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COVER PHOTOGRAPH:

The late Lewis Penny (see Obituary in this issue). Photograph kindly provided by John Catt.

OBITUARY

L.F. PENNY, 1920-2000

Lewis Penny died of cancer at his home in Northallerton on August 10th 2000, a few days before his 80th birthday. Lewis was a founder member and first Secretary/Treasurer of the Quaternary Field Study Group (1964-68), renamed the Quaternary Research Association in 1968, and was later second President of the QRA (1971-73).

After an army commission in India, Persia and Singapore during the Second World War, Lewis followed his father into the geological profession, obtaining a Double First in the Natural Sciences Tripos at Cambridge. In 1949 he was appointed Lecturer in Geology at University College Hull, where he inherited three students from a predecessor who had lasted in the post for only one year. Geology was then a Sub-Department of Geography, but when the college became an independent university in 1954 it was made a full department with Lewis as Lecturer-in-charge. He was responsible initially with just one other lecturer (J.W. Neale) for planning and teaching Special and Joint Honours Geology Degrees as well as Ancillary (1-year) and Subsidiary (2-year) courses. Lewis had become interested in the Quaternary at Cambridge, where he was inspired by W.B.R. King. As a result the Hull Special Honours degree was one of the few in Britain at that time to include a third year course on the Quaternary.

With his natural abilities and wartime experience Lewis was an excellent department head, concentrating on impeccable organisation and shielding junior colleagues from unnecessary administrative chores so that they could develop their teaching and research. As a result the miniscule Hull department was congenial, with an *esprit de corps* envied by many other departments at Hull. Despite the financial stringencies after the Second World War, it rapidly became well known for the quality of its graduates and for its research output, principally on the geology of East Yorkshire. Lewis was deeply respected and indeed loved by generations of students for his lucid teaching, wisdom, humour, integrity, hospitality and insistence on accuracy and honesty in scientific work and daily living. Even long after his retirement in 1980 he and his wife Mary maintained a great pride in the progress of Hull graduates and ex-colleagues, who were always welcomed with beaming smiles, whatever their academic records and later achievements. -

In the 1950s virtually the whole Quaternary research community worldwide was interpreting glacial successions and river terraces by almost blind long-distance correlation with the four-fold Alpine sequence of ice ages (Günz, Mindel, Riss, Würm). With his geological training, Lewis recognised the

futility of this. For many years he was virtually a lone voice emphasising instead the need for detailed field mapping, consistent stratigraphic descriptions supported by sedimentological and palaeontological studies, and more extensive application of the limited dating techniques then available. His first presidential address to the Yorkshire Geological Society, delivered in 1963, was a masterly review of the evidence for subdivision and dating of the "Last Glaciation" in Britain, and its main conclusions have been confirmed by a large volume of subsequent work. Lewis was also decades ahead of his time in recognising the importance of Quaternary studies for understanding current problems of ecology and wildlife conservation.

His letters were fascinating combinations of helpful advice and dry humour, often spiced with classical quotations or short rhymes that put problems in their true perspective. When he was Secretary of the first Geological Society Working Group on Quaternary Correlation in Britain, we exchanged numerous inconclusive letters on whether the name Dimlington (a village on the Holderness coast now lost to coast erosion) should be proposed for part or all of what we now know as the Devensian. The correspondence was closed by a letter from Lewis ending with "Further thoughts on the Dimlingtonian: Penny and Catt said how about that? But Catt and Penny weren't having any!" Many years later Jim Rose resolved our indecision by proposing the name for the LGM Stadial in Britain (Rose, J., 1985. The Dimlington Stadial/Dimlington Chronozone: a proposal for naming the main glacial episode of the Late Devensian in Britain. *Boreas* 14, 225-230).

When Hull University created a Chair of Geology in 1962, it failed to offer Lewis the post, much to the disappointment of all who knew his real abilities. He accepted the decision with characteristic dignity and focussed his attention even more sharply on the Quaternary of East Yorkshire and on service to the QFSG and QRA. In particular, he organised the 1972 QRA Easter Field Meeting at Hull and acted as Treasurer for the 1977 INQUA Congress at Birmingham. His local work was recognised by election as Presidents of the Yorkshire Geological Society and Hull Geological Society and as Secretary of the Yorkshire Naturalists' Union. He was awarded the Sorby Medal of the Yorkshire Geological Society, the Quaternary Research Medal of the University of Helsinki, a Cambridge PhD by submission of published papers and life membership of the Hull Geological Society. His prudence as INQUA Congress Treasurer led to establishment of the Royal Society fund which has assisted members of the QRA to attend subsequent congresses.

To mark Lewis's retirement in September 1980, 22 essays were collected for a Festschrift volume (Neale, J. and Flenley, J. (Eds) 1981. *The Quaternary in Britain*, Pergamon Press, Oxford). In their preface the editors wrote: "The response from colleagues, fellow research workers and friends to an invitation to contribute to a volume in his honour was most gratifying and bears eloquent

testimony to the affection and respect in which he is held." By modern standards Lewis's publication and promotion record at Hull were not outstanding, but his personal qualities and perceptive contributions to Quaternary science certainly were. All who knew him will recall these with gratitude and treasure memories of time spent in his company.

Bibliography

De Boer, G., Neale, J.W. and Penny, L.F. (1958). A guide to the geology of the area between Market Weighton and the Humber. *Proceedings of the Yorkshire Geological Society*, 31, 157-209.

Penny, L.F. (1958). Prof. H. King Obituary. *Nature*, 181, 1177.

Penny, L.F. (1959). The Last Glaciation in East Yorkshire. *Transactions of the Leeds Geological Association*, 7, 65-77.

Bisat, W.S., Penny, L.F. and Neale, J.W. (1962). Geology around the University Towns: Hull. *Geologists' Association Guides* No. 11.

Penny, L.F. (1963). Vertebrate remains from Kelsey Hill, Burstwick and Keyingham. *Hull Museum Publication* 214, 5-14.

Penny, L.F. (1964). A review of the Last Glaciation in Great Britain. *Proceedings of the Yorkshire Geological Society*, 34, 387-411.

De Boer, G., Penny, L.F. and Catt, J.A. (1965). Field Meeting, Holderness and Spurn Head, 18th to 20th September, 1964. *Proceedings of the Yorkshire Geological Society*, 35, 294-298.

Catt, J.A. and Penny, L.F. (1966). The Pleistocene deposits of Holderness, East Yorkshire. *Proceedings of the Yorkshire Geological Society*, 35, 375-420.

Penny, L.F. (1966). Obituary: Robert George Carruthers. *Proceedings of the Yorkshire Geological Society*, 35, 447-448.

Penny, L.F. (1966). Early discoverers XXIV George William Lamplugh (1859-1926). *Journal of Glaciology*, 6, 307-309.

Penny, L.F. and Catt, J.A. (1967). Stone orientation and other structural features of tills in East Yorkshire. *Geological Magazine*, 104, 344-360.

Penny, L.F. (1968). Yorkshire geology and the Yorkshire naturalist. *Yorkshire Naturalists' Trust Newsletter*, November 1968.

Penny, L.F., Coope, G.R. and Catt, J.A. (1969). Age and insect fauna of the Dimlington Silts, East Yorkshire. *Nature*, 224, 65-67.

Penny, L.F. and Rawson, P.F. (1969). Field meeting in East Yorkshire and North Lincolnshire. Report by the Directors: L.F.Penny and P.F.Rawson. *Proceedings of the Geologists' Association*, 80, 193-218.

Penny, L.F. (1971). What is a conservationist? *Yorkshire Naturalists' Trust Newsletter*, November 1971.

Penny, L.F. (Editor) (1972). *Field Guide: East Yorkshire and North Lincolnshire*. Quaternary Research Association, Hull.

Mitchell, G.H., **Penny, L.F.**, Shotton, F.W. and West, R.G. (1973). *A Correlation of Quaternary Deposits in the British Isles*. Geological Society Special Report No. 4.

Penny, L.F. (1974). Quaternary. In: Rayner, D.H. and Hemingway, J.E. (eds) *The Geology and Mineral Resources of Yorkshire*. Yorkshire Geological Society, 245-264.

Penny, L.F. (1974). Pleistocene Geology. In: Stubblefield, Sir J., William Sawney Bisat 1886-1973. *Biographical Memoirs of Fellows of the Royal Society*, 20, 35-36.

Penny, L.F. (1975). Another rock term bites the dust. *Nature*, 253, 90.

Penny, L.F. (1977). Contributions to: *1:625,000 Quaternary Map of the United Kingdom*. Institute of Geological Sciences, Keyworth.

Penny, L.F. (1977). The Hessle Till: new light on an old problem. *Humberside Geologist*, 2.

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ESTABLISHMENT OF THE L.F.PENNY MEMORIAL FUND

At its meeting in January 2001 the QRA Executive Committee agreed that a QRA fund in memory of Lewis Penny should be opened with the intention of providing a regularly awarded medal and/or prize for outstanding research by younger Quaternary scientists. The suggestion came originally from a group of Lewis's ex-students and colleagues at Hull, who wished to honour his name because they felt their careers had benefitted from his teaching, friendship and support.

Contributions to the fund are welcome from all who wish to perpetuate Lewis's name in this way, and should be sent to the QRA Treasurer, Dr. Peter Allen, 13 Churchgate, Cheshunt, Hertfordshire EN8 9NB, UK, preferably before May 1, 2001. Cheques should be made payable to "The Quaternary Research Association" and marked "L.F. Penny Memorial Fund" on the reverse. Further details of the award will be announced in due course.

