QUATERNARY NEWSLETTER

No. 48 February 1986

Quaternary Newsletters are issued in February, June and November. Closing dates for submission of copy for the relevant numbers are 1st January, 1st May and 1st October. Contributions, comprising articles, reviews, notices of forthcoming meetings, news of personal and joint research projects, etc. are invited. They should be sent to the Editor of the Quaternary Research Association, Dr. D.T. Holyoak, Department of Geography, University of Nottingham, University Park, Nottingham NG7 2RD.

ISOSTATIC DEPRESSION DURING THE LOCH LOMOND STADIAL: PRELIMINARY EVIDENCE FROM THE GREAT GLEN, NORTHERN SCOTLAND

by C.R. Firth

The Lateglacial period in Scotland is traditionally divided into two phases (Gray & Lowe 1977), the Lateglacial Interstadial (c. 13,000-11,000 a B.P.) and the Loch Lomond Stadial (c. 11,000-10,000 a B.P.). Shoreline studies indicate that the Interstadial was characterised by a period of rapid isostatic uplift (e.g. Sissons et al. 1966, Peacock et al. 1978) that accompanied the decay of the Late Devensian ice sheet (Sissons 1974). However, it is not known with certainty if complete deglaciation of Scotland occurred or whether remnants of ice remained during this period (Sutherland 1984, p. 209). In contrast, it is widely accepted that during the succeeding Loch Lomond Stadial renewed and widespread glacier growth occurred. The effect of this Stadial ice accumulation on the pattern of glacio-isostatic rebound that accompanied the decay of the last Scottish ice sheet is largely unknown (Sutherland 1984, p. 226). However, several studies (Smith 1965, Sissons 1972, Sutherland 1981, 1984, Sissons & Cornish 1982) point to the possibility that the renewed accumulation of ice may have complicated the pattern of deglacial rebound. Evidence is presented here from the Great Glen area, northern Scotland (Fig. 1), that suggests that the growth of ice in ths area during the Loch Lomond Stadial caused a redepression of the earth's crust which had previously been subjected to rapid uplift during the preceding interstadial.

Several conflicting interpretations of the Quaternary history of the Great Glen have been proposed by Synge (1977), Smith, (1977), Sissons

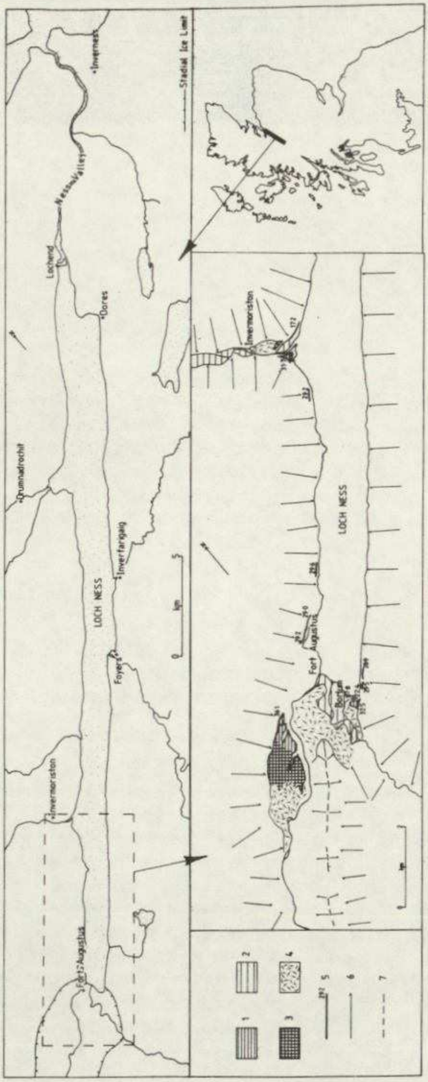

Fig. 1. Location map of the Loch Ness area with detailed morphological map of the southern end of Loch Ness. (1 delta, 2 river terraces, 3 outwash, 4 kame and kettle topography, 5 shoreline fragment with altitude (m O.D.), 6 major slope, 7 major ridge).

(1979a, 1979b, 1981) and Synge & Smith (1980). Each of these researchers concluded that glacier ice during the Loch Lomond Stadial extended northwards along the Great Glen as far as Fort Augustus (Fig. 1). In contrast, the remaining Lateglacial events in the Great Glen are the subject of two radically different interpretations (Fig. 2): these different interpretations are therefore outlined below.

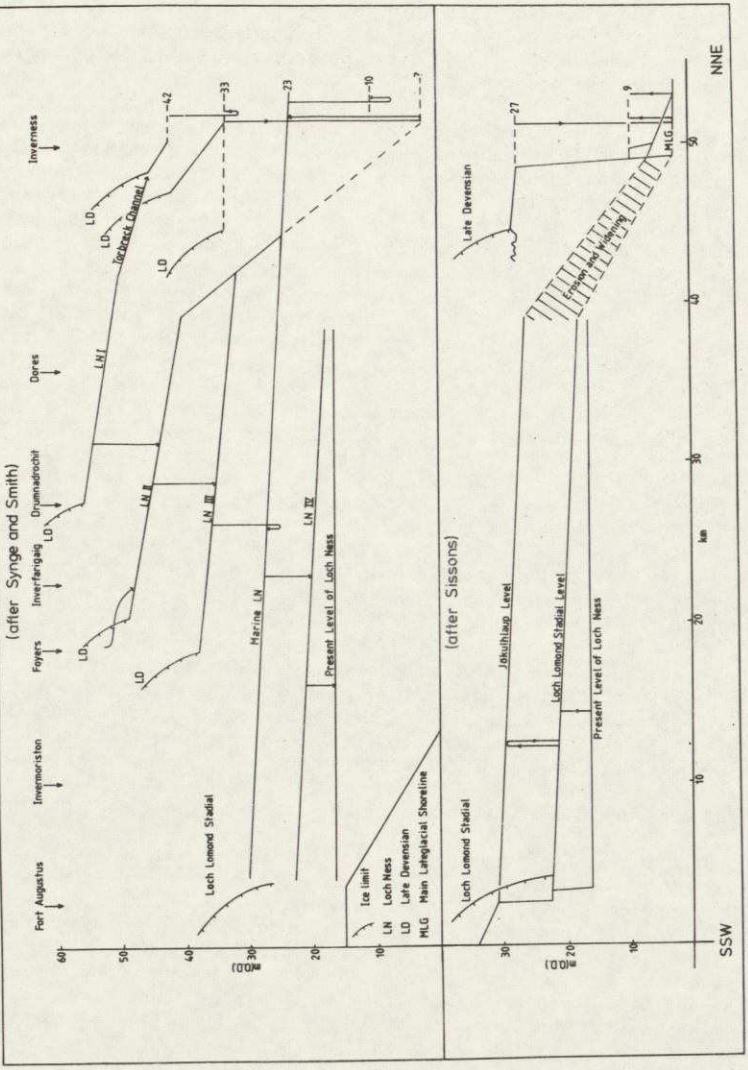

Fig. 2. The two contrasting sequences of events proposed for the Loch Ness region.

(1) Synge (1977) and Synge & Smith (1980) suggested that a series of proglacial lakes (some at levels as high as 56 m O.D.) existed in the Loch Ness area during the decay of the Late Devensian ice sheet (Fig. 2). Synge (1977) postulated that the Loch Ness area was deglaciated by c. 12,800 a B.P. He also suggested that deglaciation was followed during the Lateglacial Interstadial by a marine transgression into the Loch Ness area. This transgressive phase is said to be represented by terraces that occur up to c. 29 m O.D. (Fig. 1). Synge (1977) suggested that continued glacio-isostatic uplift eventually resulted in the isolation of (proto)

Loch Ness from the sea, and that this lacustrine phase is indicated by terrace fragments that occur as high as 22 m at the southern end of the loch. Synge & Smith (1980) did not, however, indicate when this lacustrine phase may have occurred.

(2) A contrasting view was proposed by Sissons (1979a), who suggested that only one prominent raised shoreline is present in the Loch Ness area, and that this was produced during the Loch Lomond Stadial. Sissons (1979a) suggested that this former loch level is represented by terraces at 22.8 m at Fort Augustus and 18 m at Dores. The difference in altitude he attributed to glacio-isostatic uplift (Fig. 2). Sissons (1979a, 1981) also proposed that major changes in the level of Loch Ness took place at the close of the Loch Lomond Stadial due to the catastrophic drainage of an ice-dammed lake of c. 5 km^3 in Glen Roy and Glen Spean. He considered that the subglacial jökulhlaup flood emerged from beneath the ice at Fort Augustus where it deposited an extensive sandur plain. He suggested that the rapid flow of water into Loch Ness temporarily raised the level of the loch by c. 8.5 m and that, following the outflow of the floodwaters at the northern end of the loch, the lake returned to its pre-flood level. Sissons (1981) suggested that the flood waters eroded a trench between the northern end of the loch and the sea and by implication this conflicts with the evidence presented by Synge & Smith (1980) for an Interstadial marine incursion. Sissons (1979a) also proposed that during the Flandrian stage Loch Ness was lowered by c. 2 m from its post jökulhlaup level of 18 m. This value should be revised to c. 3 m since the construction of the Caledonian Canal raised the loch by c. 1 m to its present level of 16 m O.D.

The present author readily acknowledges the raised shoreline fragments around Loch Ness identified by Synge (1977), Sissons (1979a) and Synge & Smith (1980). Similarly, the evidence cited by Sissons (1979a) to justify the formation of the jökulhlaup deposit south of Fort Augustus is accepted. However, the two interpretations of the Late Quaternary history of the Great Glen are based on a limited amount of the available field evidence, and they are difficult to reconcile with additional information.

Firstly, detailed study of the Ness Valley (Firth 1984) has indicated that there is no geomorphological evidence to support the marine incursion into Loch Ness proposed by Synge (1977). The raised shoreline fragments in the Ness Valley identified by Synge as evidence for this marine incursion are interpreted as fluvioglacial outwash deposits, since the down valley gradient of 3 m/km associated with them is considerably steeper than any determined from shorelines in the inner Moray Firth area. On this basis it is concluded that all the raised shoreline fragments around Loch Ness are lacustrine in origin.

Secondly, it is possible to identify more than one raised shoreline in the Great Glen, in contrast with the single prominent shoreline identified by Sissons (1979a). Shoreline fragments occur at several localities (Table 1) and in many cases occur in staircases. The staircases indicate that there were at least three phases of shoreline formation and that three distinct groups of shoreline fragments are present. The lowest group lies between 16-17 m and the other groups occur between 18-23 m and 24-33 m. Each group exhibits a rise in altitude towards the south-west that is attributed here to glacio-isostatic tilting. The lowest and middle groups of fragments form single shorelines which locally are eroded into (and therefore are younger than) higher lacustrine terraces. The

Location	Grid Ref	Mean Altitude	Fragment Length	Feature
Lochend	NH 6002 3838	24.33	300	Terrace
Lochend	NH 6043 3791	25.78	400	Terrace
Lochend	NH 6002 3826	16.65	350	Terrace
Lochend	NH 5983 3805	16.44	400	Terrace
Lochend	NH 6011 3784	17.26	300	Terrace
Lochend	NH 6022 3782	18.10	200	Terrace
Lochend	NH 6006 3787	19.41	600	Ridge
Dores	NH 5961 3537	25.48	250	Terrace
Dores	NH 5993 3537	28.66	600	Ridge
Dores	NH 5975 3508	20.34	600	Ridge
Dores	NH 5895 3348	13.82	350	Terrace
Glen Urquhart	NH 5231 2911	26.98	250	Terrace
Glen Urquhart	NH 5100 2993	27.09	150	Terrace
Foyers	NH 4923 2111	21.00	150	Terrace
Foyers	NH 4913 2098	28.98	250	Ridge
Foyers	NH 4950 2150	17.67	300	Ridge
Invermoriston	NH 4245 1613	31.68	300	Terrace
Invermoriston	NH 4292 1631	17.19	450	Terrace
Invermoriston	NH 4242 1505	29.18	250	Rock platform
Rhubha Ban	NH 3980 1150	29.62	300	Rock platform
Inchnacardoch	NH 3868 1051	29.11	850	Rock platform
Borlum	NH 3908 0889	28.90	200	Rock platform
Borlum	NH 3886 0858	29.53	150	Rock platform
Borlum	NH 3840 0831	32.53	350	Terrace
Borlum	NH 3813 0846	22.37	100	Terrace
Borlum	NH 3846 0851	17.83	350	Ridge
Fort Augustus	NH 3662 0902	36.06	550	Terrace

Table 1. Raised shoreline fragments in the Great Glen area.

highest group of shoreline fragments (24-33 m) can be interpreted as a single shoreline at the northern end of the loch that rises from 24 m at Lochend to c. 28 m at Foyers. However, at the southern end of Loch Ness the higher terraces occur at two distinct levels (29-29.6 m and 31-33 m). This suggests that different patterns of relative shoreline displacement occurred at the southern and northern ends of Loch Ness.

Thirdly, the Interstadial age of c. 12,800 a B.P. proposed by Synge for the supposed marine terraces at the southern end of Loch Ness at 29-30 m is difficult to reconcile with their morphology. Several of these terraces are eroded in Moine schist bedrock unaffected by fault shattering and the platforms are up to 10 m wide and locally up to 2 km in length. As a result their formation within the limited fetch environment of Loch

Ness is unlikely to have been achieved in the environment proposed for this period by Pennington et al. (1972). However, erosional platforms in areas of limited fetch have been reported from lakes in periglacial areas (J. Rose pers. comm., Matthews et al. 1986). Similar erosional features in Glen Roy (Sisssons 1978) and in coastal areas (Gray 1978, Dawson 1980) have been attributed to extensive frost action during the Loch Lomond Stadial. It thus seems probable that the raised rock platforms at the southern end of the Loch Ness were formed during the Loch Lomond Stadial and as such are representative of a former loch level during this period.

Fourthly, Sissons (1979a) identified only one outwash spread (a jökulhlaup deposit) at the southern end of Loch Ness although two separate sandar (one of which is extensively kettled) are present. Sissons suggested that a jökulhlaup deposit extended from a former ice margin 4 km inside the maximal Stadial ice limit to as far as Borlum (Fig. 1). However, detailed mapping (Firth 1984) has indicated that the outwash terrace at Borlum is related to a more advanced ice limit than that associated with the jökulhlaup deposit. Similarly, the proposal of Sissons that the sandur at Borlum is graded to the temporary jökulhlaup level of Loch Ness (c. 32 m; Fig. 2) is difficult to reconcile with the field evidence. The sandur at Borlum and the high-level delta at Invermoriston are graded to shoreline fragments at comparable altitudes (32.5 m and 31.7 m respectively) and it is difficult to conclude that two large features, many kilometres apart and deposited in separate valleys could have been formed at the same time in relation to a very short-lived jökulhlaup level of Loch Ness. In addition, the jökulhlaup deposit is graded to a shoreline fragment at 36.0 m and contrasts with the 32.5 m terrace to which the Borlum sandur is graded. For these reasons it is suggested that the jökulhlaup deposit and the Borlum sandur are separate features and that the latter probably corresponds with the high-level delta at Invermoriston. Since the sandur plain at Borlum lies 0.5 km inside the maximal Stadial ice limit it must have formed as the ice began to retreat from this limit. However, as the outwash at Borlum is associated with a more advanced ice limit than that proposed for the jökulhlaup deposit it is reasonable to assume that the feature at Borlum was formed before the Glen Roy jökulhlaup occurred.

