzols, peaty podzols, sub-alpine podzols and alpine soils. The zonal sequence is described in outline with some comments on the modifying effects of latitude, climate and soil parent material. It represents about 10,000 years of profile evolution in a maritime temperate climate. During the past 5000 years human settlement has had an increasingly important influence on profile development, and the periodic construction of mounds and other earthworks has preserved small sample areas of buried soils from which the general sequence of profile development can be inferred.

Micromorphological examination of soil thin sections, prepared from buried cultivated soils ranging in age from the Neolithic to the Iron Age Roman period, has shown that on flat land sites the profile macro and micromorphology was maintained at the 'acid brown' stage for long periods of time, probably by the transfer of fertility from outfield to infield land by careful livestock management. In these circumstances the soil organic matter content was reduced to a very low level.

A prominant feature in soil thin sections prepared from these buried soils is the presence of soil pores lined with oriented clay within the former cultivated layer and sometimes very close to the old land surface.

Work on Strathallan mound and henge and their associated buried soils has shown that clay was probably mobilized and deposited during periods of rainfall after cultivation of surface soil low in organic matter.

Oriented clay lining soil pores is frequently found in contemporary soils from 30 to 40 cm to ca 200 cm below mineral ground surface. Some of the clay accumulation may be related to the cumulative effects of early subsistence cultivation, as on the Strathallan terrace. Elsewhere at least part may be stratigraphically pre-Neolithic, or may occur in situations where early cultivation is improbable, and requires a different interpretation.

The evolution of soils and relief in Belgium during the last 20,000 years

R. Langohr and J. Sanders, State University of Ghent, Belgium

A series of very detailed soil surveys have been made in the upland areas of the Belgian loess belt. Preference was given to the study of large forested areas for which it is known, from historical data, that the influence of man on the soils and relief has been minimal. Data from soil toposequences which were investigated is used to elaborate a soils-relief evolution scheme for the last 20,000 years in the loess belt.

It seems that the relief was particularly stable during the Tardiglacial (± 18,000-10,000 years B.P.). Indeed, for this period clear traces of one single erosion cycle, only active in the valley-bottoms, are detected. During the Holocene man's activities dominate the continued evolution of the relief.

In the loess belt, the Tardiglacial soil evolution is dominated by an alternating very cold and more temperate climate. Most of the clay migration and accumulation occurred in this period. During the Holocene, bioturbation is the most active soil forming factor.

Surveys in the coversand area of Low Belgium, in the Condroz area of Middle Belgium and on the Ardennes of High Belgium, showed that the data from the loess belt can be extrapolated to the other physiographic units of the country.

ABSTRACTS OF RECENT THESES

Periglacial River Systems : Ancient and Modern

I.D. Bryant

Ph.D. Thesis, University of Reading, 1982

The thesis attempts an integrated geomorphological and sedimentological study of periglacial fluvial systems. This is achieved by a comparative study of modern rivers in the Arctic and Pleistocene alluvial sediments in southern Britain.

Rivers on Svalbard and Banks Island, N.W.T., Canada, possessing 'arctic nival' and 'arctic proglacial' annual discharge regimes were analysed with respect to depositional processes, landforms and sedimentary response. High stage flows associated with the break-up flood appeared to be responsible for the configuration of the larger bars and channels, whilst smaller scale features resulted from modification by subsequent, lower summer discharges. The extent of this reworking was dependent upon the magnitude of summer flows and/or the degree to which bed armouring had occurred during recession of the break-up flood. Thermal contraction polygons may develop in valley floor sediments away from the contemporary channel 'talik', although lateral channel migration results in casting of these features without an attendant amelioration of climate.

Pleistocene fluvial sediments underlying river terraces and floodplains beyond the Devensian glacial limit were examined at outcrop and by borehole records. Facies analyses of the sequences suggests that many accumulated in braided stream environments characterised by mobile channel belts. During periods of inactivity ice wedge polygons were propagated through the sediments. Lateral channel shift later caused casting of these features, followed by erosion to produce extensive unconformities which truncate the previous depositional cycle and contained ice wedge casts. Examination of 'valley brickearth' near Farnham suggested that this sediment is a proximal aeolian deposit of local origin. It is suggested that this interpretation may have wider application. Two generalised models of periglacial fluvial activity are presented.