ARTICLES

A CRITICAL ASSESSMENT OF 'A NEW GLACIAL STRATIGRAPHY FOR EASTERN ENGLAND'

P.H. Banham, P.L. Gibbard, J.P. Lunkka, S.A. Parfitt,
R.C. Preece and C. Turner

In their article in the previous issue of *Quaternary Newsletter* (92), Hamblin *et al.* (2000) proposed a new stratigraphical scheme for the East Anglian Middle and Upper Pleistocene glacial sequence. This scheme, principally a fragmentation of the glacial deposits of the supposedly "more complex" and generally accepted Anglian sequence (e.g. Bowen, 1999) into three glacial stages (Oxygen Isotope Stages (OISs) 16, 12 and 6), is suggested as a replacement for that by Banham (1970, 1971, 1975, 1988), Ehlers, *et al.* (1987), Ehlers and Gibbard (1991), Hart and Boulton (1991) and Lunkka (1994). No integrated account of this 'new stratigraphy' has yet been published. In the meantime the "detailed mapping, sedimentological, micropalaeontological and palynological evidence" must be sought within a recent QRA field guide (Lewis *et al.*, 2000) and in Hamblin (2000). Several more or less controversial major points emerge:

- The Walcott Diamicton is correlated with the Lowestoft Till, and both are accepted as Anglian (i.e. probably OIS 12), although it is considered that "there is no compelling evidence that Scandinavian and Scottish ice-sheets co-existed in Norfolk".
- "The mutually distinctive lithological content of the three pre-Devensian tills in East Anglia ... is best explained by formation during separate glacial events".
- An earlier glaciation has been identified and assigned to OIS 16 (i.e. during 'Cromerian Complex' times.)
- The "Overstrand Formation" (Third Cromer Till of Banham (1971, 1975, 1988), Cromer Diamicton of Lunkka (1994) and Ehlers and Gibbard (1997)) is correlated with the Welton Till and Basement Till of Lincolnshire and East Yorkshire and assigned to OIS 6.
- Glaciifluvial sediments and landforms in the Glaven Valley and Cromer Ridge are also assigned to OIS 6.

The authors thus conclude that “five glacial episodes... including the Devensian” (i.e. during OISs 16, 12, 10, 6 and 2) occurred in eastern and Midland England in the Middle to Late Pleistocene. If correct, these conclusions have profound implications for the stratigraphy and palaeogeography of the glacial Pleistocene of lowland Britain.

Assessment of the evidence

Regrettably, the evidence referred to by Hamblin *et al.* (2000) remains largely obscure. No new geological maps are presented, and there are sketch sections for just two sites: Weybourne and Leet Hill. In general accounts (e.g. Moorlock *et al.*, 2000 pp. 53, 112), much is made of the significance for the new stratigraphy of Leet Hill, but the description and interpretation of the site itself (Rose *et al.*, 2000 p. 207 *et seq.*) is relatively cautious and stays close to the generally accepted stratigraphy. Again, mineralogical and mechanical analyses are claimed to support the re-allocation of the Happisburgh and Cromer Diamictons to OISs 16 and 6, respectively (Hamblin *et al.*, 2000 p. 37), but these conclusions are reached by re-interpreting the published conclusions of others (Perrin *et al.*, 1979; Lunkka, 1994; Catt and Penny, 1966; Madgett and Catt, 1978; Catt, 1991) in the light of their own, *unpublished* results. Any further discussion of this issue must therefore be postponed. Meanwhile, Professor Catt (*pers. comm.*) “warns against comparing results from different workers until the exact details of their analytical techniques are known, especially given the general mineralogical similarity of tills throughout eastern England”. No reference is made to results from mineral grain magnetisation studies (Lunkka, 1991), which show a clear difference between the Walcott Diamicton and the Lowestoft Till across a wide range of grain-size fractions. Similarly, geomorphological evidence is not discussed in depth, although there is an ambiguous reference to the significance of “fresh”/ “apparently fresh” landforms (Hamblin *et al.*, 2000 p. 38) for the supposed OIS 6 age of the Cromer Diamicton.

A great deal of palaeontological and palynological work has apparently been carried out on some diamictons, but the results are so generally similar (Moorlock *et al.*, 2000 pp. 111-113) that conclusions for the supposedly distinctive and widely time separated Happisburgh and Walcott Diamictons are taken together in the introductory statement (Moorlock *et al.*, 2000 p. 53). Finally, and crucially where additional glacial stages are proposed, no new evidence is presented of interglacial deposits of any age.

It is worth noting that the same field guide (Lewis *et al.*, 2000) contains many detailed accounts of sites which in general develop various aspects of the *accepted* stratigraphy of the Anglian Stage. An interesting example in that

category is given by these same authors and others (Fish, *et al.*, 2000) for the 'Marly Drift' at Weybourne.

Assessment of the arguments

Setting aside these concerns at the lack of published evidence, the new scheme can also be assessed with regard to its broader implications for the Quaternary stratigraphy of lowland Britain. Not surprisingly, we find the 'new stratigraphy' gives rise to more questions than answers. For example, how could ice travel from Oslo to Diss during OIS 16 without British ice being present in East Anglia? Equally, how could ice reach the English Midlands in OIS 10 ('early 'Wolstonian' = early Saalian Complex), but there be no traces of contemporaneous glaciation *yet identified* elsewhere in temperate lowland Europe? Clearly the scheme proposed must be in error. Since the Quaternary stratigraphy of East Anglia is based on a variety of approaches (principally lithostratigraphy, but supported by biostratigraphy, geochronology and geomorphological arguments) it would require a lengthy article to weigh all aspects. However, the major components of the new stratigraphy can be evaluated in turn.

The principal reasons for the authors separating the Walcott Diamicton from the other North Sea Drift Formation tills seem to be its chalk content, its comparatively clay-rich matrix and the occurrence of palynomorphs of 'British' origin. All the tills in the Norfolk region are chalk-rich; some such as the Lowestoft Formation Marly Drift facies are 70% carbonate (Ehlers *et al.*, 1987), which is not surprising since Chalk underlies most of Norfolk, including large areas offshore. If the Walcott Member was deposited by ice moving from the northwest, a fact not in dispute, it is to be expected that it would be enriched in chalk, since it would have advanced across the high chalk ground of what is today offshore northern Norfolk. Indeed the pattern of movement of the Walcott ice lobe requires that British ice occurred in the vicinity to explain its direction (see below). It is not difficult to understand why this lobe should have reworked British debris, since it undoubtedly competed with the British (Lowestoft Formation) ice during its advance.

From the description given by Hamblin *et al.* (2000), there is no sense of how these glacial sediment units relate. Indeed no mention is made of the intimate relationship of the Walcott Member with the sediment sequences of the tills and associated meltwater sediments that both over- and underlie it. Even if the Walcott Diamicton were of British ice origin, it would still represent the same glaciation event as those of the other North Sea Drift members, since it is interstratified within the glacial sequence. It follows from the above that British and Scandinavian ice must have co-existed throughout the Anglian

glaciation. This is essential to explain the glacial path of both ice sheets. Perhaps it can be asked precisely what evidence would the authors accept to demonstrate that the two ice masses were coeval? Clear evidence for the interaction of the ice sheets is seen in the sedimentary sequences at localities such as Trimmingham and Sheringham (Norfolk), and the type area of Corton (Suffolk). At all these places the deposits of both provenances are intimately related and are nowhere separated by sediments of interglacial character.

The contention that the lithological content of the three diamicton units (Happisburgh, Walcott and Cromer Diamictons) is best explained by formation during separate glacial events is disingenuous as well as being an OIS-reading of the facts. Overall, these tills are extraordinarily similar, being dominated by silt-rich matrices, being relatively poor in chalk (although there is considerable local variation, particularly inland) and containing an erratic suite that clearly demonstrates an ultimate origin in the southernmost part of the Scandinavian peninsula (cf. Ehlers *et al.*, 1992). The contrast of these properties with those of the clay-rich Lowestoft Formation tills is generally profound. Any similarity of the Walcott Diamicton to the Lowestoft Till (cf. Hamblin, 2000) may simply reflect a British-debris contribution to the Scandinavian ice sheet. Moreover, the Cromer Diamicton is so rich in chalk, because of its content of massive chalk floes, that locally it must exceed the chalk content of the Lowestoft Till, yet the authors exclude this unit altogether from the Anglian, in spite of the fact that it is overlain by Lowestoft Formation Marly Drift-facies diamicton at several localities in Norfolk (Ehlers *et al.* 1987; Ehlers and Gibbard, 1991, 1997). In this the authors disagree with Hamblin (2000), who concludes that the "ground-up, reconstituted chalk... in the past has been mistaken for Lowestoft Till". There is also general agreement that the Corton Sands were derived from the North Sea Drift Formation ice sheet and are therefore of the same age (Banham, 1971; Bridge and Hopson, 1988; Hamblin *et al.*, 2000). The arguments that favour equating the Anglian / Elsterian Stage to OIS 12 have been frequently rehearsed and will not be repeated here, given that the evidence available suggests that this correlation is appropriate at the present state of knowledge.

The assertion that the Happisburgh Diamicton represents a glaciation in OIS 16 is, however, in direct conflict with the both litho- and biostratigraphy. The entire glacial sequence in Norfolk overlies sediments of the Cromer Forest-bed Formation (West, 1980; Gibbard *et al.*, 1991), which includes evidence for several interglacials, representing the Early (Pastonian) to early Middle Pleistocene ('Cromerian Complex'). Beneath the Happisburgh Diamicton, deposits occur at Sidestrand and Ostend (Sidestrand Unio Bed) which contain *Arvicola*, a vole that appears first in the latter part of the 'Cromerian Complex' (van Kolfschoten and Turner, 1996; Preece and Parfitt, 2000). This is strong

evidence that the overlying Happisburgh Diamicton cannot be as old as OIS 16, given that at least three newly recognized interglacials with *Mimomys* occur in the early part of the Brunhes (Preece and Parfitt, 2000). Furthermore, in eastern Europe (Russia, Belarus and Poland), as discussed below, the Don Till and its equivalents provide a more convincing candidate for an OIS 16 glaciation, undoubtedly within the 'Cromerian Complex', and there *Mimomys savini* (= *M. intermedius*) occurs within interglacial deposits both below and above that till.