Finally, Synge (1977) suggested that the higher group of shoreline fragments at the southern end of Loch Ness form a single shoreline (i.e. that the high-level delta at Invermoriston at 31.7 m corresponds with the erosional shoreline fragments between Invermoriston and Fort Augustus at 29-29.6 m (Fig. 1). The 2-2.6 m difference in altitude between the platforms and the deltas suggest that they relate to different water levels, since, although different processes were involved in their formation, no variations of this magnitude have been identified from similar situations elsewhere in the inner Moray Firth area and in other studies (e.g. Rose 1978). Since the lower (29-29.6 m) remnants are erosional in origin their lack of development on the high level deltas at Borlum and Invermoriston suggests that they predate these depositional features. This is supported by the fact that the erosional terraces are only found outside the Loch Lomond Stadial ice limit whilst the delta at Borlum lies just within this ice limit. It is possible that erosion at a later date could have destroyed the erosional terraces in front of the higher deltas (in particular Synge & Smith (1980) indicated that the delta at Invermoriston had been disturbed by the dumping of tunnel infill from a nearby hydro-electric scheme). However, there is no evidence to support another period of extensive erosion within the confines of Loch Ness, and inspection of the deposits in the Invermoriston area indicated that the tunnel infill had been deposited below the high level delta and it had not affected the frontal slope of the higher feature.

The proposed sequence of events for the Great Glen area during the Lateglacial is:

(1) The final decay of the Late Devensian ice sheet from the Loch Ness area resulted in the formation of a proto Loch Ness which remained lacustrine throughout the Lateglacial Interstadial. The altitude of this Interstadial loch is unknown, but is thought to have been at least as high as 27-29 m at the southern end of Loch Ness.

(2) Periglacial conditions, which commenced at the end of the Lateglacial Interstadial and continued into the Loch Lomond Stadial, allowed the formation of shore platforms at 29-29.6 m at the southern end of Loch Ness. During this period, renewed ice accumulation resulted in an advance of glacier ice along the Great Glen which reached its maximal limit at the southern end of Loch Ness.

(3) The Stadial ice front retreated to Borlum and high-level deltas were formed at Borlum and Invermoriston. These deltas are related to a loch level of 31-33 m, this being 2-2.6 m higher than that associated with the earlier erosional terraces at 29-29.6 m.

(4) The Stadial ice front retreated 4 km inside the maximal ice limit and the ice-dammed lake in Glen Spean and Glen Roy emptied catastrophically. The resultant jökulhlaup flood formed a large outwash spread south-west of Fort Augustus and temporarily raised the level of Loch Ness by c. 4 m from 32.5 m to 36.0 m at its southern end.

The proposed sequence of events contains one unexplained event, the rise of loch level between the formation of the erosional terraces and the high-level deltas. Evidence of this 2-2.6 rise of loch level is present only at the southern end of Loch Ness and so cannot be explained by a rise in the level of the outlet (for example, if the loch's outlet had been dammed by a landslip). The rise occurred sometime during the Loch Lomond Stadial and had been achieved by the time that the glacier front had started to retreat from its maximal limit. The simplest explanation is that glacier advance during the Loch Lomond Stadial resulted in local isostatic depression of the earth's crust which in turn resulted in a lacustrine transgression at the southern end of Loch Ness. The transgression culminated when the ice reached its maximal extent and the corresponding loch level is probably represented by the high-level delta at Borlum. In contrast, no transgression occurred at the northern end of the loch because the isostatic depression of the earth's crust either did not occur in this area or did not alter the relative level of the outlet with respect to the raised shoreline fragments in the area.

The isostatic depression implied by the evidence from the southern end of Loch Ness has considerable implications. It indicates that the build up of ice during the Stadial was of sufficient magnitude to halt isostatic rebound and re-depress at least part of the earth's crust in northern Scotland. However, since studies elsewhere (Sissons 1972, Sissons & Cornish 1982) imply that dislocation and non-uniform uplift may have been widespread during the Lateglacial, it is difficult to determine the extent of the crustal re-depression.

Acknowledgements

The writer is grateful to Dr. A.G. Dawson and Dr. D.E. Smith for comments on the draft of this paper and to Dr. D.E. Smith for invaluable assistance during shoreline levelling. The work was carried out whilst in receipt of a N.E.R.C. studentship.

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References

Dawson, A.G. 1980. Shore erosion by frost: an example from the Scottish Lateglacial. In Lowe, J.J., Gray, J.M. & Robinson, J.E. (eds.) The Lateglacial of North-West Europe, pp. 45-54.

Firth, C.R. 1984. Raised shorelines and ice limits in the inner Moray Firth and Loch Ness areas, Scotland. Unpublished Ph.D. thesis, C.N.A.A., Coventry (Lanchester) Polytechnic.

Gray, J.M. 1978. Low-level shore platforms in the south-west Scottish Highlands: altitude, age and correlation. Trans. Inst. Br. Geogr., 3, 151-164.

Gray, J.M. & Lowe, J.J. 1977. The Scottish Lateglacial environment: a synthesis. In Gray, J.M. & Lowe, J.J. (eds.) Studies in the Scottish Lateglacial environment, pp. 163-183.

Matthews, J.A., Dawson, A.G. & Shakesby, R.A. 1986. Lake shoreline development, frost weathering and rock platform erosion in an alpine periglacial environment, Jotunheimen, Southern Norway. Boreas (in press).

Peacock, J.D. 1970. Some aspects of the glacial geology of west Inverness-shire Bull. Geol. Surv. Brit., 33, 43-56.

Peacock, J.D., Graham, D.P. & Wilkinson, P. 1978. Late Glacial and post Glacial marine environments at Ardyne, Scotland and their significance in the interpretation of the history of the Clyde sea area. Rep. Inst. Geol. Sci., No. 78/17.

Pennington, W., Haworth, E.Y., Bonny, A.P. & Lishman, F.P. 1972. Lake sediments in northern Scotland. Phil. Trans. R. Soc., Lond., B 264, 191-294.

Rose, J. 1978. River terraces and sea-level change. Brighton Polytechnic Geog. Soc. Mag., No. 3.

Sissons, J.B. 1972. Dislocation and non-uniform uplift of raised shorelines in the western part of the Forth Valley. Trans. Inst. Br. Geogr., 55, 145-159.

Sissons, J.B. 1974. The Quaternary in Scotland: a review. Scot. J. Geol., 10, 34-37.

Sissons, J.B. 1978. The parallel roads of Glen Roy and adjacent glens, Scotland. Boreas, 7, 229-244.

Sissons, J.B. 1979a. Catastrophic lake drainage in Glen Spean and the Great Glen, Scotland. J. Geol. Soc. Lond., 136, 215-224.

Sissons, J.B. 1979b. The limit of the Loch Lomond Advance in Glen Roy and vicinity. Scott. J. Geol., 15, 31-42.

Sissons, J.B. 1981. Lateglacial marine erosion and a jökulhlaup deposit in the Beauly Firth. Scott. J. Geol., 17, 7-19.

Sissons, J.B. & Cornish, R. 1982. Differential glacio-isostatic uplift of crustal blocks at Glen Roy, Scotland. Quat. Res., 18, 268-288.

Sissons, J.B., Smith, D.E. & Cullingford, R.A. 1966. Lateglacial and postglacial shorelines in southeast Scotland. Trans. Inst. Br. Geogr., 39, 9-18.

Smith, D.E. 1965. Late and postglacial changes of shorelines on the north side of the Forth valley and estuary. Unpublished Ph.D. thesis, University of Edinburgh.

Smith, J.S. 1977. The last glacial epoch around the Moray Firth. In Inverness Field Club, The Moray Firth Area-Geological Studies, pp. 72-81.

Sutherland, D.G. 1981. The raised shorelines and deglaciation of the Loch Long/Loch Fyne area, western Scotland. Unpublished Ph.D. thesis, University of Edinburgh.

Sutherland, D.G. 1984. The Quaternary deposits and landforms of Scotland and the neighbouring shelves: a review. Quaternary Sci. Review., 3, 157-254.

Synge, F.M. 1977. Land and sea level changes during the waning of the Last Regional Ice Sheet in the vicinity of Inverness. In Inverness Field Club, The Moray Firth-Geological Studies, pp. 83-102.

Synge, F.M. & Smith, J.S. 1980. Quaternary Research Association Inverness Meeting 1980, p. 24.

KENT'S CAVERN, DEVON: DATING OF THE 'BLACK BAND' AND HUMAN RESETTLEMENT OF THE BRITISH ISLES FOLLOWING THE LAST GLACIAL MAXIMUM

by R.M. Jacobi, E.B. Jacobi and R. Burleigh

Kent's Cavern, beneath Lincombe Hill, Torquay, Devon (NGR SX93456415) has an assured place in the history of cave exploration in the British Isles. Thus, it would seem only fitting that it should yield apparently the earliest evidence, in the form of a radiocarbon date of 14,275 ± 120 a B.P. (GrN-6203), for the 'return' of humans to Britain soon after the last glacial maximum. This date was obtained from collagen from the tibia of a brown bear (Ursus arctos L.; Campbell & Sampson 1971) collected by William Pengelly in January 1867 from a known position in the 'black band' in the 'Vestibule' of Kent's Cavern, and has since been widely cited (see, for example, Campbell 1977, Morrison 1980, Mountain 1979, Wymer 1981). Here we present a new, much later date for another bone from an equally secure context within the black band, showing that the earlier date cannot certainly be linked with human activity or presence. The new date is 11,570 ± 410 a B.P. (BM-2168) for a bovid vertebra recently identified by Andrew Currant, Department of Palaeontology, British Museum (Natural History), amongst material from Kent's Cavern numbered by Pengelly in the BM(NH) collection. The dates of discovery and exact provenances of both of these bones (numbered 1980 and 1951, respectively) are recorded in Pengelly's manuscript 'Exploration Journal' and we are greatly indebted to Mr. B.V. Cooper, Curator of Torquay Museum, for kindly searching for this information.

In his report of the excavation, Pengelly (1868) described the black band as a 'layer of black soil' with 'numerous bits of charcoal', two to six inches (c. 5-15 cm) thick, and identified over an area of about 100 square feet (c. 9.25 m^2) in the Vestibule region of the cave. In part it was sandwiched between a capping flowstone and an underlying red cave-earth. Elsewhere, three to six inches (c. 7.5-15 cm) of red cave-earth intervened between the black soil and the flowstone. In his discussion Pengelly commented (p. 32):

"Were we to speculate respecting the probable interpretation of the Black Band found beneath the Floor of the Vestibule - bearing in mind its very limited area, its position near the northern entrance of the Cavern and within the influence of the light entering thereby, its numerous bits of charcoal and of burnt bone, its bone tools and its very abundant, keen-edged, unworn, and brittle chips and flakes of whitened flint, - we might be tempted to conclude that we had not only identified Kent's Cavern as the home of one of our early ancestors, but the Vestibule as the particular apartment in which he enjoyed the pleasures of his own fireside; where he cooked and ate his meals; and where he chipped flint nodules, and cut and scraped bones into implements of war, for the chase, and for domestic use."

Significant humanly modified items documented by Pengelly as coming from the black band include backed flint blades, when complete most usually chipped to a trapezoidal outline, end scrapers, burins and laterally retouched blades. There is also a much damaged barbed weapon-head of antler (Pengelly's No. 1970) and an eyed bone needle (Evans 1872, figs. 405, 408).

When taken together with the earlier result the new radiocarbon date helps to provide an assessment of the potential age-range of items ascribed by Pengelly to the black band. As neither of the bones that was dated displayed certain evidence of human modification the results cannot be used directly to date human use of the Vestibule area. The new determination does, however, indicate that the contents of the black band can no longer all be assumed to date only to around 14,250 a B.P. To establish a true age or age-range for the human activity in this part of the cave will require some more searching approach. That at least some part, if not all, of the humanly modified items from the black band may be more recent than about 14,250 a B.P. seems to be confirmed by the presence among them of the barbed antler weapon-head. Recent analysis by Julien (1982) of the complex and frequently contradictory chronological evidence relating to such artifacts suggests that they first appeared during the Lateglacial interstadial, most probably about 12,800 a B.P. (*ibid.*, p. 202). Chipped flint and chert items provenanced to the black band have, in turn, good typological analogues in assemblages from other British sites. At one of these, Gough's Cave, Cheddar, this type of assemblage has been shown to be only about 12,000 radiocarbon years old (Burleigh, Jacobi & Jacobi 1985).

We believe that by the Late Devensian human adaptations were sufficient to allow successful exploitation of the periglacial zone. Nevertheless, we must conclude that the evidence from the black band at Kent's Cavern is too ambiguous to help fill with any confidence the gap in the British late Pleistocene archaeological sequence. Following the last ice-maximum around 18,000 a B.P. there is no certain evidence for the presence of humans in Britain before about 12,000 a B.P.

We thank Andrew Currant, Department of Palaeontology, British Museum (Natural History), for kindly making the bovid vertebra available for dating, and also for commenting on an earlier draft of this note.

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References

Burleigh, R., Jacobi, E.B. & Jacobi, R.M. 1985. Early human resettlement of the British Isles following the last glacial maximum: new evidence from Gough's Cave, Cheddar. *Quaternary Newsletter*, no. 45, 1-6

Campbell, J.B. 1977. *The Upper Palaeolithic of Britain: a Study of Man and Nature in the Late Ice Age*. 2 vols. Oxford.

Campbell, J.B. & Sampson, C.G. 1971. A new analysis of Kent's Cavern, Devonshire, England. *University of Oregon Anthropological Papers*, No. 3.

Evans, J. 1872. *The Ancient Stone Implements, Weapons and Ornaments of Great Britain*.

Julien, M. 1982. Les Harpons Magdaléniens. 17e Supplément à Gallia Préhistoire, Editions du C.N.R.S.

Morrison, A. 1980. Early Man in Britain and Ireland. London.