A Dendroclimatic Analysis of Three Indigenous Tree Species, South Island, New Zealand.

D.A. Norton

Ph.D. Thesis, University of Canterbury, 1983

The main aims of this study were to assess the potential of three indigenous New Zealand tree species, *Libocedrus bidwillii*, *Nothofagus menziesii* and *N. solandri*, for dendroclimatological analysis, to develop tree-ring chronologies from these species and to use the chronologies to reconstruct palaeoclimates.

As a prerequisite to chronology development, the annual nature of *Nothofagus solandri* growth was investigated. Results showed that shoot and radial growth occurred during the summer months only and were closely linked to the course of temperature at this time. Growth ring formation in *N. solandri* was annual.

Thirty-three tree-ring chronologies from the three species were developed from six areas in the South Island; Craigieburn Range, Castle Hill and Flock Hill Basins, Whitcombe Valley, Landsborough Valley, Hollyford Valley and Murchison Mountains. Timberline *Nothofagus menziesii* and *N. solandri* chronologies were the most sensitive to environmental factors, assumed to be climatic (having high mean sensitivity and large common variance values), while *N. solandri* chronologies from bluff sites and subalpine *Libocedrus bidwillii* chronologies were less sensitive. With increasing altitude *N. solandri* chronologies became more sensitive, the most sensitive chronologies being developed from trees growing close to, but not forming, the alpine timberline.

Climatic analysis of the chronologies showed that the timberline *Nothofagus menziesii* and *N. solandri* chronologies were strongly associated with growing season temperature while the three *N. solandri* chronologies developed at montane bluff sites were strongly associated with growing season fainfall. The *Libocedrus bidwillii* chronologies were only poorly associated with climate.

Two reconstructions of past rainfall (for Amberley and Lake Coleridge) and one of riverflow (Hurunui River) were developed using mainly the rainfall sensitive bluff site *Nothofagus solandri* chronologies. The reconstructions extend back to 1840 A.D. Variance explained in calibration ranged from 46% to 60% and in verification from 44% to 66%.

The reconstructed Hurunui riverflow record suggests that riverflows during the period of modern observations may have been higher than the long term average. This reconstruction and future reconstructions from other rivers presents a potentially important source of information for hydro-electric power generation and in irrigation development planning.

New Zealand summer temperature was reconstructed using a grid of seven timberline *Nothofagus menziesii* and *N. solandri* chronologies. 59% of the variance was explained in calibrating the reconstruction while 49% of the variance was explained in verifying the calibration with independent data. Based on this, a reconstruction of summer temperature to 1730 A.D. was developed.

The three climate reconstructions were interpreted in terms of atmospheric circulation patterns affecting New Zealand and were used to verify other proxy evidence for climatic variation during the last 250 years. In the period 1730 to 1900 A.D. cool summers were common in the 1740's, about 1760 and from 1830 to 1860 and were probably periods of increased southwest to west airflows onto the South Island.

Canterbury rainfall, reconstructed as below average in the 1850's, also suggested more persistent westerly airflow at this time. Runs of warm summers occurred more commonly about 1780, from 1790 to 1820 and from 1870 to 1890. Northerly airflows were probably more persistent at these times.

It is concluded from the research presented in this thesis that the potential of dendroclimatology as a means to reconstruct past climates in New Zealand is considerable.

Some Properties of Recent Tills from Central Norway

M.P. Lee

M.Sc. Thesis, University of Keele, 1982

This thesis considers various sedimentological and engineering properties of newly formed glacial tills from central Norway. Previous work on tills is reviewed with reference to morphology, material and process. Laboratory and analytical techniques are applied to samples from various glacier sites in the Jotunheim massifs and from the Hardangerjokul outlet glacier, Blaisen. Matrix properties are measured using the static cone penetration test, whilst strength is determined by the unconfined compression test. The results are interpreted by analysis of variance, correlation, multiple regression, principal components analysis and canonical correlation. Thus the variability in three strength parameters is related to the simpler sedimentological and engineering properties by way of predictive equations. Finally, some pointers to further research are made.