Having considered the biostratigraphical evidence for the age of the base of the glacial sequence in Norfolk, it is pertinent to look at its upper boundary. A minimum age is provided by organic deposits which rest within a hollow on the surface of the youngest diamicton, the 'Hanworth Till Member' (Third Cromer Till, Cromer Diamicton), between Sidestrand and Trimmingham. These lacustrine organic deposits have yielded a pollen sequence attributed to the late Anglian and early Hoxnian (Hart and Peglar, 1990). Attribution of the 'Hanworth Till Member' to OIS 6 would place the succeeding organic deposits within OIS 5 or younger. However, the palynological characteristics of the Sidestrand organic deposit, especially the frequency of *Hippophae*, do not match any late-glacial to pre-temperate pollen sequences associated with Ipswichian sites so far recorded in Britain. The age of the glacial sequence is therefore tightly constrained by the Sidestrand Unio Bed below and this organic lake bed above.

As noted above, there is no question that substantial glaciation occurred in northern Europe during 'Cromerian Complex' times. During this period, ice reached as far south as central Poland and as far west as the coast of Jutland. This glaciation is conventionally placed in 'Glacial b' (*sensu* Zagwijn, 1996; Turner, 1996) and is termed the Don Glaciation in European Russia (Donian Stage). It is conceivable, therefore, that glacial ice from the mountains entered the upper catchments of the English Midland rivers, a fact that could adequately explain the occurrence of erratics in the Bytham Formation river sediments. However, nowhere in Britain does any Don Glaciation-equivalent appear to have been as extensive as that during the Anglian Stage.

Moreover, regarding any resemblances between the Cromer Diamicton (i.e. the 'Hanworth Till Member') and the tills in Lincolnshire and Yorkshire, it is perfectly possible that ice repeatedly worked the same sources. Regarding the Glaven Valley landforms, their age is clearly indicated by their internal structure and sequence, evidence *not* mentioned by the authors. Throughout the area, but particularly at sections at Wiveton Down, the Glaven Valley quarry and Smoker's Hole, these sediments are intimately interstratified with Lowestoft Formation Marly Drift-facies diamicton (Gale and Hoare, 1986; Ehlers *et al.*, 1987, 1991; Bannerman, 1991; Gray, J.M., 1997; Banham, 2000). Therefore it must be misleading to suggest that they are younger, since, as the authors

themselves acknowledge, the Lowestoft Formation tills underlie Hoxnian-age deposits, such as the Nar Valley Clay further west (Ventris, 1996). Even considering recent suggestions that the Nar Valley Formation belongs to a stage younger than the Hoxnian (Rowe *et al.*, 1997; Scourse *et al.*, 1999), the underlying till cannot relate to OIS 6. Furthermore, directly overlying the Nar Valley Formation near Kings Lynn, the glaciodeltaic Tottenham Gravel undoubtedly represents a glaciation intermediate in age between the Hoxnian and Ipswichian stages, as the authors agree. However, there are no reasonable grounds for assigning this to any event other than that seen in the neighbouring central Netherlands and Germany, i.e. the Drenthe Substage of the Saalian Complex (= 'Wolstonian', ?OIS 6), as stated in the original reports (Gibbard *et al.*, 1991, 1992).

Conclusion

Thus, both the evidence and the arguments set out by Hamblin *et al.* (2000) for a new scheme of glaciation history in eastern England fail to stand up to scrutiny. Matters may become clearer when new mineralogical analyses and detailed mapping are published. Further evidence of interglacial deposits within the proposed sequence would be even more useful. The points raised concerning the lithology of the diamictos, particularly the Walcott Diamictos, may be significant, but they do not invalidate the established lithostratigraphy, although some minor modification of the terminology may be desirable. We see no justification for the erection of a new Overstrand Formation, nor for changing the term Cromer Diamictos, nor yet, on the basis of the evidence presented, for assigning it to a later glacial event. We therefore urge colleagues not to adopt the new subdivision, but to retain the scheme of Lowestoft and North Sea Drift Formations.

Regarding the identification of a five-fold scheme of glaciation in eastern (and Midland) England, we agree that there is ample evidence for glaciation during the Anglian (?OIS 12), 'Wolstonian' (?OIS 6) and Devensian (OIS 2) Stages, but glaciation in the early 'Wolstonian' (?OIS 10) is unfounded. Moreover, we do not accept the arguments for glaciation reaching Norfolk, nor the adjacent southern North Sea basin, during 'Cromerian Complex' times (i.e. during OIS 16). Instead, we continue to hold the view that the Happisburgh Diamictos represents the basal member of the North Sea Drift Formation and that it formed during the Anglian Stage. Indeed, this view has been strengthened by recent biostratigraphical evidence of the occurrence of *Arvicola* and a number of stratigraphically significant molluscs from the Sidestrand Unio Bed.

References

- Banham, P.H. (1970). Notes on Norfolk coastal sections. In: Boulton G.S. (ed) *East Anglia. Field Guide*. Quaternary Research Association, Norwich.
- Banham, P.H. (1971). Pleistocene beds at Corton, Suffolk. *Geological Magazine*, 108, 281-285.
- Banham, P.H. (1975). Glaciotectonic structures: a general discussion with particular reference to the Contorted Drift of Norfolk. In: Wright A.E. and Moseley F. (eds) *Ice Ages: Ancient and Modern*. Geological Journal Special Issue no. 6, Seel House Press, 69-94.
- Banham, P.H. (1988). Polyphase glaciotectonic deformation in the Contorted Drift of Norfolk. In: Croot, D. (ed) *Glaciotectonics: Forms and Processes*. Balkema, Rotterdam, 27-32.
- Banham, P.H. (2000). C.E. Ranson's data from the glaciifluvial and other sands and gravels of North Norfolk, England. *Bulletin of the Geological Society of Norfolk*, 50, 5-20.
- Bannerman, C.A. (1991). *Glacial deposits in north Norfolk*. M.Phil. Thesis, University of Cambridge.
- Bowen, D.Q. (ed) (1999). *A Revised Correlation of Quaternary Deposits in the British Isles*. Geological Society Report no. 23.
- Bridge, D. and Hopson, P. (1988). Corton Cliffs. In: Gibbard, P.L. and Zalasiewicz, J.A. (eds) *Pliocene - Middle Pleistocene of East Anglia*. Field Guide. Quaternary Research Association, Cambridge, 119-129.
- Catt, J.A. and Penny, L.F. (1966). The Pleistocene deposits of Holderness, East Yorkshire. *Proceedings of the Yorkshire Geological Society*, 35, 375-420.
- Catt, J.A. (1991). Quaternary history and glacial deposits of East Yorkshire. In: Ehlers, J., Gibbard, P.L. and Rose, J. (eds) *Glacial Deposits in Great Britain and Ireland*. Balkema, Rotterdam, 185-192.
- Ehlers, J. and Gibbard, P. (1991). Anglian glaciation and glacial deposits in Britain. In: Ehlers, J., Gibbard, P.L. and Rose, J. (eds) *Glacial Deposits in Great Britain and Ireland*. Balkema, Rotterdam, 17-24.
- Ehlers, J. and Gibbard, P. (1997). The contorted drift of Norfolk, England. In: *Festschrift für Professor Dr Lothar Eißmann*. Leipziger Geowissenschaften, 5, 105-113.
- Ehlers, J., Gibbard, P. and Whiteman, C.A. (1987). Recent investigations of the Marly Drift of NW Norfolk, England. In: van der Meer, J.J.M. (ed.) *Tills and End Moraines*. Balkema, Rotterdam, 39-54.
- Ehlers, J., Gibbard, P. and Whiteman, C.A. (1991). North Norfolk. In: Ehlers,

J., Gibbard, P. L. and Rose, J. (eds) *Glacial Deposits in Great Britain and Ireland*. Balkema, Rotterdam, 223-232.

Ehlers, J., Gibbard, P. and Whiteman, C.A. (1992). Elsterzeitliche (Anglian) Eisdynamik in East Anglia. *Eiszeitalter und Gegenwart*, 42, 80-93.

Fish, P.R., Whiteman, C.A., Moorlock, B.S.P., Hamblin, R.J.O. and Wilkinson, I.P. (2000). Weybourne, North Norfolk: a new analysis based on Chalk micropalaeontology. In Lewis, S. G., Whiteman, C.A. and Preece, R.C.(eds) *The Quaternary of Norfolk & Suffolk*. Field Guide. Quaternary Research Association, London, 119-130.

Gale, S.J. and Hoare, P.G. (1986). Blakeney ridge sands and gravels. In: West, R.G. and Whiteman, C.A. (eds) *The Nar Valley and North Norfolk*. Field Guide. Quaternary Research Association, Cambridge, 94-95.

Gibbard, P.L., West, R.G., Andrew, R. and Pettit, M. (1991). Tottenhill. In: Lewis, S.G., Whiteman, C.A. and Bridgland, D.R. (eds) *Central East Anglia & the Fen Basin*. Field Guide. Quaternary Research Association, Cambridge, 131-143.

Gibbard, P.L., West R.G., Andrew, R. and Pettit, M. (1992). The margin of a Middle Pleistocene ice advance at Tottenhill, Norfolk, England. *Geological Magazine*, 129, 59-76.