Mountain, M.J. 1979. Exploitation and adaptation in pre-agricultural communities. In J.V.S. Megaw & D.D.A. Simpson (eds.), Introduction to British Prehistory, Leicester University Press.

Pengelly, W. 1868. Third Report of the Committee for Exploring Kent's Cavern, Devonshire. Rept. 37th Meeting Brit. Assoc. Adv. Sci., Dundee, 1867, pp. 24-34.

Wymer, J.J. 1981. The Palaeolithic. In I. Simmons & M. Tooley (eds.), The Environment in British Prehistory, pp. 49-81.

AN ATTEMPT TO LOCATE THE "WOLVERCOTE CHANNEL" IN THE RAILWAY CUTTING ADJACENT TO WOLVERCOTE BRICK PIT

by D. Bridgland and P. Harding

Wolvercote Brick Pit, it has been claimed "... is the most important Palaeolithic site in the Upper Thames Valley" (Wymer 1968, p. 87). The site is no less important for Pleistocene studies, since the artefacts have been derived from a channel, cut into Oxford Clay bedrock, which contains interglacial sediments yielding faunal and floral remains. No extensive exposures of these deposits have been available since the 1930's and residential development appears to preclude re-investigation in the old pit. No modern studies have, therefore, been carried out, although contrasting interpretations of the site have been put forward in recent years (e.g. Bishop 1958, Tomlinson 1963, Evans 1971, Shotton 1973) and a temporary exposure in the channel was described from the east side of the brick pit by Briggs et al. (1985).

It is difficult to determine from the early descriptions of the site (Bell 1894, 1904, Pocock 1908, Sandford 1924, 1926) the exact location and orientation of the channel within Wolvercote Brick Pit, although it was clearly present at the southern end. Equivalent deposits were, however, reported from temporary exposures in Banbury Road (SP 503106; Wymer 1968), suggesting an east-west trend. This strongly suggested that the channel might intersect at some point with the cutting through which the Oxford to Bedford railway passes less than 100 metres from the western edge of the brick pit. No published description of the geology of this cutting has been located to date, however.

Although there have been few recent opportunities to re-evaluate the Wolvercote deposits, the past two decades have seen an expansion of work and interest in the Upper Thames. A number of important new interglacial sites have been discovered (Fig. 1), ranging from Sugworth, associated with Plateau drift and thought to be Cromerian (Shotton et al. 1980), to Stanton Harcourt, where organic deposits occupy a channel beneath Summertown-Radley Terrace deposits (Briggs et al. 1985). The latter is of considerable interest, since interglacial faunas had previously been

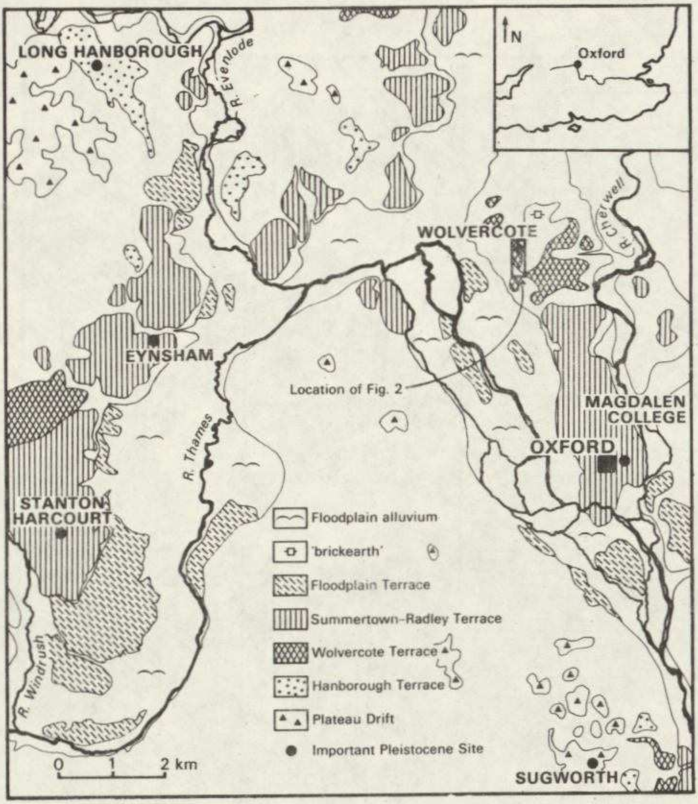

Fig. 1. The location of the Wolvercote site in relation to the terraces of the Upper Thames.

described in the upper levels of the Summertown-Radley aggradation at a number of sites, (Sandford 1924, Dines 1946, Briggs et al. 1985), notably Eynsham and Magdalen College, Oxford, both re-investigated by the Nature Conservancy Council (NCC) during 1984 (Bridgland 1985). Many authors have equated the Wolvercote Channel interglacial with that in the Summertown-Radley Terrace, even though the channel is at Wolvercote Terrace altitude, apparently cutting through gravels of the latter terrace (Sandford 1924). The discovery that two separate interglacial episodes may be represented in the Summertown-Radley sequence raises questions about which, if either, can be correlated with the Wolvercote Channel. As the Wolvercote Terrace is generally considered to contain outwash from the Wolstonian glaciation of the Southern Midlands (e.g. Bishop 1958), this raises the possibility that three post-Wolstonian/pre-Devensian warm periods may exist in the Oxford area. The present climate of controversy and interest makes a new investigation of the Wolvercote material highly desirable.

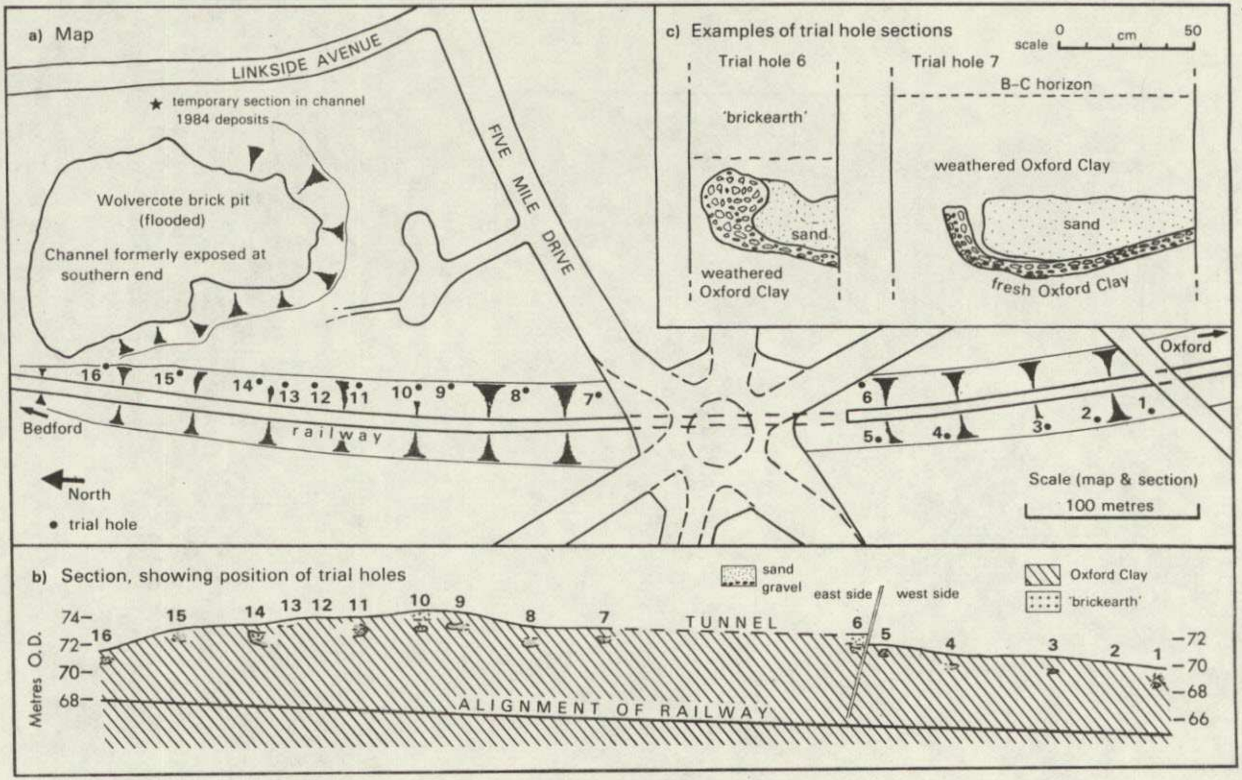

Fig. 2. Map and geological section, Wolvercote railway cutting, Oxfordshire.

In April 1985 the authors carried out excavations in the Wolvercote railway cutting on behalf of the Geological Conservation Review Unit of the NCC, as part of that unit's site investigation programme. Had this work successfully located Wolvercote Channel deposits, an appropriate section of the cutting would have been considered for conservation as a geological Site of Special Scientific Interest. Regrettably a series of trial pits dug at regular intervals along the cutting (Fig. 2) encountered only pockets of sand and gravel preserved in the top of the Oxford Clay. These often retained traces of fluvial bedding, albeit considerably disturbed (Fig. 2, inset). Occasionally a layer of silt/'loam' (brickearth) was preserved beneath the topsoil, but despite the cutting north of the tunnel falling within the area mapped as Wolvercote Terrace (Geological Survey, New Series, Sheet 236), the Oxford Clay could normally be traced to the surface between the gravelly pockets. The pockets may be of periglacial origin (involutions) or they may result from the loading of thin fluvial deposits into the top of the clay; the latter process is, in any case, probably promoted by periglacial conditions and may be a normal part of the formation of involutions. The above observations appear to confirm the description of the Wolvercote site by Pocock (1908, p. 89), who described gravel in "holes in the Oxford Clay" on the western side of the pit, near the railway. Samples of this gravel were collected and will be analysed in the future as part of work in progress on recent temporary sections which exposed Wolvercote Channel sediments on the opposite side of the brick pit (see above, Fig. 2 and Briggs et al. 1985).

Any possibility that the channel intersects with the railway cutting further south seems to be ruled out by this investigation, assuming its width is not drastically different from the published descriptions, which place it at c. 50 m. The area of tunnel under the roundabout could not be investigated, but it seems unlikely that the feature could pass through this area with no indication of its margins in holes 5, 6 or 7 (Fig. 2). It must be concluded that further work in the railway cutting in connection with the Wolvercote interglacial deposits would be fruitless. This note is intended primarily to record these facts and prevent any future waste of resources in a repeat exercise.

Acknowledgements

The authors wish to thank the Nature Conservancy Council (Geological Conservation Review Unit) for funding the operation and British Railways for allowing the investigation to take place. They are grateful to Mr Ed. Oliver for lettering the diagrams and to Mrs Shirley Drake for typing the manuscript.

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References

Bell, A.M. 1894. Palaeolithic remains at Wolvercote, Oxfordshire I & II. Antiquary 30, 148-152, 192-198.

Bell, A.M. 1904. Implementiferous sections at Wolvercote (Oxfordshire). Q. Jl. geol. Soc. Lond. 60, 120-132.

Bishop, W.W. 1958. The Pleistocene geology and geomorphology of three gaps in the Midland Jurassic escarpment. Phil. Trans. R. Soc. B 241, 255-306.

Bridgland, D.R. 1985. Upper Thames sites at Magdalen College deer park and Eynsham Station Pit, Oxfordshire. Earth Sci. Conservation 22, 37.

Briggs, D.J., Coope, G.R. & Gilbertson, D.D. 1985. The chronology and environmental framework of early man in the Upper Thames Valley. Brit. Archaeol. Rep. 137, 176 pp.

Dines, H.G. 1946. Pleistocene and recent deposits. In Richardson, L., Arkell, W.J. & Dines, H.J. Geology of the country around Witney. Mem. Geol. Surv. U.K.

Evans, P. 1971. Towards a Pleistocene Time Scale. Part 2 of 'The Phanerozoic Time Scale - A Supplement'. Spec. Pub. Geol. Soc. Lond. No. 5, 123-356.

Pocock, T.I. 1908. The geology of the country around Oxford. Mem. Geol. Surv. U.K.

Sandford, K.S. 1924. The river gravels of the Oxford district. Q. Jl. Geol. Soc. Lond. 80, 112-179.

Sandford, K.S. 1926. Pleistocene deposits etc. In Pringle, J. (et al.). The geology of the Country around Oxford. Mem. Geol. Surv. U.K.

Shotton, F.W. 1973. English Midlands. In Mitchell, G.F., Penny, L.F., Shotton, F.W. & West, R.G. A correlation of Quaternary deposits in the British Isles. Geol. Soc. Lond. Spec. Rep. No. 4, 99 pp.

Shotton, F.W., Goudie, A.S., Briggs, D.J., & Osmaston, H.A. 1980. Cromerian interglacial deposits at Sugworth, near Oxford, England, and their relation to the plateau drift of the Cotswolds and the terrace sequences of the Upper and Middle Thames. Phil. Trans. R. Soc. B. 289, 55-86.

Tomlinson, M.E. 1963. The Pleistocene Chronology of the Midlands. Proc. Geol. Ass. 74, 187-202.

Wymer, J. 1968. Lower Palaeolithic Archaeology in Britain, as represented by the Thames Valley. John Baker, London. 429 pp.

A PRELIMINARY REPORT ON THE QUATERNARY SEDIMENTS AT LEYS GRAVEL PIT, BUCHAN, SCOTLAND

by A.M. Hall and E.R. Connell

Introduction

Recent workings at Leys gravel pit (NK 006525), Buchan, have revealed a previously unknown sequence of glacifluvial gravels and sands overlain by head and till. The site is located at c.65 m O.D. on the northern margin of the North Ugie Water valley 4.2 km N. of Mintlaw (Fig. 1) and stands c. 12 m above the Sandhole fan delta, the highest local representative of the Late Devensian glacifluvial and glaciolacustrine fill in the Ugie valley (Connell in Hall 1984, pp. 83-86). The Kirkhill site with its complex Middle to Late Pleistocene sequence of glacial, periglacial and glacifluvial deposits and associated palaeosols lies 0.6 km to the NE. (Connell, Edwards & Hall 1982, Connell & Hall in Hall 1984, pp. 59-81). Local geology comprises Dalradian metasediments intruded by basic igneous rocks and by a pair of broad W.-E. trending felsite dykes. The Leys deposit occupies a topographic and bedrock hollow eroded in metasediments between the dykes.