REVIEW

Tracers in the Sea by Wallace S. Broecker and Tsung-Hung Peng
Eldigio Press, Lamont-Doherty Geological Observatory, Palisades,
New York 10964, U.S.A. price 35 U.S. dollars including postage.

This is an unusual and remarkable book. At almost 700 large pages it is excellent value for money. Marine geochemists need read no further - just buy it. Other readers of the Quaternary Newsletter will want to know more.

Ocean geochemistry is a fascinating area for many reasons. To take one, the carbon dioxide content of the atmosphere is controlled by the total CO_2 content of the surface of the ocean. This is kept below the CO_2 level in the interior of the ocean by photosynthesis at the surface, which removes as much carbon dioxide as the nutrient content permits, and thus is controlled by ocean chemistry. This is just one area in which there are links between life in the ocean, chemistry in the ocean, and our climate.

All aspects of ocean chemistry are controlled by a dynamic balance between what enters via rivers, and what exists as sediment. To understand the system, one has to be a Quaternary geologist, and of course Wally Broecker has made many fundamental contributions to our understanding of the Quaternary, especially through his interest in developing a reliable chronology. To understand the system one also needs data, and a major rationale for this book is to shortcut the slow transfer of the findings of the GEOSECS expeditions from the realms of esoteric research publications to essential common knowledge. GEOSECS (Geochemical Ocean Sections) collected water samples, and produced quantities of analytical data, from about 450 ocean stations, each sampled at intervals from sea surface to bottom. Most of this book is very new (references up to 1982, the publication year) and there is a great deal of entirely original presentation and synthesis. The overall balance is best seen through the chapter contents.

Chapter 1 introduces us to elemental cycling from rivers through the ocean to the sediment and explains the distinction between bio-limiting constituents (almost entirely depleted from the sea surface by living organisms), bio-intermediate and bio-unlimiting constituents. The chapter, typically, has 19 Figures and 7 Tables (including the ocean residence times for most elements) and ends with 6 problems and a "superproblem".

Chapter 2 ("The sedimentary Sink") explains why the sediments are as they are, which necessitates a discussion of carbonate chemistry and dissolution (ending, like many other chapters, with a last-minute addition dated September 1982). Chapter 3 ("The atmospheric imprint") deals with gases in the ocean and their exchange with the atmosphere. Chapter 4 covers the cycle of metals in the sea.

Chapter 5 ("How fast does the mill grind?") brings in the radioactive elements: the distribution of ^{14}C in the ocean and atmosphere, the various radio-isotope methods for dating sediments and some of the stratigraphic records that provide the real data for observing how fast the system runs. Chapter 6 ("What keeps the system in whack") discusses the mechanisms which operate to control ocean chemistry. This turns out to be very fascinating because it is clear that the ocean has been perturbed in various directions during the Quaternary. How does it keep control? Have overshoots in the system contributed in any way to climatic change?

In chapter 7 we come on to ocean water circulation and the tracing of water masses: chemical tracers, how mixing between water masses operates. Chapter 8 ("The anthropogenic invasion") looks on the shorter timescale at bomb-produced ^{14}C and tritium, at the freon compounds, and the information these can give us about ocean circulation. Chapter 9 ("Ice sheets and ocean phosphate") discusses ocean chemical changes on a glacial-interglacial timescale and how they may have caused changes in atmospheric CO_2 content. This chapter is also an introduction to Quaternary climatic change. Like the other chapters, this one is fully up-to-date and replete with pointers for future research. Chapter 10 ("Can man override the controls") discusses the fossil fuel CO_2 problem, with excellent discussions of the factors controlling the uptake of CO_2 into the ocean.

The last 100 pages of the book comprise a topic-organised bibliography, each of the 737 references having a one-sentence description. For most topics the bibliography starts around 1970 and ends in the 1980's. One of the few slips I found was in the description of the paper by Urey (1947), so old that Broecker has forgotten what it contains!