Gibbard, P. L., West, R.G., Zagwijn, W. H. *et al.* (1991). Early and early Middle Pleistocene correlations in the southern North Sea Basin. *Quaternary Science Reviews*, 10, 23-52.

Gray, J. M. (1997). The origin of the Blakeny Esker, Norfolk. *Proceedings of the Geologists' Association*, 108, 177-182.

Hamblin, R.J.O. (2000). A new glacial stratigraphy for East Anglia. *Mercian Geologist*, 15, 59-62.

Hamblin, R.J.O., Moorlock, B. and Rose, J. (2000). A new glacial stratigraphy for eastern England. *Quaternary Newsletter*, 92, 35-43.

Hart, J.K. and Boulton, G.S. (1991). The glacial drifts of Norfolk. In: Ehlers, J., Gibbard, P. L. and Rose, J. (eds) *Glacial Deposits in Great Britain and Ireland*. Balkema, Rotterdam, 233-243.

Hart, J.K. and Peglar, S. M. (1990). Further evidence for the timing of the Middle Pleistocene glaciation in Britain. *Proceedings of the Geologists' Association*, 101, 187-196.

Lewis, S.G., Whiteman, C.A. and Preece, R. C. (eds) (2000). *The Quaternary of Norfolk and Suffolk*. Field Guide. Quaternary Research Association, London.

Lunkka, J.P. (1991). Sedimentology of the Anglian glacial deposits of northeast Norfolk, England. *PhD Thesis, University of Cambridge*.

Lunkka, J.P. (1994). Sedimentation and lithostratigraphy of the North Sea Drift and Lowestoft Till Formations in the coastal cliffs of northeast Norfolk, England. *Journal of Quaternary Science*, 9, 209-233.

Madgett, P.A. and Catt, J.A. (1979). Petrography, stratigraphy and weathering of Late Pleistocene tills in east Yorkshire, Lincolnshire and North Norfolk. *Proceedings of the Yorkshire Geological Society*, 42, 55-108.

Moorlock, B.S.P., Booth, S., Fish, P., Hamblin, R.J.O., Kessler, H., Riding, J., Rose, J. and Whiteman, C.A. (2000). A revised glacial stratigraphy of Norfolk, 53-54; Happisburgh cliffs (TG 383312), 111-114; Briton's Lane Gravel Pit, Beeston Regis, 115-118. In: Lewis, S.G., Whiteman, C.A. and Preece, R.C. (eds) *The Quaternary of Norfolk & Suffolk*. Field Guide. Quaternary Research Association, London.

Perrin, R.M.S., Rose, J. and Davies, H. (1979). The distribution, variation and origins of pre-Devensian tills in eastern England. *Philosophical Transactions of the Royal Society of London*, B 287, 535-570.

Preece, R.C.P. and Parfitt, S.A. (2000). The Cromer Forest-bed Formation: new thoughts on an old problem. In: Lewis, S.G., Whiteman, C.A. and Preece, R.C. (eds) *The Quaternary of Norfolk & Suffolk*. Field Guide. Quaternary Research Association, London, 1-27.

Rose, J., Candy, I. and Lee, J.R. (2000). Leet Hill (TM 384926): pre-glacial and glaciofluvial river deposits - with possible evidence for a major glaciation prior to the deposition of the Lowestoft Till. In: Lewis, S.G., Whiteman, C.A. and Preece, R.C. (eds) *The Quaternary of Norfolk & Suffolk*. Field Guide. Quaternary Research Association, London, 297-218.

Rowe, P.J., Richards, D.R., Atkinson, T.C., Bottrell, S.H. and Cliff, R.A. (1997). Geochemistry and radiometric dating of a Middle Pleistocene peat. *Geochimica et Cosmochimica Acta*, 61, 4201-4211.

Scourse, J.D., Austin, W.E.N., Sejrup, H.-P. and Ansari, M.H. (1999). Foraminiferal isoleucine epimerization determinations from the Nar Valley Clay, Norfolk, UK: implications for Quaternary correlations in the southern North Sea basin. *Geological Magazine*, 136, 543-560.

Turner, C. (1996). A brief survey of the early Middle Pleistocene in Europe. In: Turner, C. (ed), *The early Middle Pleistocene in Europe*. Balkema, Rotterdam, 295-317.

van Kolfschoten, T. and Turner, E. (1996). Early Middle Pleistocene mammalian faunas from Karlich and Mesenheim 1 and their biostratigraphical implications. In: Turner, C. (ed) *The early Middle Pleistocene in Europe*. Balkema, Rotterdam, 227-253.

Ventris, P.A. (1996). Hoxnian interglacial freshwater and marine deposits in north-west Norfolk, England and their implications for sea-level reconstruction. *Quaternary Science Reviews*, 15, 437-450.

West, R.G. (1980). *The pre-glacial Pleistocene of the Norfolk and Suffolk coasts*. Cambridge University Press, Cambridge.

Zagwijn, W.H. (1996). The Cromerian Complex Stage of the Netherlands and correlation with other areas in Europe. In Turner, C. (ed) *The early Middle Pleistocene in Europe*. Balkema, Rotterdam, 145-172.

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SPECULATIONS ON THE GLACIATION OF DARTMOOR

Stephan Harrison

Introduction

The uplands of southwest England have long been considered to be relict periglacial landscapes lying outside the Quaternary glacial ice limits. However, two recent papers (Harrison *et al.*, 1998, in press) have demonstrated the existence of glacial tills and associated glacial landforms in the vicinity of The Punchbowl, on Exmoor, a north-facing valley 2 km west of the village of Winsford at SS 883343. Although I do not wish to revisit all the evidence used for these studies, two points deserve reiteration. First, the glacial tills have been deposited at relatively low altitudes (down to 255 m OD; Harrison *et al.*, in press). Second, consideration of the geomorphology of the site suggests that the glacier was not constrained by The Punchbowl itself but flowed from a small ice cap located on the summit plateau of Winsford Hill (426m O.D.). From this standpoint I would like to: (1) speculate about the likelihood of similar ice masses having formed at high altitudes on Dartmoor, (2) discuss briefly the nature of these possible former glaciers; and (3) examine their geomorphological significance to our understanding of the upland landscape.

The Punchbowl glacier: one of many?

Immediately outside the limits of contemporary ice sheets and ice caps (and even small valley glaciers) it is usual to find high ground nurturing small glaciers and ice masses whose distribution is controlled by the local equilibrium line and the nature of the topography. Various lines of evidence support the view that ice sheets reached the Southwest Peninsula during the Quaternary. The Fremington Clay has long been viewed as a glacial deposit, although recent interpretations suggest that it might have been deposited beyond the southern limits of the ice (Campbell and Croot, 1998). Further west, detailed sedimentological and palaeobotanical studies from the Scilly Isles (Scourse, 1991, reviewed in Scourse, 1998) demonstrate the presence of glacial tills of possible Late Devensian age. And more recent work (Van Vliet-Lanoë *et al.*, 2000) suggests the proximity of ice sheets to the Southwest Peninsula at various times during the Quaternary by demonstrating that raised beaches in the English Channel show at least three phases of shore-ice rafting in the Western Approaches after the Middle Pleistocene. Therefore, although the age of the Punchbowl glacier has yet to be determined it would be of little surprise that glacial ice occurred on the uplands of southwest England during the cold stages

of the Quaternary when large ice sheets reached the Bristol Channel and the Western Approaches. What is perhaps more surprising is the absence of other well-defined glacial cirque basins and glaciated valleys on Exmoor or Dartmoor, although I will argue later that much of the glacial ice may have had an essentially protective rather than erosive role. The only other place on Exmoor where a north-facing overdeepened valley similar to The Punchbowl exists is east of Rowley Down on the western edge of the moor at SS 676431, and this feature is far less developed. It appears that no valley heads on Dartmoor are of similar form to the Punchbowl, although the valley to the west of Black Tor (the West Okement Valley; SX 568888), on the northern edge of Dartmoor, has an overdeepened form.

Previous Work

The glaciation of Dartmoor has certainly been considered before (e.g. Ormerod, 1869; Somervail, 1897; Pillar, 1917). In the most detailed treatment, Pickard (1943) argued for the former existence of extensive glaciers and small ice caps on Dartmoor during the Quaternary. He subdivided the landform evidence into: "(a) worn boulders, (b) moraines, (c) grooved rocks, (d) slabs, (e) the terrain, and (f) gravels" (Pickard, 1943, p. 28), inferring that: (1) many of the "worn boulders" had been transported and modified by ice; (2) ridges of blocky debris in many of the valleys were moraines; and (3) asymmetrically-shaped boulders and cobbles, and shallow grooves on these and on bedrock, resulted from glacial erosion. Although no *detailed* rebuttal of these arguments have (to the present author's knowledge) been published, the modern consensus is that the landform evidence presented by Pickard did not reflect the former presence of glacial ice on the moor.

There are, however, two main lines of landform evidence which point to the former existence of ice masses on Dartmoor. First, overdeepened valleys and valley heads exist on the northern flanks of the moor, especially near Sourton Common, Okehampton Common and South Tawton Common (Figure 1). Associated with these are linear boulder spreads and ridges which run along the east-facing hillsides above the West Okement River at the Slipper Stones (SX 562888) and in the Taw Valley (SX 620905). These and other boulder ridges were interpreted as medial and lateral moraines by Pickard (1943), and it is difficult to see how such depositionally and topographically distinct ridges could have been formed by periglacial or fluvial processes. They do not possess the characteristics of protalus ramparts. Second, thick accumulations of bouldery debris have been described from valley-bottom locations at several places around the margins of Dartmoor and attributed to fluvial reworking of periglacial sediments. For instance, at Ivybridge, on the southern edge of Dartmoor,

Gilbertson and Sims (1974) have described a suite of debris cones and alluvial fans containing poorly sorted deposits and boulders up to 2 m long. They assumed that these were deposited by periglacial 'earthflows' and 'slushflows'. However, such accumulations are also common in glaciated areas, where they reflect the importance of sediment transport by meltwater. Whilst a reinterpretation of these and other deposits derived from Dartmoor (such as those infilling Plymouth Sound and in the South Hams district) is beyond the scope of this paper, it is clear that there are components of the landscape which require further investigation. It is also clear that the evidence for the glaciation of Dartmoor (if it exists at all) is equivocal.