Two contrasting models currently exist for the Devensian glaciation of this part of Buchan. Following Synge (1956), a number of recent authors have suggested that the Ugie valley lay within an unglaciated enclave in the Late Devensian. The principal evidence for this is the existence of thick glaciolacustrine deposits within the valley (McMillan & Aitken 1981) but the view that large parts of Buchan were unglaciated in the Late Devensian is backed by drift stratigraphy in coastal districts (Hall 1984, Sutherland 1984) where inland tills can be observed to pass below coastal drift sheets and by the greater degree of periglacial modification of drift sheets in inland areas as compared with coastal districts (Synge 1956, Hall 1984). An alternative model is that the whole of Buchan was ice-covered in the Late Devensian with enhanced cryogenic disturbance in inland areas reflecting early deglaciation and activity during the Loch Lomond Stadial (Clapperton & Sugden 1975, 1977).

The only published data on the site is a brief description in Hall (1984, p. 82) who mentions the wide range of periglacial features displayed by the head and the existence of large wedge structures in the glacifluvial gravels. The aim of this paper is to provide a more detailed discussion of the sediments at Leys and to explore possible correlations between the Leys sediments and the Kirkhill sequence. Gravel extraction continues at Leys and the sequence is being monitored.

Description of Stratigraphy

The maximum thickness of deposit revealed in the pit is 6 m and bedrock is not seen. Working faces are up to 3.5 m high and show beds of gravels and sands overlain by up to 1.6 m of head. A veneer of cryoturbated till, up to 1.2 m thick, caps the sequence in Section E (Fig. 2).

A. Gravels and sands

The gravels are coarse, with occasional boulders up to 1 m in diameter, and contain cobbles and pebbles in a matrix of white to pink felsitic sand. Clasts comprise over 90 per cent felsite together with basic and intermediate igneous rocks, gneisses, vein quartz and occasional schists (Table 1).

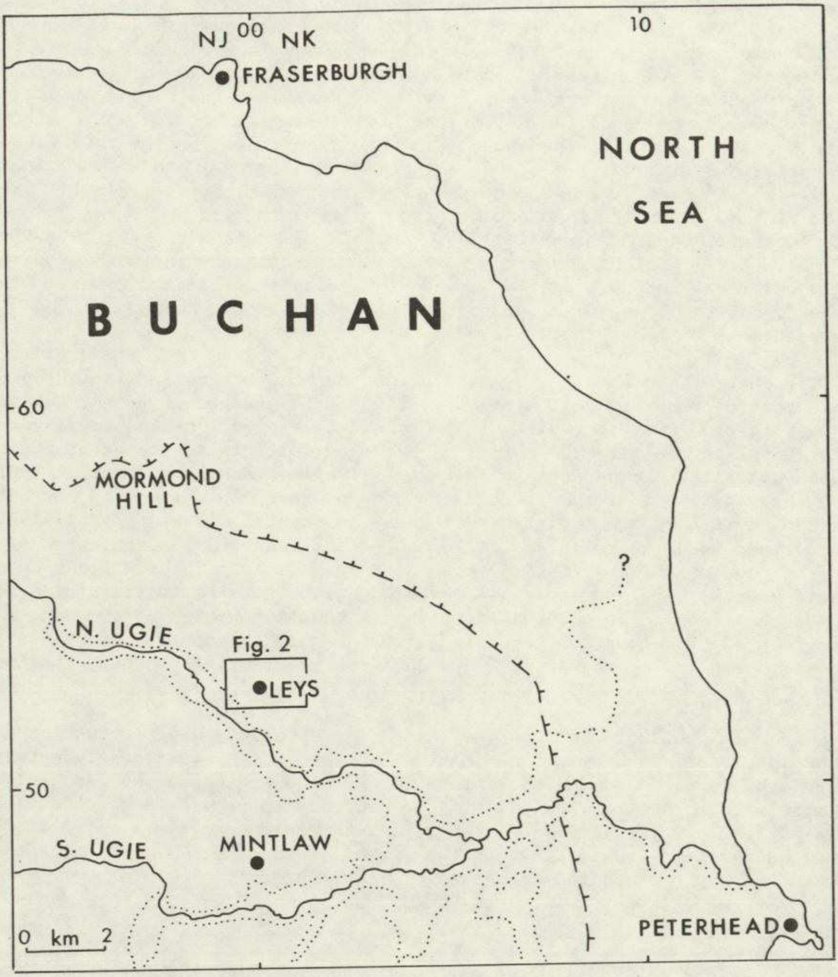


Fig. 1. Location of the Leys gravel pit. For explanation of symbols see Fig. 2.

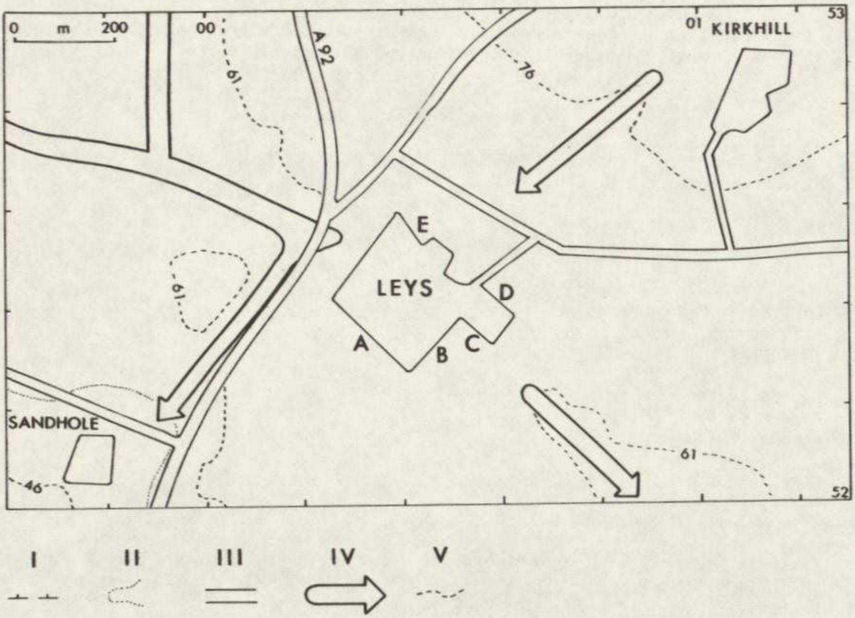


Fig. 2. Setting of the Leys gravel pit.

I Generalised limit of coastal ice masses during the Late Devensian (after Synge 1956);

II Limit of the Late Devensian glacifluvial and glacilacustrine fill of the Ugie Valley (mainly after McMillan & Aitken 1981);

III Road; IV Meltwater Channel; V Contours (metres);

A-E refer to important sections in the pit.

In Sections A-D (Fig. 2), the main primary structure in the gravels is crude parallel stratification. In all faces impersistent beds and lenses of sand are common and one prominent sand layer, with trough cross-stratification, can be traced over a distance of 80 m in Sections A and B. Section E shows large-scale planar cross-stratified gravels with crude fining-upwards sequences dipping at 20-25°. Orientation of both planar and trough cross-stratification indicates deposition by water moving towards the NW.

Post-depositional disturbance of the gravels is widespread and takes two main forms:

(i) Folding; Bedded gravels and sands in Sections A-D show various low amplitude flexures and higher amplitude folds. Three symmetric and assymetric folds in Section A have amplitudes of c. 4 m and wavelengths of

Table 1. Stone counts from Leys gravel pit. (P = present within the unit even if not detected in stone count samples).

Deposit and Size Fraction	% Stone Counts: Lithologies												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Leys Till, Face E (100 stones, 10-40 mm)	3	11	22	-	14	-	-	-	P	P	6	20	24
Leys Head, Face A (100 stones, 10-40 mm)	4	1	89	-	1	-	-	-	P	-	P	P	5
Leys Gravels Face A (100 stones, 10-40 mm)	2	P	96	-	P	-	-	-	-	-	-	P	2
Kirkhill Upper Till (700 stones, 8-16 mm)	8	8	10	-	17	P	P	-	P	-	4	20	33
Kirkhill Lower Till (2100 stones, 8-16 mm)	9	21	15	P	1	-	5	P	P	-	7	17	25

Key to lithologies:

A vein quartz/quartzite, B red granite, C felsite, D grey (Strichen) granite, E basic igneous, F rhomb porphyry, G yellow-brown red sandstone, H red-stained ORS quartzite cobbles, I flint, J red clay clast (Strathmore Drift ?), K phyllite, slate and hornfels, L pelitic schists, M psammites, mainly quartzitic.

c. 20 m (Fig. 3). An extensive sand bed within the folded gravel sequence in Sections A and B contains numerous internal faults but faults are not generally apparent in the gravels, possibly due to their coarseness and poorly-sorted nature.

(ii) Localised collapse and slumping; Folded gravel beds in Sections A-D are in places disrupted by large wedge-shaped structures (Fig. 4). Most wedges are symmetric with upper widths which may exceed 10 m and taper with depth to penetrate beneath the base of exposures. Wedge margins are defined by lines of steeply-dipping clasts and may be planar and follow high angle normal faults or step-like and follow apparent knee-folds. The wedge fill varies in character from downwarped beds of gravel which retain primary parallel stratification to dislocated pockets of crudely sorted but unstratified granule to boulder gravel.

Reconstitution of gravel beds preserved in the wedges by down-warping and collapse and the widespread evidence of truncation of anticlinal fold crests indicates that several metres, at least, of gravel was removed by erosion before deposition of flat-bedded sands (Wedge D, Section D, Fig. 4) and later head.

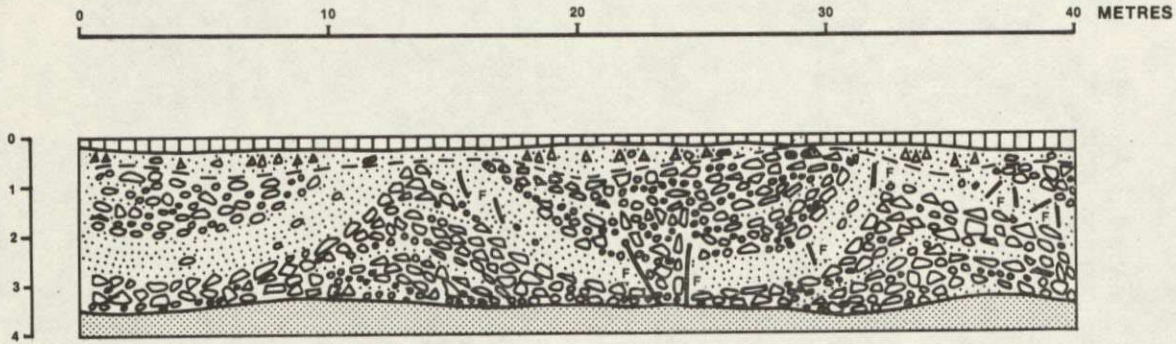


Fig. 3. Folded gravel and sand sequence, Face A.

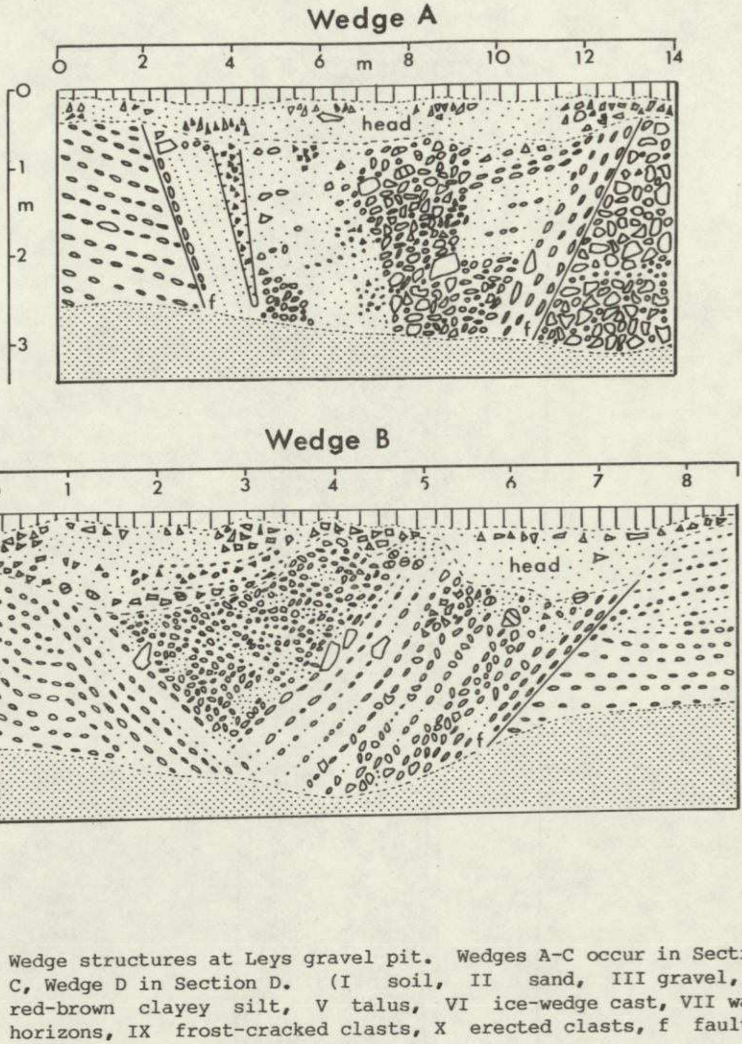
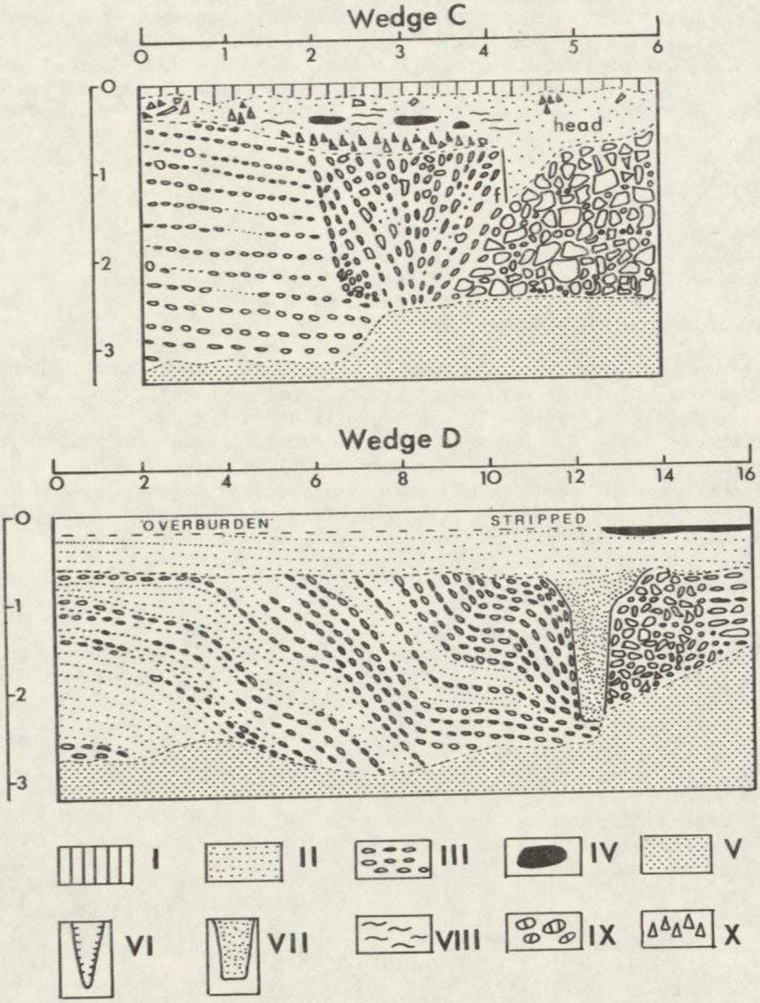


Fig. 4. Wedge structures at Leys gravel pit. Wedges A-C occur in Section C, Wedge D in Section D. (I soil, II sand, III gravel, IV red-brown clayey silt, V talus, VI ice-wedge cast, VII wash horizons, IX frost-cracked clasts, X erected clasts, f fault).