I have found this a very easy book to use. It is clearly written and generously laid out; the few of the large pages that do not contain figures contain about 600 words. The "superproblems" are both thought-provoking and humerous.

Many Quaternary teachers must occasionally wonder why the Quaternary needs special attention. This book gives one kind of answer. When we say "the present is the key to the past", the "present" is a short time interval that is long enough to observe the process for which we seek the key. "Long enough" almost invariably takes us into the domain of the Quaternary geologist. No marine geochemist can afford to ignore the changes that have occurred during the Quaternary. This book provides an interface through which the readers of this newsletter can communicate with marine geochemists.

Wally Broecker is primarily a geochemist and one of the purposes of this, a geochemist's book, is to simplify complex observations to a point where they can be explained by simple models. I, like most of the readers of this newsletter, am primarily a stratigrapher, committed to making the record more complex by looking at it more carefully.

I believe both points of view to be essential. This book is a marvellous pointer to those observations that have to be made more carefully, and for what reason, as well as being an excellent textbook.

N.J. Shackleton,
Sub-department of Quaternary Research,
Cambridge.

NOTICES

Fifth Congress - AQQUA

First Circular

The 5th Congress of AQQUA, which marks the 10th anniversary of the Association, will be held October 4-7, 1984 and will have as its theme:

"Pleistocene and Holocene Stratigraphy and Paleoenvironments of Québec and Adjacent Regions".

The main objective of AQQUA congresses is to provide a forum for the discussion of results of specific and more general studies, and reviews of the "state of the art" on Quaternary themes in Québec and adjacent areas (Ontario, New England and the Maritime Provinces).

This is a multidisciplinary congress, thus papers concerned with the theme from any discipline are invited.

Programme and Field Trip

Two days for the presentation of papers are planned which will permit adequate time for their presentation and discussion.

A further two days will be devoted to a field trip to visit the critical stratigraphic sites concerned with the glaciation and deglaciation of the southern Appalachians of Québec and the Saint Lawrence Lowlands.

Location

The Université de Sherbrooke is located in the southern Appalachians of Québec within easy access to most parts of north-eastern North America. Adequate lodging is available in several inns and hotels in the city and special student housing will be organised.

Information

Dr. Hugh Gwyn, Département de géographie
Université de Sherbrooke, SHERBROOKE (Québec) J1K 2R1

XIV INTERNATIONAL BOTANICAL CONGRESS

Under the auspices of the International Union of Biological Sciences

Berlin (West), Germany, 24th July to 1st August 1987

The Programme will comprise 6 Divisions: metabolic botany, developmental botany, genetics and plant breeding, structural botany, systematic and evolutionary botany, and environmental botany. All plant groups will be considered and aspects of both pure and applied research will be covered. Special emphasis will be laid on inter- and multi-disciplinary topics. There will be plenary sessions, symposia, and sessions for submitted contributions (posters).

The Nomenclature Section will convene in Berlin on 20th to 24th July 1987.

Pre- and post-congress scientific Field Trips will be arranged to various parts of Central, South and North Europe.

The First Circular, containing further details and a preliminary registration form, is now available. Send your name and full address to ensure your inclusion on the mailing list. Your early reply will be appreciated.

Chairman of the Organising Committee: Prof. Dr. Dr. h.c. K. Esser.

Enquiries should be sent to the Secretary of the Organising Committee, Prof. Dr. W. Greuter.

Congress Address: XIV IBC, Bot. Garden & Museum, Konigin-Luise-Str. 6-8, D-1000 Berlin (West) 33, Germany.

LONDON QUATERNARY LECTURES

The LONDON QUATERNARY LECTURES series was inaugurated in 1977 by Murray Gray (Queen Mary College), John Lowe (City of London Polytechnic) and Jim Rose (Birkbeck College). They provide an opportunity for final year undergraduate students, part-time and full-time research students, and staff in establishments in and around London, whose interests include Quaternary investigations and associated techniques, to meet regularly, to hear the results of active research projects or reviews of particular fields, and generally to broaden their background knowledge in Quaternary matters. One lecture is presented at each of the three London colleges named above each academic year, and the sessions are regularly attended by students and staff from a number of London colleges and institutions, and occasionally by parties from establishments outside London. The following is a list of the lectures presented since inauguration on 7th December, 1977:-

1. 1977 Professor R.G. West (University of Cambridge)

Aspects of the pre-glacial Pleistocene of the East Anglian coast.