The possible nature of the Dartmoor ice masses and some implications for landform development

If glacier ice existed on Dartmoor during the Quaternary, what form might it have taken and what sort of sediment accumulations could it have produced? The ice masses were probably thin and, in the absence of steep slopes, subglacial shear stresses would have been low and the ice slow moving. Since the former presence of extensive permafrost at low altitudes in southwest England during the Late Devensian is reflected by ice-wedge casts (*cf.* Ballantyne and Harris, 1994), we would expect that at these, and earlier, times the climate on the Dartmoor uplands would have been colder. As a result, the glaciers here would probably have been cold-based on the highest ground and perhaps warm-based or polythermal only along the deeper valleys. Accumulation of ice would have been facilitated by snow drifting on the extensive plateaus and by the addition of rime ice on exposed bedrock surfaces. But if glacial ice did develop on Dartmoor, where is the unequivocal landform evidence? Pickard's (1943) observations and subsequent work suggest that this evidence is subtle and open to other interpretations, and this equivocality might well reflect the nature of the ice masses. This can be explained in three ways:

1. Thin ice on low-angled slopes would have only generated low shear stresses (perhaps in the order of 40 to 45 kNm⁻²), and as a result, movement would have been slow. Thus it is unlikely that ice velocities would have been high enough to generate lee-side cavities in hummocky bedrock terrain, and, therefore, erosional bedrock features such as roches moutonnées would be unlikely to have formed. The absence of small-scale erosional features such as striations and chattermarks simply reflects the fact that the coarse crystalline Dartmoor granites are not suitable for their preservation. Striations are preserved, however, on the Exmoor slates (see Harrison *et al.*, 1998, Figure 8).
2. Glacier ice frozen to its bed would have protected, rather than eroded it,

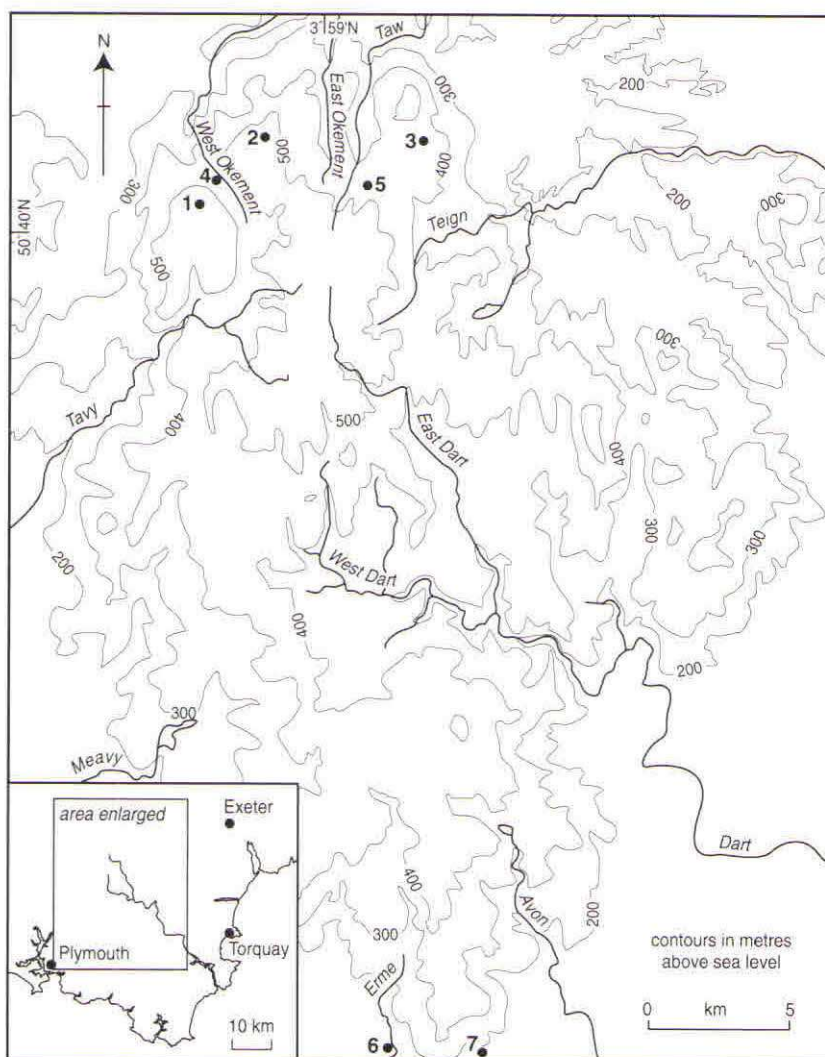


Figure 1. Location map of Dartmoor showing the main rivers and localities described in the text. 1. Sourton Common; 2. Okehampton Common and High Willhays (621 m OD); 3. South Tawton Common; 4. Slipper Stones; 5. Taw Valley; 6. Ivybridge; 7. South Hams.

allowing even delicate periglacial landforms and sediments to survive perhaps repeated glaciations (*cf.* Kleman, 1994; Kleman and Borgström, 1994).

3. The absence of high bedrock cliffs above the accumulation areas of the ice masses would have prevented rock debris from falling onto the glacier surfaces and being incorporated to form the material deposited as glacial moraines and till. The only material available for entrainment would have been the unconsolidated weathered granite common on Dartmoor. Low ice velocities and the prevailing thermal regime may have precluded the large-scale entrainment and transport of this material, but if this had happened locally, it might be difficult to differentiate between glacially-transported weathered granite and that moved by slope processes.

Whilst the role of glacial ice over much of Dartmoor's high ground may have been protective, it is likely that along the deeper valleys (e.g. West Okement Valley; Figure 1) ice accumulation would have been sufficient to increase subglacial shear stresses enough to have permitted glacial erosion. And so it may be at these locations that evidence for glacial erosion should be sought; if found, this would demonstrate that Dartmoor is not a true periglacial landscape but one which owes much of its form to glacial protection and, perhaps, limited glacial modification.

Discussion

Two points are developed in this section. The first briefly considers the sometimes equivocal nature of the geomorphic evidence used to distinguish between glaciated and non-glaciated uplands. The second addresses some of the philosophical issues raised by such studies.

The geomorphic evidence

Many studies testify to the essentially protective role that glacial ice may assume and the resulting limited landscape modification. Examples of the protective role of glacial ice can be seen in contemporary mountain environments and in elements of the British landscape. For instance, in parts of northern Norway, extensive polythermal ice fields occur on plateau surfaces. Where the ice fields are cold-based, pre-glacial and periglacial landscapes and features including well-developed blockfields and periglacial stone circles have been preserved under the ice (e.g. Whalley *et al.*, 1981; Rea *et al.*, 1996a and b).

In addition, several upland regions of the British Isles display many of the landscape features found on Dartmoor yet are considered to have undergone

repeated glaciation. For example, the rolling hills and plateaus of the Cheviots in northern England and southern Scotland resemble in many respects the Dartmoor uplands. They form peat-covered rounded hills underlain by granites and andesites and exhibit a range of periglacial features, including well-developed tors with extensive clitter fields, cryoplanation terraces and solifluction sheets (Clapperton, 1970; Douglas and Harrison, 1985). Chemical weathering of granite bedrock in the Cheviots occurs to a depth of 17 m or so (Awujoola, 1987) and is considered to be of Tertiary age. However, the evidence to show that the Cheviot Hills were repeatedly glaciated is not in doubt, because meltwater channels are common (Clapperton, 1971) and glacial till is found in many of the valley bottoms and, in several places, overlying deeply-weathered bedrock (Harrison, 1994). Glacial ice in the Cheviots covered the highest summits, and it is considered that several elements of the periglacial landscape (including the tors and cryoplanation terraces) pre-date at least the last glaciation (Clapperton, 1970). As a result, the presence of periglacial landforms in an area, even when it is considered that their formation may require several glacial cycles to complete, may not necessarily indicate the absence of glaciation. Whilst Dartmoor exhibits many of the periglacial landscape features found in the Cheviot Hills, unequivocal glacial tills have not, as yet, been discovered. This may be explained in two ways. First, the relative relief of the Cheviot Hills exceeds that of Dartmoor. For instance, the summit of The Cheviot (the highest point in the Cheviot Hills) is at 815 m whilst the floor of the nearby, glacially-modified College Valley is at c. 170 m, giving a relative relief of 645 m. This can be contrasted with a maximum of 250 m on Dartmoor, taken from the highest point (High Willhays at 621 m) to the bottom of the West Okement Valley (c. 370 m O.D.) 1 km to the west. The greater relative relief in the Cheviot Hills may have allowed increased ice thicknesses over the valleys which in turn promoted higher shear stresses, higher rates of deformation (*cf.* Glasser, 1995) greater debris entrainment and transportation and, hence, a higher likelihood of glacial deposition. Second, the Cheviot Hills are well within the limits of ice-sheet glaciation in the British Isles; lie some 600 km to the north of Dartmoor, on the colder (but also drier) east coast of the country; and are much higher, with eight hill tops exceeding the altitude of High Willhays. Dartmoor, on the other hand, may be considered to be at the margins of glaciation in the British Isles and this combination of geographical and topographic factors may explain the contrasts in the glaciation of the two upland massifs.