Wedge C
0 1 2 3 4 5 6
0
1
2
3
head
f
Wedge D
0 2 4 6 8 10 12 14 16
0
1
2
3
OVERBURDEN
STRIPPED
I
II
III
IV
V
VI
VII
VIII
IX
X

The gravels are locally stained by Fe and Mn oxides or leached of these oxides and lightened in colour. The degree of staining or bleaching varies between sections and even between adjacent clasts. The overlying head includes frost-shattered, previously-rounded clasts which display either stained or bleached exteriors but fresh frost-shattered faces. The dominant felsite clasts in the head are unaffected by staining and bleaching. In Section C, ice-wedge casts infilled by unstained sand and gravel penetrate stained gravels. These observations suggest that the main phase of staining and bleaching of the gravels took place before head accumulation.

B. Head

The gravels are overlain by 0.4-1.6 m of brownish head generally comprising angular, tabular felsite clasts with occasional erratics (Table 1) in a matrix of felsitic silty sand. The head has an undulating, merging contact with the underlying gravel from which its coarser constituents have been derived. The head displays a wide range of periglacial features including involutions, with stone pillars, near-surface concentrations of frost-heaved clasts and erected and frost-cracked pebbles and cobbles. In Sections B and C the head locally thickens to 1.6 m across wedge structures and displays clear internal stratigraphy. In Section B, a layer of clearly-defined erected pebbles between 0.9 and 1.6 m overlies bedded gravel and passes up into a 0.2-0.3 m thick layer of red brown clayey silt with prominent, undulating wash horizons (see Fig. 3, Wedge C). Above this and extending to the base of the modern soil lies c. 0.6 m of cryoturbated silty sand showing localised and weakly-developed erection of angular pebbles. The sequence indicates two separate periods of cryoturbation before and after deposition of the red-brown silt.

A relatively late periglacial event at the site is marked by numerous ice-wedge casts which extend down from close to the present land surface to depths of up to 3 m. These casts have upper widths of up to 1 m and are infilled by head with rounded clasts.

C. Till

In Section E, head is overlain by up to 1.2 m of reddish-brown till with metamorphic and basic igneous erratics (Table 1). The till has been cryoturbated and shows a lobate, but generally sharp contact with the underlying head.

Interpretation of Stratigraphy

Crude parallel stratification of the gravels and sands suggests deposition as longitudinal bar forms within a braided river environment with trough cross-stratified sands deposited as dune bed-forms in channels between bars at low-flow stages (Miall 1977, 1978). The extensive cross-stratified gravels in Section E probably represent delta-front foresets formed during infill of a small lake.

The origin of the folded gravel beds at Leys is problematic. Gibbard (in Rose & Gibbard 1978, pp. 77-78) describes comparable folding in sands and gravels from the Vale of St. Albans related to compression due to over-riding by glacier ice. At Leys, however, there is no evidence that the gravel was over-ridden by ice soon after deposition and truncation of deformed gravel beds before accumulation of head throughout the quarry demonstrates that the ice which deposited the till in Section E was not responsible for large-scale deformation. Moreover, fold axes in Sections A-C are oblique and do not support uni-directional ice-push. An alternative explanation, which is favoured here, is that the folds are a result of the melt-out of lenses of buried glacier ice after gravel deposition as part of a valley sandar (cf. Price 1969, especially Fig. 8). Associated faulting is assumed to have been obscured by the coarseness of the gravel and by its poorly-sorted and crudely-bedded nature.

The wedge structures present in the gravels lie beneath a layer of head and might be interpreted as the casts of very large ice-wedges. This interpretation is rejected on the following grounds:

(i) The wedge structures are far larger than any ice-wedge casts yet reported as developed in gravels in north-east Scotland. Upper widths of ice-wedge casts in this area seldom exceed 1 m (Galloway 1961). Whilst oblique sections through ice-wedge casts may give an exaggerated impression of the width of casts, the location of multiple wedge structures in sections with different orientations makes consistent, fortuitous oblique sectioning highly unlikely at Leys.

(ii) The sorting parallel to wedge margins typical of many ice-wedge casts is absent or weakly developed in the wedge structures at Leys.

(iii) The margins of Wedges A, B and C are defined by sharp contacts (Fig. 4) suggestive of slide or collapse.

(iv) The thicknesses of gravels slumped into the wedges indicate that the ice which originally filled the wedges was buried by at least 2-4 m of gravel. The position of the wedges close to the present landsurface reflects later erosion.

The Leys wedges were clearly originally subsurface features and closely resemble in both dimensions and form glacitectonic structures described by Eyles (1977, especially Fig. 5) from Newfoundland and attributed to slump and collapse after melt-out of buried blocks of glacier ice. Similar structures occur in the Late Devensian kame complex in the Eddleston valley, South of Edinburgh, and, together with those at Leys, are also regarded as the products of the melt-out of buried glacier ice.

The coarseness of the gravels and the rapid lateral and vertical variations in sorting and calibre indicate high but variable palaeoflow regimes. Sedimentary structures indicate a braided river environment, draining to the NW., with subordinate deposition into a small proglacial lake giving large-scale cross-stratified gravels in the NW. corner of the quarry. Glacitectonic structures indicate deposition on to blocks of glacier ice. Taken together, these characteristics indicate deposition as part of a valley sandar extending towards the Ugie Valley from an ice margin lying to the east.

Gravel deposition and deformation was followed by a major erosional event which truncated the gravels. The incorporation of previously stained and bleached, rounded felsite clasts into head immediately overlying the gravel demonstrates that a considerable period of time elapsed between deposition of the gravel and formation of the head.

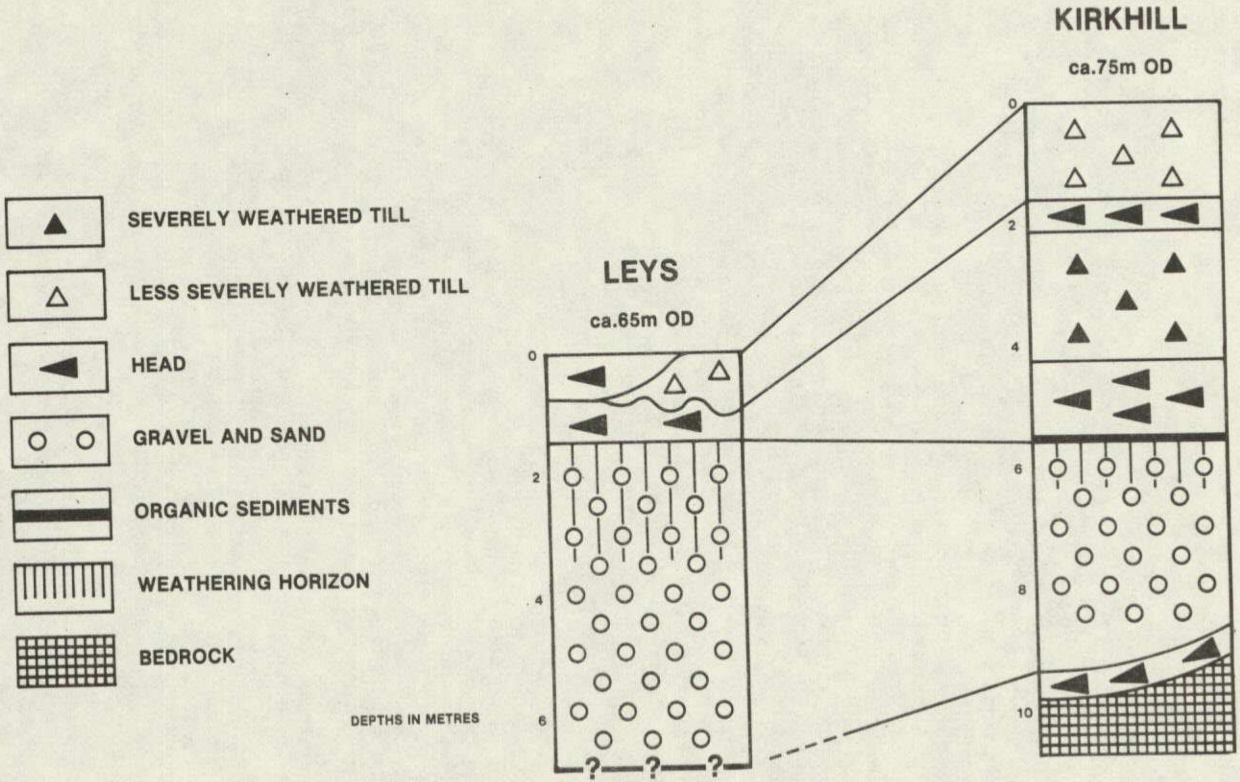


Fig. 5. A tentative correlation between the sedimentary sequences at Leys and Kirkhill. Representation of topography is simplified and schematic.

During this time oxide concentrations were formed in the gravels by precipitation of Mn, Fe and organic compounds carried to the site in groundwater (Vasari, Koljonen & Laakso 1972).

Localised thinning of head deposits indicates infill of shallow suface depressions. Two head units separated by reddish brown silt are found in Sections B and C. In Section E, a head layer underlies reddish brown till which is itself cryoturbated. Although the condensed nature of the upper stratigraphy hampers interpretation, it does suggest that an initial period of head accumulation was followed by till deposition and later by renewed cryoturbation, head accumulation and, finally, ice wedge growth.

Possible Correlations with the Kirkhill sequence

As the Kirkhill sequence lies only 0.6 km to the NE. of Leys, it is reasonable to attempt to correlate the sequences at these two sites (Fig. 5). Striking similarities exist between the Leys gravels and thin boulder gravels beneath the lower palaeosol in the NE. Face at Kirkhill (Hall 1984, p. 62), namely:

(i) The deposition of both sets of gravels in E.-W. trending bedrock hollows;
(ii) The highly distinctive calibre and felsitic lithology of the gravels;
(iii) The evidence of post-depositional weathering at both sites, represented by the lower buried soil at Kirkhill and by staining and bleaching at Leys;
(iv) The occurrence of a major erosional event subsequent to gravel deposition at both sites;
(v) The evidence of later cryoturbation and head formation at both sites.
A provisional correlation between these deposits is proposed.

At Kirkhill the lower palaeosol is overlain by, amongst other deposits, a sequence of two separate tills and at least three head units. At least one interglacial period is represented by a truncated soil profile developed in the lower till. However, the basic and metamorphic clast assemblage in the till at Leys suggests correlation with the upper till at Kirkhill (Table 1). This correlation, if correct, implies that sediments representing the considerable time period between deposition of the upper till and formation of the lower palaeosol at Kirkhill are scarcely represented at Leys.

Firm correlation of the head units at Leys is not possible at present. Ice-wedge casts at Leys probably are equivalent in age to ice-wedge casts and networks found in the Ugie valley and elsewhere in north-east Scotland which probably date from Loch Lomond Stadial, other Late-Glacial and, perhaps, older periglacial episodes (Gemmell & Ralston 1984). However, the depth and degree of cryoturbation at Leys far exceeds that observed in Late Devensian glacifluvial gravels in the Ugie valley where primary sedimentary structures can be traced undisturbed virtually to the present landsurface. The recognition at Leys of two separate head units, one lying beneath till, implies that head formation may have involved a long time period. The lower head at Leys possibly corresponds to at least one of the two head units beneath the upper till at Kirkhill.

Acknowledgements

The comments of two referees and Dr G.S.P. Thomas concerning the origins of the wedge structures at Leys were most useful.

References

Clapperton, C.M. & Sugden, D.E. 1975. The glaciation of Buchan - a reappraisal. In Gemmell, A.M.D. (ed.), Quaternary Studies in North-East Scotland, pp. 19-22. Aberdeen University.

Clapperton, C.M. & Sugden, D.E. 1977. The Late-Devensian glaciation of North-East Scotland. In Gray, J.M. & Lowe, J.J. (eds.) Studies in the Scottish Lateglacial Environment, pp. 1-13. Pergamon Press, Oxford.

Connell, E.R., Edwards, K.J. & Hall, A.M. 1982. Evidence for two pre-Flandrian palaesols in Buchan, Scotland. Nature, Lond. 297, 570-572.

Eyles, N. 1977. Late Wisconsin glacitectonic structures and evidence of postglacial permafrost in north-central Newfoundland. Can. J. Earth Sci. 14, 2797-2806.

Galloway, R.W. 1961. Ice wedges and involutions in Scotland. Biul. Peryglac. 10, 169-193.

Hall, A.M. 1984. Buchan Field Guide. Quaternary Research Association, Cambridge.

McMillan, A.A. & Aitken, A.M. 1981. The sand and gravel resources of the country west of Peterhead, Grampian region. Description of 1:25 000 Sheet NK04 and parts of NJ94, 95 and NK05, 14 and 15. Mineral Assessment Report Inst. Geol. Sci., No. 58.

Miall, A.D. 1977. A review of the braided river depositional environment. Earth Sci. Rev. 13, 1-62.

Miall, A.D. 1978. Lithofacies types and vertical profile models in braided river deposits: a summary. In Miall, A.D. (Ed.) Fluvial Sedimentology. Can. Soc. petrol. Geol. Mem. 5, 597-604.

Price, R.J. 1969. Moraines, Sandar, Kames and Eskers near Breidamerkurjokull, Iceland. Trans. Inst. Brit. Geogr. 46, 17-43.

Sutherland, D.G. 1984. The Quaternary deposits and landforms of Scotland and the neighbouring shelves. Quat. Sci. Rev. 3, 157-254.

Synge, F.M. 1956. The glaciation of North-East Scotland. Scott. Geogr. Mag. 72, 129-143.

Vasari, Y., Koljonen, T. & Laakso, K. 1972. A case of manganese precipitate in the Taviharju Esker, Kuusamo, North-East Finland. Bull. Geol. Soc. Finland 44, 133-140.