2. 1978 Dr. J.B. Sissons (University of Edinburgh)

The last glaciers in Scotland.

3. Dr. D.Q. Bowen (University College Wales)

How should the Quaternary be subdivided?

4. 1979 Professor F. Oldfield (University of Liverpool)

The role of magnetic measurements in Quaternary studies.

5. J.J. Wymer

Archaeology and Quaternary Geology.

6. Dr. M.J. Tooley (University of Durham)

Flandrian sea-level changes: problems of interpretation.

7. Dr. D.J. Drewry (Scott Polar Research Institute)

Glacio-marine sedimentation: models and implications for glacial geology.

8. 1980 Dr. R. Anderton (University of Strathclyde)

Deformation structures in glacial sediments.

9. Professor W. Watts (Trinity, Dublin)

Change in vegetation and climate of the Florida Peninsula and Mexico in the last 40,000 years: timing and response rate.

10. Dr. H.J.B. Birks (University of Cambridge)

Late Wisconsin vegetational and climatic history of Minnesota, U.S.A.: its relation to the glacial history of the Great Lakes Region.

11. 1981 Dr. A. Goudie (University of Oxford)

The Quaternary of the Tropics.

12. Dr. P. Worsley (University of Reading)

Neoglacial glacier variations - a stratigraphic approach.

13. 1982 Dr. N.J. Shackleton (University of Cambridge)

The Quaternary as seen in the Oceans.

14. Professor F.W. Shotton (University of Birmingham)

The interpretation of the British Quaternary stratigraphy - a personal approach.

15. Professor B. Bannister (University of Arizona)

Dendrochronology - a review.

16. Dr. G.S. Boulton (University of East Anglia)

Glaciation of Spitsbergen and adjacent areas.

17. 1983 Dr. A.J. Sutcliffe (British Museum)

A fresh look at the British Pleistocene mammalian sequence.

18. P. Smart (University of Bristol)

Interpretation of Uranium Series dates from cave deposits in the Mendip Hills.

If you wish your name, or that of your institution, to be added to the circulation list for notification of future lectures then please send particulars to Dr. J.M. Gray, Department of Geography, Queen Mary College, Mile End Road, London E1 4NS.

John Lowe.

CALENDAR OF MEETINGS

6th - 7th January 1984	Quaternary Research Association Discussion Meeting on Palaeosols. Organiser Dr. J. Boardman. Further details and a booking form are issued with this Newsletter.
24th March 1984	Quaternary Research Association 20th Anniversary Dinner at St. John's College, Cambridge. Organisers Dr. P.L. Gibbard and J. Scourse.
14th-17th April 1984	Quaternary Research Association Annual Field Meeting in West Wales, based at Carmarthen. Organiser Dr. D.Q. Bowen. Further details and a booking form are issued with this Newsletter.
4th - 8th May 1984	Quaternary Research Association Short Field Meeting in Mull. Organisers Dr. J.J. Lowe and Dr. M.J.C. Walker. Further details and booking forms will be issued with Newsletter 42.
11th May 1984	Geophysical Section of The Royal Astronomical Society: Physical methods of dating in the Quaternary. Meeting to be held at the Geological Society Lecture Theatre, Burlington House. Organiser, Dr. A.G. Wintle.
4th - 7th October 1984	AQQUA Meeting University of Sherbrooke, Québec. For further details see Notice on p. 55 of this Newsletter.

QUATERNARY NEWSLETTER

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F.M. Synge

It is with great regret that we record the death of the Vice-President of the Q.R.A. Francis Synge. He died on Saturday, 1st October, at his home at Dalkey, Co. Dublin after a long illness. The condolences of the Q.R.A. are extended to Margaret Synge and family.

A full obituary will be published in the next Newsletter.