Significantly, although Linton (1949, 1955) initially proposed that tors could not survive under glacial ice, he later modified this view by arguing that survival could occur if the ice were thin and slow moving. This principle of limited glacial erosion has been used to explain much of the landscape and

preservation of tors in the Cairngorms (Sugden, 1968) and the presence of preglacially weathered *in situ* bedrock in glaciated northeast Scotland (Hall and Sugden, 1987; Hall and Mellor, 1988). Similarly, other landforms such as nivation hollows may also be able to survive glaciation. Nivation hollows have been described from a number of locations on Dartmoor (e.g. Gerrard, 1988) and are assumed to be the product of extensive periods of snow-patch erosion during prolonged periglacial episodes. However, Rapp (1984) has shown that these may exist in areas which underwent glaciation, arguing that they may be protected from the erosive effects of glacial ice by an infilling of nival ice. In the Cheviot Hills, several shallow hillside hollows have been interpreted as nivation hollows (Douglas and Harrison, 1987; Harrison, 1989) and contain glacial tills, suggesting that their formation predates at least the last glaciation.

Philosophical implications

Critics of these views may argue that this paper spends a long time showing why unequivocal evidence for the glaciation of Dartmoor might not be available and will point to the continued absence of glacial erosional and depositional landforms from the area as support for the interpretation of Dartmoor as having been ice-free during the Quaternary. Since 'absence of evidence is not evidence of absence' I have suggested that some of the landforms of the uplands may have had different histories than has previously been accepted. Whilst extrapolation from theoretical considerations to argue for the existence of phenomena and the former operation of processes for which no evidence has been found occurs elsewhere in science (e.g. the initial arguments about antimatter and black holes in physics and cosmology), this seems rarer in geomorphology and Quaternary Science. However, there may be a number of ways forward where we can begin to falsify the hypothesis that ice did *not* develop on Dartmoor. First, if in some of Dartmoor's deeper valleys diamicts are found with macrofabrics associated with high compressional stresses, then this would suggest strongly that subglacial processes had modified the pre-existing regolith. Second, if detailed lithological analysis of detached boulders on Dartmoor demonstrated that they had been moved considerable distances and against gravity from the parent bedrock, then this would also argue for the former presence of glaciers. To the present author's knowledge, these analyses remain to be carried out systematically and could yield important data.

These arguments emphasize two philosophical issues. First, questions such as whether Dartmoor and other uplands of the Southwest Peninsula were glaciated highlight the nature of question-and-answer logic espoused by philosophers such as Collingwood (1938, 1994). This logic suggests that the answers obtained from the system under observation depend largely upon the questions that are asked of it, and elements of this philosophy have been used in

fundamental explorations of ontology in science (see Wheeler, 1986). Thus, by only "asking" Dartmoor periglacial questions elicits only periglacial answers. It is when different types of questions are asked that different possibilities and landscape histories are envisaged. Such a view mirrors Latour's (1987) Rule 3 of science, which states that "Since the settlement of a controversy is the *cause* of Nature's representation, not its consequence, we can never use this consequence, Nature, to explain how and why a controversy has been settled" (p. 258). Perhaps debates about the geomorphological histories of equivocal and subtle landscapes highlight the need for a more interpretative, qualitative and narrative approach to landscape descriptions away from the increasingly reductionist schemes such as the construction of process-form models. Baker's recent (1999) call for a geosemiotics in which geological thought and practice are "embedded in an intricate web of signs" may provide one way forward.

Second, Dartmoor has been the focus of the enduring debate on the origin of the British tors (*cf.* Linton, 1955; Palmer and Radley, 1961; Palmer and Neilson, 1962). It has often been assumed that the tors represent a classic case of equifinality, whereby different processes produce similar landforms. Equifinality, however, may be seen to reflect the problems of adequate and appropriate landform classification (and hence their correct interpretation) and may be a consequence of the uncertainties created by the deductive approach to geomorphological investigation; here, we attempt to reconstruct past environments from the configurations of present-day ones. However, this approach makes the untestable assumption that we are able to differentiate between landscape types and that these unequivocally mirror different past environments. It also fails to recognise that the non-linear nature of many geomorphological processes means that the *outcomes* from the initial system configuration cannot be predicted. Therefore for the deductive approach, it is not at all clear that retrodiction is possible (Harrison, 1999), and this highlights one of the central philosophical problems with the concept of uniformitarianism (or at least modern applications of it). These arguments about the correct interpretation of equivocal landscapes also serve to invalidate the successful application of landform/sediment associations as generic classifications in such cases. Notwithstanding this, however, the issues addressed in this paper concerning the evidence for and against the glaciation of Dartmoor suggest that the concept of equifinality (flawed as it is) may apply as much to *landscapes* as *landforms*.

Conclusions

The occurrence of glacial tills and well-developed glacial landforms at 250-290 m O.D. on Exmoor forms the southernmost site of glaciation hitherto found on the British mainland and the first evidence of glaciation from the uplands of

the Southwest Peninsula. This paper argues that small, probably cold-based ice caps and polythermal valley glaciers may also have existed on the higher ground of Dartmoor at various times during the Quaternary. This suggestion overturns the long-held view of Dartmoor as a truly periglacial landscape and highlights the equifinal nature of certain landscapes and landforms.

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References

- Auwjoola, A.I. (1987). *The occurrence and nature of deep saprolites on Cheviot granites*. Ph.D. thesis, University of Newcastle upon Tyne.
- Baker, V.R. (1999). Geosemiosis. *Bulletin of the Geological Society of America*, 111, 633-645.
- Ballantyne, C.K. and Harris, C. (1994). *The Periglaciation of Great Britain*. Cambridge University Press, Cambridge.
- Campbell, S. and Croot, D.G. (1998). Brannam's Clay pit. In: Campbell, S., Hunt, C.O., Scourse, J.D. and Keen, D.H. (eds) *Quaternary of South-West England*. Geological Conservation Review Series, Chapman and Hall, 203-210.
- Clapperton, C.M. (1970). The evidence for a Cheviot ice cap. *Transactions of the Institute of British Geographers*, 50, 115-126.
- Clapperton, C.M. (1971). The pattern of deglaciation in part of north Northumberland. *Transactions of the Institute of British Geographers*, 53, 67-78.
- Collingwood, R.G. (1938). *An Autobiography*. Oxford Paperbacks, Oxford.
- Collingwood, R.G. (1994). *The Idea of History*. Revised Edition, Oxford University Press, Oxford.
- Douglas, T.D. and Harrison, S. (1985). Periglacial landforms and sediments in

the Cheviots. In: Boardman, J. (ed) *Field Guide to the Periglacial Landforms of Northern England*. Quaternary Research Association, Cambridge, 68-76.

Douglas, T.D. and Harrison, S. (1987). Late Devensian periglacial slope deposits in the Cheviot Hills. In: J Boardman (ed) *Periglacial Processes and Landforms in Britain and Ireland*. Cambridge University Press, Cambridge, 237-244.

Gerrard, A.J. (1988). Periglacial modification of the Cox Tor-Staples Tor area of western Dartmoor, England. *Physical Geography*, 9, 280-300.

Glasser, N. (1995). Modelling the effects of topography on ice sheet erosion, Scotland. *Geografiska Annaler*, 77A, 67-82.

Hall, A.M. and Mellor, A. (1988). The characteristics and significance of deep weathering in the Gaick area, Grampian Highlands, Scotland. *Geografiska Annaler*, 70A, 309-314.

Hall, A.M. and Sugden, D.E. (1987). Limited modification of mid-latitude landscapes by ice sheets: the case of northeast Scotland. *Earth Surface Processes and Landforms*, 12, 531-542.

Harrison, S. (1989). *Late Devensian Solifluction Sheets in the Cheviot Hills*. Ph.D. thesis, Newcastle upon Tyne Polytechnic.

Harrison, S. (1994). The Harthope Valley upstream of Skirl Naked and the solifluction of gelifracted bedrock. In: S. Harrison and R.M. Tipping (eds) *The Geomorphology and Late Quaternary Evolution of the Cheviot Hills*. B.G.R.G. Field Guide, 56-77.

Harrison, S., Anderson, E. and Passmore, D.G. (1998). A small glacial cirque basin on Exmoor, Somerset. *Proceedings of the Geologists' Association*, 109, 149-158.

Harrison, S., Anderson, E. and Passmore, D.G. (in press). Further glacial tills on Exmoor: implications for small ice-cap and valley glaciation, southwest England. *Proceedings of the Geologists' Association*, 111.

Harrison, S. (1999). The problem with landscape: some philosophical and practical questions. *Geography*, 84, 355-363.

Kleman, J. (1994). Preservation of landforms under ice sheets and ice caps. *Geomorphology*, 9, 19-32.

Kleman, J. and Borgström, I. (1994). Glacial land forms indicative of a partly frozen bed. *Journal of Glaciology*, 40, 255-264.