CORRESPONDENCE

QUATERNARY MAGNETOSTRATIGRAPHY IN BRITAIN

by S.J. Gale

In his recent review of the methods by which British Quaternary sediments have been correlated, Shotton (1985, p. 29) dismissed the use of magnetostratigraphic techniques with the comment "With virtually no deposits in Britain encouraging the use of this technique, no serious British contribution can be reported". This conclusion appears to be unjustified, both in view of the frequent occurrence in Britain of deposits susceptible to palaeomagnetic analysis and in view of the existence of a range of recently published work concerning Quaternary magnetostratigraphic correlation in Britain.

The bulk of Quaternary palaeomagnetic work in Britain has been on deposits of lacustrine origin. Most of the sediments investigated were laid down in the period 0-15 ka B.P., and curves of secular variations in palaeomagnetism during that time have now been obtained from Blelham Tarn, Ennerdale Water and Lake Windermere in Cumbria (Mackereth 1971, Creer *et al.* 1972, 1976, Thompson 1973, 1975, Mackereth in Thompson 1975, Thompson & Turner 1979, Turner & Thompson 1981); from Skipsea Withow Mere in North Humberside (Gale 1984a); from Llyn Geirionydd in north Wales (Turner & Thompson 1981); from Loch Lomond and Loch Shiel in Scotland (Dickson *et al.* 1978, Thompson & Turner 1979, Thompson & Wain-Hobson 1979, Turner & Thompson 1979, 1981); and from Lough Catherine, Lough Gall, Killymaddy Lough and Lough Neagh in Northern Ireland (Molyneux *et al.* 1972, Thompson 1973, 1975, Thompson & Edwards 1982, Hirons 1983, pp. 100-101). As a result of this work, Thompson & Turner (1979) and Turner & Thompson (1981) were able to establish the first ever regional master-curve of secular variations in palaeomagnetism. This curve, covering the period 0-10 ka B.P., was obtained from measurements made on 10 cores from Lake Windermere, Llyn Geirionydd and Loch Lomond, and was independently dated by a combination of ^{14}C, ^{210}Pb, ^{137}Cs, geomagnetic, archaeomagnetic and pollen zonation methods. Thompson & Edwards (1982) subsequently established a similar master curve covering the same period in Ireland.

Lake sediments deposited earlier in the Quaternary in Britain have also yielded distinct patterns of secular changes in palaeomagnetism (see, for example, Thompson *et al.* 1974). Although these sediments have not yet been firmly dated, palaeomagnetic methods exhibit considerable potential for their correlation in the future.

A second depositional environment in which palaeomagnetic methods have been successfully applied in Britain is that of caves. Because bioturbation is almost absent in the cave environment and because cave deposits are largely protected from erosion by subaerial processes, cave deposits often provide excellent palaeomagnetic records. So far, almost all studies of British cave deposits have dealt with clastic sediments. In Kirkhead Cave, Cumbria, for example, magnetostratigraphic methods have been used to establish the Late-glacial, late pollen-zone III age of Later Upper Palaeolithic artifacts found within laminated deposits in the cave (Gale *et al.* 1984). In Youd's Level, Matlock, Derbyshire, Noel (1985) has recorded a clear upsection change from reversed to normal polarity within 4 metres of fine-grained sediments. This is most likely to represent the boundary of the Matuyama and the Brunhes polarity epochs, located at c. 0.73 Ma B.P. (Mankinen & Dalrymple 1979). Palaeomagnetic measurements have also been made in several other cave sites, including Victoria Cave and Gaping Gill in North Yorkshire (Homonko 1978, pp. 86-92, Stober 1978, pp. 157-162); Grizedale Wood Drainage Level in Lancashire (Gale 1984b); Peak Cavern in Derbyshire (Noel 1985); Manor Farm Swallet in Somerset (Austin in Atkinson & Smart 1982); and Agen Allwedd in Powys (Homonko 1978, pp. 70-85, Noel et al. 1979, 1981, Noel 1983). However, in the absence of a British palaeomagnetic master-curve extending back much beyond the end of the last glacial, the age of these deposits cannot yet be determined. Despite this, the existence of palaeomagnetic polarity excursions within certain of these sediments does provide a means of estimating at least the minimum age of their deposition.

A second type of cave deposit, the speleothem, has also yielded interpretable palaeomagnetic results. Latham et al. (1979) and Latham (1981, pp. 128-144) have investigated deposits of this sort from the West Kingsdale System in North Yorkshire. These provided evidence of secular variations in palaeomagnetic direction during the period c. 7-13 ka B.P. Other preliminary work has also confirmed that certain British speleothems possess stable remanent magnetisations which may reflect the geomagnetic conditions under which they were deposited (see, for example, Homonko 1978, pp. 92-95).

A third depositional environment which exhibits considerable potential for Quaternary palaeomagnetic work in Britain is the marine continental shelf. Stoker et al. (1983), for example, claimed to be able to recognise magnetic polarity changes extending as far back as the Jaramillo event (c. 0.90-0.97 Ma B.P.) (Mankinen & Dalrymple 1979) in cores taken from the central North Sea. Marine deposits were also amongst those investigated by Montfrans (1971) in his study of East Anglian Quaternary sediments ranging in age from "pre-Ludhamian" to "Hoxnian". Although all the deposits studied by Montfrans exhibited normal magnetisation, preliminary investigation of East Anglian Quaternary marine deposits at Easton Bavents by Noltimier (1967) has provided some evidence of reversed magnetisation. Over a shorter timescale, Bishop (1975) has used measurements of relative magnetic declination to correlate Post-glacial marine deposits in the Inner Sound in northwest Scotland.

Finally, inter-tidal and estuarine deposits have been used to date sedimentary events of later Post-glacial age. Suttill (1980) used palaeomagnetic methods to date deposits in the Wash to 0-1 ka B.P., whilst Austin (1983) was able to date an episode of estuarine deposition along the River Crouch in Essex to 1.5-3.5 ka B.P.

It is clear from the above that there exists a wide range of Quaternary deposits in Britain able to preserve evidence of palaeomagnetic conditions, and that these have been more widely studied than has perhaps generally been recognised. Indeed, the palaeomagnetism of British Quaternary deposits is amongst the most intensely investigated and best understood of any in the world, and, with the extension of regional master-curves of secular variation back in time, it is likely that palaeomagnetism will become a more and more powerful means of correlating deposits throughout the entire range of the Quaternary in Britain.

Acknowledgements

I thank T.J.F. Austin and Dr P.G. Hoare for their comments on an earlier draft of this letter.

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References

Atkinson, T.C. & Smart, P.L. 1982. Fleet Street, Manor Farm Swallet, Charterhouse on Mendip, ST 498.556. Proc. Univ. Bristol spelaeol. Soc. 16, 85-91.

Austin, T.J.F. 1983. Preliminary palaeomagnetic results. In Wilkinson, T.J. (ed.), The Hullbridge Basin Survey Interim Report No. 4. Essex County Council, pp. 27-29.

Bishop, P. 1975. The palaeomagnetism of muddy sediment cores from the Inner Sound, northwest Scotland, and the glacial and post-glacial history of sedimentation in the area. Earth planet. Sci. Lett. 27, 51-56.

Creer, K.M., Gross, D.L. & Lineback, J.A. 1976. Origin of regional geomagnetic variations recorded by Wisconsinan and Holocene sediments from Lake Michigan, U.S.A., and Lake Winderemere, England. Bull. geol. Soc. Am. 87, 531-540.

Creer, K.M., Thompson, R., Molyneux, L. & Mackereth, F.J.H. 1972. Geomagnetic secular variation recorded in the stable magnetic remanence of recent sediments. Earth planet. Sci. Lett. 14, 115-127.

Dickson, J.H., Stewart, D.A., Baxter, M.S., Drndarsky, N.D., Thompson, R., Turner, G.M. & Rose, J. 1978. Palynology, palaeomagnetism and radiometric dating of Flandrian marine and freshwater sediments of Loch Lomond. Nature, Lond. 274, 548-553.

Gale, S.J. 1984a. Palaeomagnetic studies of Late-Devensian lake deposits at Skipsea Withow Mere. In Gilbertson, D.D. (ed.), Late Quaternary Environments and Man in Holderness. Br. Archaeol. Rep., Br. Ser. 134, 73-80.

Gale, S.J. 1984b. Quaternary hydrological development in the Morecambe Bay karst, northwest England. Norsk geogr. Tiddskr 38, 185-192.

Gale, S.J., Hunt, C.O. & Southgate, G.A. 1984. Kirkhead Cave: biostratigraphy and magnetostratigraphy. Archaeometry 26, 192-198.

Hirons, K.R. 1983. Percentage and accumulation rate pollen diagrams from east Co. Tyrone. In Reeves-Smyth, T.J.C. & Hamond, F.W. (eds.), Landscape Archaeology in Ireland. Br. Archaeol. Rep., Br. Ser. 116, 95-117.

Homonko, P. 1978. A Palaeomagnetic Study of Cave and Lake Deposits in Britain. Unpub. M.Sc. thesis, Univ. Newcastle, 101 pp.

Latham, A.G. 1981. Palaeomagnetism, Rock Magnetism and U-Th Dating of Speleothem Deposits. Unpub. Ph.D. thesis, McMaster Univ., 507 pp.

Latham, A.G., Schwarcz, H.P., Ford, D.C. & Pearce, G.W. 1979. Palaeomagnetism of stalagmite deposits. Nature, Lond. 280, 383-385.

Mackereth, F.J.H. 1971. On the variation in direction of the horizontal component of remanent magnetization in lake sediments. Earth planet. Sci. Lett. 12, 332-338.

Mankinen, E.A. & Dalrymple, G.B. 1979. Revised geomagnetic polarity time scale for the interval 0-5 m.y. B.P. J. geophys. Res. 84B, 615-626.

Molyneux, L., Thompson, R., Oldfield, F. & McCallan, M.E. 1972. Rapid measurement of the remanent magnetization of long cores of sediment. Nature Phys. Sci. 237, 42-43.

Montfrans, H.M. van. 1971. Palaeomagnetic Dating in the North Sea Basin. Princo N.V., Rotterdam, 113 pp.

Noel, M. 1983. The magnetic remanence and anisotropy of susceptibility of cave sediments from Agen Allwedd, South Wales. Geophys. J. R. astr. Soc. 72, 557-570.

Noel, M. 1985. Caves, mud and magnetism: an update. Bull. Br. Cave Res. Assoc. N.S. 27, 14-15.

Noel, M., Homonko, P. & Bull, P.A. 1979. The palaeomagnetism of sediments from Agen Allwedd, Powys. Trans. Br. Cave Res. Assoc. 6, 85-92.

Noel, M., Retallick, W.G. & Bull, P.A. 1981. Further palaeomagnetic studies of sediments from Agen Allwedd. Trans. Br. Cave Res. Assoc. 8, 178-187.

Noltimier, H.C. 1967. Impregnation of weak sediments for palaeomagnetic measurements. Earth planet. Sci. Lett. 2, 177-178.

Shotton, F.W. 1985. IGCP 24 Quaternary Glaciations in the Northern Hemisphere. Quat. Newsl. 45, 28-36.

Stober, J.C. 1978. Palaeomagnetic Secular Variation Studies in Holocene Lake Sediments. Unpub. Ph.D. thesis, Univ. Edinburgh, 168 pp.

Stoker, M.S., Skinner, A.C., Fyfe, J.A. & Long, D. 1983. Palaeomagnetic evidence for early Pleistocene in the central and northern North Sea. Nature, Lond. 304, 332-334.

Suttill, R.J. 1980. Post-depositional remanent magnetisation in recent tidal-flat sediments. Earth planet. Sci. Lett. 49, 132-140.

Thompson, R. 1973. Palaeolimnology and palaeomagnetism. Nature Phys. Sci. 242, 182-184.

Thompson, R. 1975. Long period European geomagnetic secular variation confirmed. Geophys. J. R. astr. Soc. 43, 847-859.

Thompson, R., Aitken, M.J., Gibbard, P.L. & Wymer, J.J. 1974. Palaeomagnetic study of Hoxnian lacustrine sediments. Archaeometry 16, 233-237.

Thompson, R. & Edwards, K.J. 1982. A Holocene palaeomagnetic record and a geomagnetic master curve from Ireland. Boreas 11, 335-349.

Thompson, R. & Turner, G.M. 1979. British geomagnetic master curve 10,000-0 yr B.P. for dating European sediments. Geophys. Res. Lett. 6, 249-252.

Thompson, R. & Wain-Hobson, T. 1979. Palaeomagnetic and stratigraphic study of the Loch Shiel marine regression and overlying gyttja. Jl geol. Soc. Lond. 136, 383-388.

Turner, G.M. & Thompson, R. 1979. The behaviour of the Earth's magnetic field as recorded in the sediments of Loch Lomond. Earth planet. Sci. Lett. 42, 412-426.

Turner, G.M. & Thompson, R. 1981. Lake sediment record of the geomagnetic secular variation in Britain during Holocene times. Geophys. J. R. astr. Soc. 65, 703-725.

REPLY TO DR. GALE BY PROF. F.W. SHOTTON

In replying to Dr Gales' criticism of my summary paper in the QRA Newsletter of February 1985, or more strictly speaking, of my dismissal of magnetostratigraphy as not having contributed significantly to the British problems within IGCP Project 24, it is important to emphasise certain facts. Project 24, "Glaciations of the Northern Hemisphere" was accepted into the IGCP programme in 1973, held its first international meeting in 1974 and its final meeting in Paris in September 1982. As chairman of the British delegation to that Congress, I had to present the final British report. Subsequently, essentially the same report was presented to the Royal Society Committee for the IGCP, in which I was National Correspondent. Because neither of these reports was likely to be seen by many British workers on the Pleistocene, it was represented to me that it would be useful to publish in the QRA Newsletter. This explains why there could have been no consideration of those papers cited by Dr. Gale as published between 1982 and 1985, even had I thought these to be relevant.

The real theme of Project 24 was International correlation of Glaciations north of the Equator during the last two million years or so. As far as Britain was concerned we felt that our remit ended with the close of the Devensian (Wisconsinan, Weichselian, Vistulian). So interesting though magnetostratigraphy might be in its own right, within the Holocene it has little or no relevance to Project 24. Even if one accepts that the uppermost British Pleistocene, the few thousand years of the Loch Lomond stadial and the Windermere interstadial, come in the purview of Project 24, I believe it is still true to say that Britain has not used palaeomagnetism over that period for international correlation.