- Latour, B. (1987). *Science in Action*. Harvard University Press, Cambridge, Massachusetts.
- Linton, D.L. (1949). Unglaciaded areas in Scandinavia and Great Britain. *Irish Geography*, 2, 25-33.
- Linton, D.L. (1955). The problem of tors. *Geographical Journal*, 121, 470-487.
- Ormerod, E. (1869). Sketch of the granite of the northerly and easterly sides of Dartmoor. *Report of the British Association, Transactions of the Sections*, 98-99.
- Palmer, J.A. and Neilson, R.A. (1962). The origin of granite tors on Dartmoor, Devonshire. *Proceedings of the Yorkshire Geological Society*, 33, 315-339.
- Palmer, J.A. and Radley, J. (1961). Gritstone tors of the English Pennines. *Zeitschrift für Geomorphologie*, 5, 37-52.
- Pickard, R. (1943). Glaciation on Dartmoor. *Transactions of the Devonshire Association*, 75, 25-52.
- Pillar, J.E. (1917). Evidence of glaciation in the west. *Transactions of the Plymouth Institute*, 16, 179-187.
- Rapp, A. (1984). Nivation hollows and glacial cirques in Söderåsen, Scania, south Sweden. *Geografiska Annaler*, 66A, 11-28.
- Rea, B.R., Whalley, W.B., Rainey, M.M. and Gordon, J.E. (1996a). Blockfields old or new? Evidence and implications from some plateaus in northern Norway. *Geomorphology*, 15, 109-121.
- Rea, B.R., Whalley, W.B. and Porter, E.M. (1996b). Rock weathering and the formation of summit blockfield slopes in Norway: examples and implications. In: M.G. Anderson and S.M. Brooks (eds) *Advances in Hillslope Processes*. John Wiley, 1257-1275.
- Scourse, J.D. (1991). Late Pleistocene stratigraphy and paleobotany of the Isles of Scilly. *Philosophical Transactions of the Royal Society of London*, B334, 405-448.
- Scourse, J.D. (1998). Bread and Cheese Cove, St. Martin's. In: Campbell, S., Hunt, C.O., Scourse, J.D. and Keen, D.H. (eds) *Quaternary of South-West England*. Geological Conservation Review Series, Chapman and Hall, 269-273.
- Somervail, A. (1897). On the absence of small lakes or tarns from the area of

Dartmoor. *Transactions of the Devonshire Association*, 29, 333-339.

Sugden, D.E. (1968). The selectivity of glacial erosion in the Cairngorm Mountains, Scotland. *Transactions of the Institute of British Geographers*, 45, 79-92.

van Vliet-Lanoë, B., Laurent, M., Bahain, J.L., Balescu, S., Falguères, C., Field, M., Hallégouët, B. and Keen, D.H. (2000). Middle Pleistocene raised beach anomalies in the English Channel: regional and global stratigraphic implications. *Journal of Geodynamics*, 29, 15-41.

Whalley, W.B., Gordon, J.E. and Thompson, D.L. (1981). Periglacial features on the margins of a receding plateau ice cap, Lyngen, North Norway. *Journal of Glaciology*, 27, 492-496.

Wheeler, J.A. (1986). In: P.C.W. Davies and J.R. Brown (eds) *The Ghost in the Atom: a discussion of the mysteries of quantum physics*. Cambridge University Press, Cambridge, 58-69.

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QRA ANNUAL FIELD MEETING 2000: SEDIMENTOLOGICAL INTERPRETATION AND PALYNOLOGICAL DATA FROM SECTIONS OPENED AT HOXNE, SUFFOLK

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Introduction

The Quaternary Research Association (QRA) Annual Field Meeting in April 2000 (Lewis *et al.*, 2000; Lawson and Allen 2000) visited Hoxne (TM 176 769), the stratotype of the Hoxnian interglacial (West, 1956). The visit saw the first sections opened at the site since those of the extensive archaeological investigation in 1973 (Singer *et al.*, 1993). The recent work was undertaken by Simon Lewis, Nick Ashton and Simon Parfitt, as part of an on-going research project investigating the dating of the site and the relationship between the lacustrine and fluvial sequences. Previous work has raised questions about the complexity of the sediments deposited in the latter stages of the interglacial (Turner and West, 1994; J. Wymer, *pers. comm.*). A detailed stratigraphic study and pollen data have allowed these newly-opened sections to be related accurately to a three-dimensional computer model of the previous lithostratigraphic studies carried out at the site (Gosling, 1999). This paper aims to record these new sections and place them in the context of these previous studies, using the sedimentological characteristics and key palynological indicators.

The continuity of deposition through the interglacial sequence varies across the Hoxne basin, and differing time-equivalent facies hamper the construction of a 'typical' stratigraphy. An example of this is the separation of Strata B and C by West (1956), an interpretation which was later revised Singer *et al.* (1993), whose Beds 1-4 were defined as lateral equivalents of the brecciated clay-mud of Stratum C (Table 1). Stratum C and its equivalents contain important archaeological evidence (Singer *et al.*, 1993) and have yielded diverse assemblages of macrofossils (Turner, 1968) and mammals (Singer *et al.*, 1982; Schreve, 2000). Hoxnian lake-level fluctuations identified at other East Anglian sites (e.g. Gibbard and Aalto, 1977; Boreham *et al.*, 1999) and the transition period into full-glacial conditions (West, 1956) produced complex patterns of sedimentation. The sediments preserved at Hoxne from the end of the interglacial period are not only discontinuous to varying degrees (West, 1956), but also exhibit significant facies changes across the basin (Singer *et al.*, 1993). A full understanding of the lithostratigraphy is critical because it provides the contextual framework for biostratigraphy and the archaeological horizons.

To understand and correlate the deposits, a clear understanding of the nomenclatures used by West (1956) and Singer *et al.* (1993) is required (Table 1).

Table 1 Correlation of stratigraphic nomenclatures and sediment descriptions

| West (1956) | | Singer <i>et al.</i> (1993) | |
|-------------------|---|-----------------------------|--|
| Nomen- clature | Descriptions | Nomen clature | Descriptions |
| A1 | Fine Sand with Flint | 9 | Gravel and Sand |
| A2 | Clay and Sand | 8 | Laminated Sands and Silts |
| | | 7 | Laminated Sands and Silts |
| | | 6 | Coarse Gravel |
| | | 5 | Silt |
| B | Stratified Clay, Sand and Gravel | 4 | Lateral Equivalent of C |
| C | Brecciated Clay-Mud with interbedded Silt and Drift Mud | 4 | Chalky Flint Gravel |
| | | 3 | Laminated Clay and Sand |
| | | 2 | Cross-bedded Sand and Clay |
| | | 1 | Laminated Chalky Sand Clay and Detrital Mud |
| D | Detritus Mud | D | Peaty Detrital Mud |
| E | Clay Mud | E | Clay-Mud |
| F | Clay Mud and Marl | F | Clay-Mud |
| G | Chalky Boulder Clay | G | "Chalky Boulder Clay" |

The variations in the depositional environment and sediment preservation have resulted in a fragmentary pollen record from certain parts of the basin (Table 2).

Section MM-1

Section MM-1 (TM 1742 7665) (Figure 1), seen during the 2000 QRA field trip (Lawson and Allen, 2000), lies west of the road that bisects the Hoxne site (for map see Lewis *et al.*, 2000), just south of the Oakley Park Pit described in Singer *et al.* (1993). The deposits formed an area of raised ground running north-south with the main Hoxne lake deposits located downslope towards the east. The sedimentology of the upper sequence exposed around Oakley Park Pit is

Table 2 Summary of previous palynological studies

| Published | Diagram Reference | Location | Grid Reference (TM) | Litho-stratigraphy | Bio-stratigraphy |
|-------------------|-------------------|------------------|---------------------|-----------------------|--------------------------|
| West (1956) | Hoxne I | Bore Hole No. 36 | 17508 76611 | Strata F - C | Stages I - IV |
| West (1956) | Hoxne II | Section No. 100 | 17422 76684 | Strata F - E | Stages I - IId |
| West (1956) | Hoxne III | Bore Hole No. 11 | 17469 76850 | Strata F - E | Stages I - IId |
| West (1956) | Hoxne V | Section No. 37 | 17576 76669 | Strata E - D | Stages IId - III |
| West (1956) | Hoxne VI | Bore Hole No. 16 | 17789 76632 | Strata F - E | Stages I - IIc |
| Mullenders (1993) | Profile C | Cutting II | 17462 76674 | Strata G - D | Late Glacial, Ho I - IIc |
| Mullenders (1993) | Profile F | Cutting XXIII | 17423 76632 | Stratum D, Beds 1 - 5 | Ho IIc, IIb - IVa |
| Mullenders (1993) | Profile P | Cutting XXIX | 17430 76613 | Beds 5 - 8 | Ho IVa - IVb, DoC IV |

complex and fragmentary, and contains reworked material from earlier beds and strata (West, 1956). The sequence exposed in section MM-1 can be demonstrated, using sedimentology and palynology, to represent the upper part of the Hoxne sequence containing material from Beds 5 – 9 of Singer *et al.* (1993).

The lithostratigraphy of section MM-1 consists of five units (Figure 1). Measurements given below are from the base of the section upwards:

| | |
|---------------------|--|
| 0 - 70 cm | Grey silt with pockets of orange sand. |
| 70 - 75 cm | Clast-supported cobbles, present at the north end the section; where absent, they are represented by a sharp contact indicating an erosional surface at 70 cm. |
| 70 - 120 cm | Sandy silts with angular flints grading into mottled orange grey sandy-silt. |
| 120 - 190 cm | Gravelly sand containing angular flints and quartz, with evidence of fining upwards internally into red / brown gravelly-sand. |

To place these deposits into the context of existing lithostratigraphic descriptions (Table 1), elevation and site position must be considered. Located to the west of the site, with a surface elevation of 34 m OD, these deposits represent some of the most elevated sediments laid down at the site and therefore the youngest remaining. This is because the main interglacial lake deposits (Stratum E) are not recorded above 30 m OD (West, 1956; Singer *et al.*, 1993). There is no evidence at any point in section MM-1 for brecciation, indicating that there is no obvious correlation with Stratum C as defined by West (1956).