Correlations within the Pleistocene stemming from palaeomagnetic measurements would certainly have been relevant to the British report but statements in Dr. Gales' letter indicate the uncertainty which surrounds the results. (In the ensuing sentences, underlined words are taken from that letter). Thus Noel (1985 - N.B. post-1982) records an upward change from reversed to normal polarity in a cave's sediments which is most likely to represent the Brunhes-Matuyama boundary. Referring to measurements made in six other caves with no such reversal, Dr. Gale writes "... in the absence of a British palaeomagnetic master curve extending back much beyond the end of the last Glacial, the age of these deposits cannot yet be determined. Montfrans' (1971) study which covered the whole of the East Anglian Pleistocene from base to the Hoxnian, found no change from normal magnetisation despite the fact that Nollimier some years earlier, provided some evidence of reversed magnetisation at Easton Bavents in the middle of the sequence studied by Montfrans.

So it cannot be said that palaeomagnetisation measurements within British deposits had by 1982 made significant contributions to the objectives of Project 24. Such work has, of course, been extremely important in other areas such as central Europe where thick loess sequences exist, in China or in North America where lavas interbed with glacial sediments. The British Isles, however, has only one long sequence of the Pleistocene and even that has many gaps in its completeness and much of it is not favourable to the retention of remanent magnetism. In view of the results of palaeomagnetic studies which have so far been made, I do not regret my somewhat curt dismissal of their relevance to Project 24. That is not to dismiss them for the future.

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ABSTRACTS OF RECENT PH.D. THESES

QUATERNARY GEOLOGY OF LARGE-SCALE SUPERFICIAL FEATURES AT ASHFORD HILL, HAMPSHIRE, ENGLAND

D.M. Hill

Ph.D. Thesis, University of Reading, 1985

A diapiric mass of chalk rises some 35 m through Palaeogene strata beneath the floodplain of the Baughurst Stream, a tributary of the River Kennet. It is argued that this chalk anomaly was initially formed by the rise of Upper Chalk during a period(s) of permafrost degradation. This ultimately pierced the valley floor. Shattering and mobility of chalk at depth apparently arose from repeated permafrost formation to a minimum depth of 75 m. Once present, upflow of groundwater in succeeding cold stages promoted the development of ground ice bodies possibly as pingos. Subsequently ground ice degradation resulted in rockhead depressions within which a tripartite Quaternary succession is recognised. This consists of: (i) "Lower Silts" - deposited in an isolated deep lake(s), (ii) "Middle Gravels" - deposited in a subsiding basin resulting from thermal degradation of ground ice and, (iii) "Upper Silts" - associated with a subsequent lacustrine phase. The latter implies continued

subsidence after the cessation of gravel transport. A biogenic-rich bed at the base of the "Upper Silts" contains early Flandrian pollen and freshwater Mollusca including the first post glacial record of *Gyraulus laevis* in the Kennet catchment. Infilling of the lake and aggradation of the flood plain commenced after c. 9 ka B.P., the silts probably being derived from anthropogenic disturbance. An alternative mechanism for valley bulging and hillslope cambering, without invoking prior incision, is proposed. This is allied to periglacial mass movement over a low-strength zone resulting from transient high pore-water pressures during permafrost degradation. Comparison with other sites in the Thames Valley, and with pingos and pingo remnants, reveals parallels which could help locate similar features. A new discovery at Coinbrook, Buckinghamshire, is described.

LATE QUATERNARY ENVIRONMENTAL CHANGE AT EASTBOURNE, EAST SUSSEX

S.C. Jennings

Ph.D. Thesis, C.N.A.A., The Polytechnic of North London, 1985.

This study is an examination of the late-Quaternary palaeo-environments of the Eastbourne area. The principal techniques employed are pollen, Foraminifera, Ostracoda, Mollusca and sediment particle size analyses. The lithostratigraphic investigation, using hand auger and a commercial drilling rig, revealed extensive unconsolidated sediments to a maximum depth of 33 m which consist of gravels, sand, silt and clay with restricted peat development.

The history of the vegetation has been traced back to the Lateglacial when, it is argued, an unusually thermophilous community which included *Alnus* prospered. The early Flandrian vegetation was dominated by *Corylus* and *Pinus*, the latter genus being replaced by members of the 'Mixed-Oak Forest' before 8,770 ± 50 a B.P. Prior to this date, *Juniperus* expanded. The nature of the mid-Flandrian vegetation is unclear due to the presence of secondary pollen. However, this secondary pollen has been used to provide information on the nature of sedimentation on Willingdon Levels. In addition, a model of pollen transfer in estuarine sediments is proposed. Poor pollen preservation has allowed an examination of pollen deterioration and its possible use for palaeoenvironmental reconstruction to be attempted. The late-Flandrian vegetation reveals the impact of both anthropogenic factors and coastal changes.

The pattern of Flandrian coastal/sea-level change has been reconstructed through an examination of transgressive and regressive contacts and overlaps and their associated biostratigraphies. In addition to two contacts, three phases of positive dominant tendency and two phases of negative dominant tendency of relative sea-level movement are recognised. It is argued that the coastal sediments at Eastbourne are probably the result of the growth and over-running of depositional features superimposed upon the main Flandrian rise in sea-level, rather than reflecting eustatic oscillations.

THE BIOSTRATIGRAPHY OF FLANDRIAN TUFA DEPOSITS IN THE COTSWOLD AND MENDIP DISTRICTS

M.J. Willing

Ph.D. thesis, University of Sussex, 1985

Detailed biostratigraphical studies of late Devensian and Flandrian deposits in Kent (Kerney et al. 1980) and elsewhere in southern Britain (Preece 1978), have demonstrated an ordered pattern of colonization by non-marine Mollusca. The constancy of this pattern at several sites prompted the definition of a series of molluscan assemblage zones (Kerney 1977).

This thesis presents the first comparable results from deposits in the Cotswold and Mendip districts.

The biostratigraphy of each sequence is described and the Mollusca and other fossils (ostracods, plant macrofossils, pollen) used to suggest environmental changes. At two localities, multiple sequences were investigated to discover the degree of lateral facies variation.

Local assemblage zones are described for each locality, leading to the establishment of a regional assemblage zonation for the Cotswold/Mendip districts. These data are comparable with results from elsewhere in southern Britain and reveal the general validity of Kerney's original scheme.

Several radiocarbon dated assemblages from different sites indicate the broad synchroneity of certain zones throughout southern Britain. Although most of the critical species appeared in a similar order in both the Cotswolds/Mendips and in Kent, a number of minor differences are discussed. In the light of these new data, a slightly modified scheme is proposed for the Flandrian of southern Britain.

A critical review of the ecology of British terrestrial Mollusca reveals the difficulties of using them in palaeoenvironmental reconstructions.

REVIEWS

Quaternary Environments: eastern Canadian Arctic, Baffin Bay and western Greenland. Edited by J.T. Andrews (1985), (ISBN 0-04-551094), 774 pages, numerous figures. George Allen & Unwin (Publishers), London. £50.00 or US$75.00 per volume (hardcover).

A potential reader, picking up this book and trying to find out what it is about, is immediately in trouble. It apparently originated in a suggestion that 'it would be a good idea to try and consolidate all the work that has gone on concerning the Quaternary history of the eastern Canadian Arctic' (Preface). Andrews & Funder (p. 1) state that 'it deals with Quaternary history of the areas around Baffin Bay' and this is fairly close to the mark: the title is misleading. It is about Quaternary history, not environments, and it is mostly about Baffin Island and the adjacent sea (Baffin Bay, principally) rather than the eastern Canadian Arctic as a whole. Of the 26 chapters, 2 are introductory, 19 deal with Baffin Island or Baffin Bay, 1 each with aspects of Bylot Island and Devon Island, 3 with Greenland (one with eastern Greenland!) and 2 with the Labrador Sea, to the south of Baffin Bay (there is some overlap between chapters). Further on (p. 3), Andrews & Funder suggest that the book should 'be considered as a companion study of the "Paleoecology of Beringia" (eds. D.M. Hopkins et al. 1982). Paleoecology of Beringia resulted from the discussions of a group of scientists invited to consider a well-defined problem. The papers were revised in the light of discussions and are skilfully integrated by the editors. It is an excellent and stimulating read. Quaternary Environments is also a series of invited papers, but, in contrast, they have minimal reference to each other, minimal editorial linking, and no defined central problem, except the vague statement quoted above. This all makes it hard to read and digest.

The 26 chapters, by 25 authors, are grouped into five Parts. In Part I, 2 chapters describe the history of Quaternary research in Baffin Island and Greenland, and discuss the modern environment. Part II contains four chapters on aspects of glacial landforms and sediments. Part III has five chapters based on ocean cores (sediments, foraminifera, oxygen isotopes and pollen) and the Devon Island ice core. Eight chapters in Part IV discuss aspects of terrestrial Pleistocene stratigraphy, including weathering and soil development, aminostratigraphy and pre-Holocene biostratigraphy. Finally, the seven chapters of Part V describe events during the Holocene - sealevel change, vegetation history, neoglaciation, archaeology and palaeoclimatology. Botanically-minded palaeoecologists will enjoy the chapters by Short et al. and Fredskild on vegetation history of Baffin Island and Greenland respectively. Fredskild's chapter is carefully reasoned, based on many lake sediment cores and well worth reading by anyone working on the problems of postglacial vegetation development and plant 'migration'. The chapter by Short et al. is based on the use of 'transfer functions' which apparently have the magical ability to 'disregard the complicated relationship between pollen and vegetation and proceed directly to an empirical relationship between pollen and climate'. (p. 609). In this case it is clear (using the discussion of Andrew & Funder, p. 9) that the Greenland tradition of systematic and continuous gathering of "standard information" has ultimately been much more successful than the American tradition of concentrated efforts dedicated to the solution of specific problems (climate, in this example). All the Parts are followed by a 2-3 page summary by Andrews. They contain interesting ideas and suggestions, but are not long enough to serve as linkage between the papers. There is no overall conclusion or synthesis, nor an index.

Many of the papers are excellent, and should be read by others working in the same field, but the lack of integration and focus to the book will make most of them inaccessible to non-specialists, which is a pity. The book appears to have been prepared by the editor and his assistants on a word-processor, camera ready. Despite this, the price is very high, and it is riddled with typographical errors. Most libraries will want a copy, but few individuals. Andrews succeeds in his aim of presenting the latest thinking and observation, but digesting nearly 800 pages of it is a task few will attempt.

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Modern Geology, Volume 9, No. 2 (1985), pp. 101-239 + fold-out map: British Geological Survey - Quaternary Geology of East Anglia. Distributed by STBS Ltd., 1 Bedford Street, London WC2E 9PP. ISSN 0026-7775.

This issue of Modern Geology contains eight articles describing work done during the first stage of the BGS Regional Survey of East Anglia. The regional survey was inaugurated in 1982 to complete and update the geological mapping of the country's most important area of Quaternary deposition, hitherto much neglected by BGS. It is a multidisciplinary survey involving collaboration between specialists from BGS and other institutions, and is co-ordinated by F.C. Cox.

In an introductory overview of the regional survey, Cox explains that the foremost objective was "to test the stratigraphy approved by the Geological Society of London". This and other contributions to the issue hint that the climatostratigraphic subdivision of the British Quaternary proposed in 1973 by the Society is imperfect. But this has long ceased to be hot news, and judging by this collection of papers the BGS is still some way off proposing a satisfactory alternative.

Detailed investigations are being made in eight selected areas, the Nar and Waveney Valleys, the tunnel valley areas of central Norfolk and Woolpit (Suffolk), the Aldeburgh-Orford region, a segment of Fenland near Peterborough, the Contorted Drift of the Norfolk coast, and a borehole at Ormesby near Great Yarmouth. 1:10,000 mapping in the first six of the areas will eventually be linked by traverses and corridors, to give an integrated survey of the whole region. As a case study of one area, Mathers & Zalasiewicz describe the production of a "three dimensional geological map" of the Aldeburgh-Orford region. Variations in the thickness of the Crags, the Kesgrave Sands and Gravels, and the marginal deposits of the Anglian ice sheet are portrayed by a "fence diagram" of regularly spaced sections drawn along N.-S. and E.-W. grid lines at 2 km intervals. The information, based on various drilling and geophysical techniques, is an undoubted improvement on the usual portrayal of surface drift deposits identified by shallow augering, but there is no discussion of relative costs and benefits. Geophysical methods used for mapping East Anglian Quaternary deposits, such as the EM 31 electromagnetic conductivity meter, are described in more detail by Cornwell of the Geophysics Directorate of BGS.

Bridge & Hopson describe the application of petrographic analyses to glacial sediments in another area selected for detailed investigation, the lower Waveney Valley. Inland of Corton outwash from the North Sea (Cromer Till) advance deposited proximal gravels and three fining-upwards cycles of distal sands related to fluctuations in the ice margin position. The Corton Sands are also interpreted as outwash from the same ice sheet; they were partly eroded and locally calcreted before being over-ridden by the Lowestoft advance.

Probably the most interesting article in the issue, though strictly not part of the regional survey work, is an account by Balson & Cameron of offshore Quaternary deposits between 3^{o}E. and the coastline of Suffolk, Norfolk and Lincolnshire. During the early Pleistocene after the Thurnian Stage deltas spread across the shelf sea due to a massive influx of sediment from the south and from Britain. Because of tectonic subsidence the deltaic sediments exceed 350 m in the east. They are overlain unconformably by Anglian glacial and glaciolacustrine sediments, mainly filling NNW.-SSE. subglacial valleys which are locally 400 m deep. No Wolstonian glacial deposits have been identified, but shallow-water Eemian sediments are widespread NE. of East Anglia, and are succeeded by Devensian till to the north and by brackish-water Devensian clays to the south.

The remaining papers in the issue are an account of the BGS Mineral Assessment Unit's work on sand and gravel resources in East Anglia by Auton, a preliminary description of arthropod remains from various stratigraphic levels in the Waveney and Wensum Valleys by Taylor & Coope, and a study of the geochemistry and provenance of the Crags, Kesgrave Formation and Anglian glacial deposits in the Woodbridge area by Peachey and others. Like the other five they are all worthy (though not outstandingly important) scientific contributions, but because of the unreasonably high cost of a subscription to Modern Geology they are unlikely to be purchased and read by many QRA members. Single issues of the journal cost in excess of $50 US! For about 140 pages of Quaternary geology this can hardly be called good value for money; it merely serves to emphasize how much of a bargain the new Journal of Quaternary Science is at £15 per year (including QRA membership)!

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On the Track of Ice Age Mammals. By A.J. Sutcliffe, 1985. British Museum (Natural History), London. 224 pp. Price £12.95. ISBN 0-565-00869-2.

Some years ago the Natural History Museum opened a new exhibit dealing with Pleistocene mammals. It was at once obvious that we were entering a new and more exciting era of museum displays, and it was further clear that the exhibit was based on considerable experience, material and expertise.

In this book Dr. Sutcliffe, curator at the museum, provides an expert account of the history of research on Ice Age mammals and an up-to-date summary of significant conclusions, many of which are related to the themes of the exhibit.

He emphasises the pervasive and continuing effects of climatic change on mammals, including man, through the last two million years and, importantly, shows that the study of mammals depends heavily on advances made in other related fields of Quaternary research such as taphonomy, sedimentology, palaeobotany and radioisotope studies.

Introductory chapters indicate the nature of climatic change popularly known as the Ice Age and cover the early history of discovery of fossil remains. These are followed by chapters on taphonomy ("looking for Ice Age mammals") and dating, leading to development of a modern chronology for the Quaternary based directly on the deep sea oxygen isotope record, and indicating the evident disparity between this and older chronologies.

The importance of caves in studies of Pleistocene faunas has been so great that the types of cave and the special characteristics of cave deposits are handled in a separate section. This leads on to a useful account of representation of mammals in palaeolithic cave art ("What the cave men saw"). Special attention is also given to the preservation of mammoths and other mammals in permafrost.

The longest chapter handles the changing Ice Age faunas of the British Isles. This is not an in-depth study of the faunas of various localities (provided elsewhere by Stuart 1982), but is a more general account with emphasis on succession of various faunas based on mammalian and geological (terrace) evidence, and excluding biostratigraphic evidence based on palynology. This leads to a scheme in which the Ipswichian fauna (equivalent to deep-sea stage 5e) postdates the Middle Terrace deposits at Crayford, Ilford and Aveley. The alternative interpretation which has been adopted is that these localities belong to a later part of the Ipswichian (Stuart 1982). Since the discussion on this point has been going on since at least 1972 and the members of the QRA are possibly familiar with it, perhaps it will suffice to point out that if the evidence is capable of divergent interpretation it should be checked and improved. Possibly new studies of intra-Saalian faunas from the Netherlands may provide a lead here. Certainly, the points in which stratigraphic schemes based on mammal and plant evidence differ should be the focal areas for further work.

The final section of the book covers the East African rift valley, the New World and Australia, ending with a brief chapter on extinctions.

There are many illustrations, all of high standard. Particularly noteworthy are colour plates by Peter Snowball reconstructing past environments. The text is clearly written in a style which should make it accessible to general as well as specialised readership. Nevertheless, no attempt has been made to oversimplify difficult concepts, and some attention is given to explanations of complex phenomena such as shore lines and river terraces. Suggestions for further reading (no text references) are given per chapter at the end of the book, which has a fairly comprehensive index. There are very few errors (typographic or otherwise) and the general level of production and printing is high. All in all this book represents good value for money, and despite the basic orientation towards a more popular readership it will be useful background reading for many of the members of the QRA.

Reference

Stuart, A.J. 1982. Pleistocene Vertebrates in the British Isles. Longman: London.

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Principles of Sedimentary Basin Analysis. By Andrew D. Miall, 1984. ISBN 3-540-90941-9, 490 pp., 387 figs. Springer-Verlag: Berlin. Price US $44.80 hardback.

Andrew Miall's 'Principles of Sedimentary Basin Analysis' represents a timely and welcome addition to the literature on stratigraphy and sedimentation. Unlike most recent treatments of these subjects this book represents a practical rather than a theoretical approach which will serve as an extremely useful guide to those beginning work on the stratigraphy of sedimentary rocks. Although clearly aimed at graduate and undergraduate geologists intending to make a career in the mineral exploration industry, much of the book has considerable relevance to those working on Quaternary stratigraphy. In many ways the book is a bible for what Miall terms the 'New Stratigraphy', a subject which has given rise to considerable debate in the context of Quaternary studies in recent months (see Eyles, Eyles & Miall (1983) and replies by Karrow and others (1984) for instance), and it is extremely valuable to read such a full exposition of the methodological underpinnings of this science. In this respect the book might perhaps be more useful to those British Quaternary workers whose initial training is in Geography than to those with a formal Geological training, since the latter are more lkely to already be familiar with the material.

For Quaternary workers the first six chapters of the book are likely to prove the most relevant. These deal with the collection of sedimentological data, with methods of stratigraphic correlation, with facies analysis and the construction of facies models, with basin mapping methods and with depositional systems analysis. The final three chapters are concerned with burial history, problems of cyclicity in sedimentation and with the relationships between sedimentation and tectonics, subjects which (with the notable exception of the search for Milankovich cycles in deep sea sediments) have received relatively little attention in the Quaternary literature because of the relatively short timescales involved. Throughout the book the emphasis is on the large scale, broad brush approach to stratigraphy, and Miall is highly critical of studies which define too small an area as the focus of interest.

The main thrust of the book is to sketch out the major developments which have brought about dissatisfaction with the traditional 'layer-cake' view of stratigraphy in which sediments are seen as 'geometrically uniform blankets bounded by the sharp vertical lines of the correlation table' (p. 2), and to argue how stratigraphic practice should be modified to take account of these developments. These he argues are (1) the use of facies studies and facies models to explain the origins of rocks. Whilst Miall provides cogent arguments in favour of the facies approach to sedimentology, his statement that 'Nowadays, it is possible to interpret and predict the composition, geometry and orientation of virtually all stratigraphic units using this approach' (p. 3) shows a degree of faith which brought a smile to my face. In the glacial field at least our understanding of sedimentary processes and environments is nowhere near as good as Miall suggests, and in the light of recent literature concerning the recognition of Quaternary glaciomarine sediments his argument seems particularly unconvincing (see Eyles & Eyles 1984 and reply by Thomas & Dackombe 1985, for instance); (2) application of the depositional systems method to stratigraphy. This involves recognition of the importance of lateral facies relationships to the interpretation of vertical facies successions and the realisation that depositional systems consist of packages of sedimentary environments and their depositional products. These are bounded by unconformities or facies transitions to genetically unrelated depositional systems and should provide the basis for subdivision of the stratigraphic column. In this model, detailed sedimentological analysis becomes a key part of any stratigraphic investigation; (3) the use of seismic stratigraphy which has made possible the mapping of the fine details of the architecture of sedimentary basins. Although this method has been widely used for the investigation of offshore Quaternary sediments, its potential for the study of onshore sequences has yet to be fully explored; (4) the development of the theory of plate tectonics which has led to improved understanding of the evolution of sedimentary basins and their infills, and (5) the use of radiometric methods and magnetic reversal stratigraphy to provide a firm basis for the development of chronostratigraphies. Stratigraphic correlation based upon either these methods or biostratigraphy is viewed as an essential precursor to the development of a formal stratigraphy. Miall considers the use of lithostratigraphy as a basis for the construction of chronostratigraphy to be obsolete, an obvious conclusion from his review of the depositional systems method, but one which has yet to be taken on board by much of the Quaternary community. This is perhaps because one becomes more aware of the limitations of dating methods as one becomes concerned with the shorter timescales relevant to the understanding of Quaternary environmental changes, and as a result becomes more tolerant of the limitations of other methods. 'Principles of Sedimentary Basin Analysis' offers both a robust statement of opinion on modern stratigraphic method and a clear and valuable guide to the practice of stratigraphy in the field. It would make an excellent text for courses in stratigraphy and sedimentology and it is therefore regrettable that its price is likely to exclude it from the student market. As a book it is generally well presented with a number of extremely useful figures. My only complaint in this respect is that important information such as the key to codes used on figures is occasionally omitted 'for reasons of space'. If space is really at such a premium surely the first thing to cut should be figures which in their present form are unintelligible? Otherwise this is a book to be heartily recommended.

References

Eyles, C.H. & Eyles, N. 1984. Glaciomarine sediments of the Isle of Man as a key to Late Pleistocene stratigraphic investigations in the Irish Sea Basin. Geology 12, 359-364.

Eyles, N., Eyles, C.H. & Miall, A.D. 1983. Lithofacies types and vertical profile models; an alternative approach to the description and environmental interpretation of glacial diamict and diamictite sequences. Sedimentology 30, 393-410.

Karrow, P.F. and others 1984. Discussion: Lithofacies types and vertical profile models; an alternative approach to the description and environmental interpretation of glacial diamict and diamictite sequences. Sedimentology 31, 883-898.

Thomas, G.S.P. & Dackombe, R.V. 1985. Comment on Glaciomarine sediments of the Isle of Man as a key to Late Pleistocene stratigraphic investigations in the Irish Sea Basin. Geology 13, 445-446.

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Dating Methods of Pleistocene deposits and their problems. Edited by N.W. Rutter (1985), 87 pp., Geological Association of Canada. ISBN 0-919216-15-3. Price Canadian $12 softback.

This relatively inexpensive book covers nine chronological techniques, both relative and absolute, which are applicable to Quaternary deposits. All except one of the chapters appeared in Geoscience Canada, a quarterly journal of the Geological Association of Canada, between 1978 and 1982, although the original sources are not given. Most of the papers have been updated and references from 1983 and 1984 have been included.

The chapters review uranium series disequilibrium dating, accelerator mass spectrometry for radiocarbon dating, amino acid racemization, thermoluminescence, electron spin resonance and fission track dating, as well as palaeomagnetism and the use of palaeosols and weathering features. They give good outlines of the techniques and have extensive bibliographies. In spite of being written mainly by Canadians, the examples presented to illustrate the techniques are not just from North America. Since each chapter is written by a practitioner in the field, the limitations of each method are made clear. This results in an honest aproach which may stimulate future generations of researchers to overcome the problems associated with each method.

This book will provide a useful text to support an undergraduate, or graduate, course for geology, geography or archaeology students. No text which deals specifically with Quaternary dating methods currently exists and this book will help to fill the gap.

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NOTICES

THE S.E.M. IN ARCHAEOLOGY CONFERENCE

Will be held at the Institute of Archaeology, University of London on 18th and 19th April 1986. Details from: Dr. Sandra Olsen, Organiser, Institute of Archaeology, 31-34 Gordon Square, London WC1H OPY.

INTERNATIONAL SYMPOSIUM AND WORKSHOP ON GLOBAL CHANGE IN AFRICA DURING QUATERNARY: PAST- PRESENT- FUTURE

This Meeting, organised by INQUA Inter-Congress Committee for the Quaternary of Africa and ASEQUA Senegalese Committee of INQUA, will be held at Dakar, Senegal from 21st-25th April 1986. Details from: Symposium Secretariat, Liliane FAURE, INQUA/1986 Dakar Symposium, Laboratoire de Géologie du Quaternaire, Faculté des Sciences -LUMINY-, Case 907, 13288 Marseille Cedex 9, France (TELEX CNRSLUM 430838F).

JOINT MEETING OF THE INQUA LOESS COMMISSION AND THE IGU COMMISSION ON THE SIGNIFICANCE OF THE PERIGLACIAL PHENOMENA

Will be held in Normandy, Jersey and Brittany from 20th-27th August 1986. Details from: J.P. LAUTRIDOU, Centre de Géomorphologie du CNRS, rue des Tilleuls, 14000 Caen, France.

THE EVOLUTION OF ROMNEY MARSH

A Conference organised by the Department for External Studies, University of Oxford, in association with the Romney Marsh- Dungeness Research Group will be held at Hertford College, Oxford on 20th-21st September 1986. Details from: The Archaeology/Local History Course Secretary, Oxford University Department for External Studies, Rewley House, 1 Wellington Square, Oxford OX1 2JA.

SYMPOSIUM ON COASTAL LOWLANDS: GEOLOGY AND GEOTECHNOLOGY

To be held at The Hague, Netherlands from 25th-27th May 1987. Details from Coastal Lowlands Symposium, c/o CONGREX, Keizersgracht 610, 1017 EP Amsterdam, The Netherlands.

XIIth INQUA CONGRESS, OTTAWA, CANADA

Will be held in Ottawa from 31st July-9th August 1987. Details from Secretariat, XII INQUA Congress, c/o National Research Council of Canada, Ottawa, Ontario, Canada K1A OR6. The organisers of the Congress report that the number of persons hoping to attend was 1267 by October 1985. There is a student rate for Congress registration.

28TH INTERNATIONAL GEOLOGICAL CONGRESS

To be held in Washington, D.C., U.S.A. from 9th-19th July 1989. Details from: International Geological Congress, P.O. Box 1001, Herndon, Virginia 22070, U.S.A.

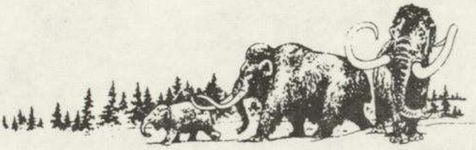
New field guides

available from the Secretary

ISLAND OF MULL by M. Walker, M. Gray & J. Lowe
price £3.50 per copy (non-members £5.50)

PERIGLACIAL LANDFORMS OF NORTHERN ENGLAND by J. Boardman
price £3.50 per copy (non-members £5.50)

PEAK DISTRICT & NORTHERN DUKERIES by D. Briggs, D. Gilbertson & R. Jenkinson
price £3.50 per copy (non-members £5.50)



CALENDAR OF MEETINGS

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

18th-19th April 1986	The S.E.M. in Archaeology Conference, at Institute of Archaeology, University of London (see notice above).
21st-25th April 1986	International Symposium and Workshop on Global Change in Africa during Quaternary: Past- Present- Future, to be held in Dakar, Senegal (see notice above).
23rd-25th May 1986	IGCP 200 Workshop to be held near Montrose, Scotland (see the Circular and Newsletter 47, p. 58).
2nd-4th June 1986	9th Biennial Meeting of American Quaternary Association on University of Illinois-Champaign Campus (see Newsletter 47, p. 58).
29th June -7th July 1986	International Symposium and Field Excursion "The Cultural Landscape - Past, Present and Future" at University of Bergen, Norway (see Newsletter 47, p. 58).
30th June -4th July 1986	Sixth International Conference on Geochronology, Cosmochronology and Isotope Geology, Cambridge (see Newsletter 47, p. 58).
20th-27th August 1986	Joint Meeting of the INQUA Loess Commission and the IGU Commission on the Significance of the Periglacial Phenomena, to be held in Normandy, Jersey and Brittany, France (see notice above).
20th-21st September 1986	Conference on The Evolution of Romney Marsh, at Hertford College, Oxford (see notice above).
21st-25th September 1986	Third Symposium on the Geology of Libya, in Tripoli (see Newsletter 47, p. 58).
25th-27th May 1987	Symposium on Coastal Lowlands: Geology and Geotechnology, at The Hague, Netherlands (see notice above).
31st July-9th August 1987	XIIth INQUA Congress, Ottawa, Canada (see notice above).
9th-19th July 1989	28th International Geological Congress to be held at Washington, D.C., U.S.A. (see notice above).

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No. 48 February 1986

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ISSN 0143-2826.