The sedimentary sequence fits well with the descriptions of Beds 5 - 9 (Figure 1, Table 1). This also correlates well with descriptions of sections at the nearby Oakley Park Pit (Singer *et al.*, 1993; Lewis *et al.*, 2000). The lowest deposits are silts, which suggests a correlation with Bed 5. The colour difference with those deposits described by Singer *et al.*, (1993) could be a result of post-depositional processes. A change in depositional environment is evident at 70 cm, where the presence of cobbles signifies an episode of high-energy fluvial activity. The sharp contact at 70 cm represents an erosional phase over parts of the site. The two units overlying the cobbles consist of predominantly sands and gravels whose bedding indicates fluvial deposition; there is no clear erosional contact between these two units. The fining-up sequence, demonstrated within these by the graded transition between the gravelly-sands and the sandy-silts, suggests a gradual change in either climate or sediment supply (Figure 1).

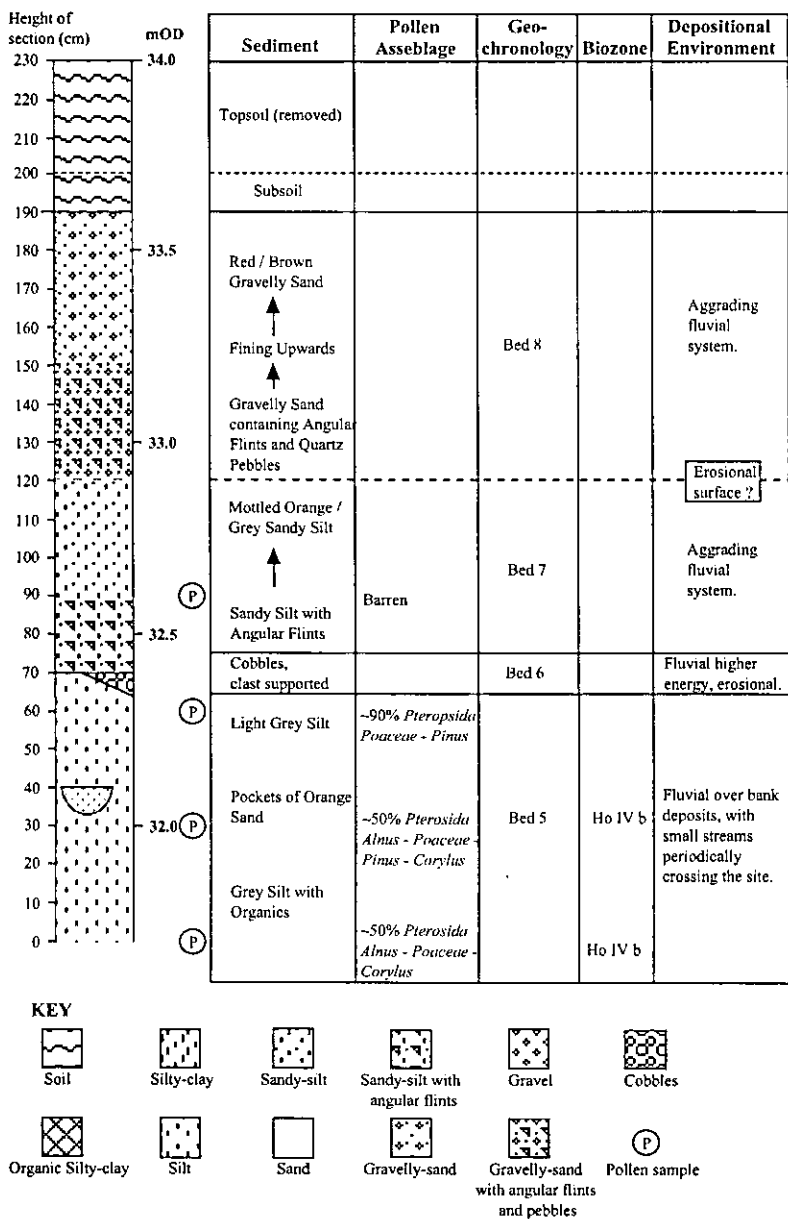


Figure 1. HOXNE 2000 SECTION MM-1 (TM 1742 7665)

The dominance of *Pteropsida* (monolete) undiff. fern spores throughout section MM-1 indicates reworking (Figure 1) (Havinga, 1964, 1984). The underlying pollen of the lowest two samples (0 and 30 cm) is an *Alnus* - *Poaceae* (alder - grass) assemblage. This is typical of the Ho. IVb assemblage identified for Bed 5 by Mullenders (1993). The Ho. IVb assemblage demonstrated at Marks Tey (Turner, 1970) and Tye Green (Boreham *et al.*, 1999) shows a *Betula* - *Pinus* (birch - pine) rise as an important biostratigraphic marker, which is also present here. The high values for *Alnus* are probably due to the reworking of exceptionally high local concentrations of this pollen. The alder carr present in Stratum D may have been able to persist into the following cold period as an isolated patch which was able to survive due to localised water logging (Bennett, 1990). Alder carr was potentially the vegetation present during the transition into the following glacial period when this reworking occurred. Oxygen Isotope Stage 10 can be correlated with this period (Grün and Schwarcz, 2000). The biostratigraphic evidence from Mullenders (1993) (Table 2) shows that pollen from Ho. IVa and IVb is represented in Bed 5; this pollen, however, was reworked, possibly during the following glacial.

The key difference between the samples taken at 0 cm and at 30 cm is the abundance of *Pediastrum*. At 30 cm the *Pediastrum* is almost 1:1 with the pollen. This abundance is accompanied by an increased diversity in the aquatic pollen, such as *Lemna* sp. (duckweed) and *Potamogeton* sp. (pondweed). This indicates locally wetter conditions with possibly a shallow pool forming in this particular locality. Some pockets of orange sand show evidence of internal lamination, suggesting that they possibly represent small streams crossing the landscape (Figure 1) during the cold and temperate stages following the Hoxnian (Rowe *et al.*, 1999; Grün and Schwarcz, 2000).

Towards the top of the silt *Pteropsida* approaches 90%, with grass and pine present. This shows evidence for significant reworking and sub-aerial exposure during the post temperate Ho. IVb. A sample from the gravelly-sand yielded no pollen, and it can be reasonably assumed that the sediments of this unit and above are also barren, because they have a similar nature. Mullenders (1993) achieved counts of ~300 for some of these upper beds; however, large samples were required (~ 1 kg) (C. Turner, *pers. comm.*). The presence of two distinct fining-up sequences within this upper sequence possibly represents subsequent glacial - interglacial cycles (Singer *et al.*, 1993, table 10.1; Rowe *et al.*, 1999; Grün and Schwarcz, 2000). The lack of accommodation space after the temperate infilling of the lake precluded substantial deposition at this location, resulting in this period being represented by a series of fragmentary fluvial deposits.

Section MM-2 and MM-2a

Sections MM-2 and MM-2a (TM 1765 7663) (Figure 2) are both located in the

pit opened in the woodland area (~26 m OD) to the east of the road and adjacent to the Gold Brook. This is towards the south-eastern edge of the main Hoxne lake deposits and represents a sequence marginal to the main sediment body (Gosling, 1999).

The sediments in section MM-2 are silty-clays, containing shell fragments and rootlets. A pollen assemblage dominated by *Alnus* - *Corylus* (alder - hazel), with *Abies* (fir) and *Carpinus* (hornbeam) present in low numbers indicates that this sequence represents the Ho. IIc - IIIa transition (Turner, 1970). Sands overlie the clay-muds in section MM-2 and form part of palaeochannel-fill visible to the northern end of the pit. The sharp contact at the channel base indicates an erosion surface (Figure 2). The close proximity to the present course of the Gold Brook and the lack of laterally-equivalent Hoxnian deposits at this elevation suggest that the sand probably records fluvial activity cutting down into the Hoxnian sediments in a subsequent cold phase.

In section MM-2a on the eastern side of the same pit is a 10 cm organic deposit within a shallow palaeochannel just beneath the sand-filled palaeochannel, which was dug out by Steve Boreham and myself after the field meeting.

Section MM-2a exposes four additional units to those shown in MM-2, measured from the bottom of each section (Figure 2):

MM-2

- 0 - 160 cm** Light grey silty-clay, with some shelly and organic fragments.
160 - 200 cm Light brown sands with a sharp contact at base, part of the adjacent channel.

MM-2a

- 0 - 18 cm** Light grey silty-clay, with some shelly and organic fragments.
18 - 22 cm Organic horizon, consisting of clay clasts, root fragments and perisporium of *Azolla filiculoides* (water fern), similar to those described by West (1952). No other macro fossils present. The sediment structure consisted of clumps of these organic clay clasts with red staining on all but one side with a sharp contact at base.
22 - 30 cm Soft brown silty clay.
30 - 50 cm Light grey sandy silt, little mottling, containing a thin fine gravel stringer at 45 cm.
50 - 60 cm Orange / brown sand and occasional gravel.
60 - 70 cm Grey / orange / brown sandy-silt.
70 - 100 cm Light brown sands with a sharp contact at base, part of the adjacent channel.

The pollen analysis from the silty-clay at the base of MM-2a (Figure 2) clearly shows that these are interglacial lake deposits of Stratum E and that they continue in the sequence shown for section MM-2. The organic horizon contains abundant and well-preserved pollen. Careful examination revealed six grains of type-X, and this coupled with the presence of *Azolla*, confirms that the deposit is of Middle Pleistocene age. The assemblage is dominated by *Alnus* (~50%) and *Corylus* (~24%), with low levels of *Abies* and *Quercus* (oak), which place this in Ho. IIIa (Turner, 1970). However, no comparable stratigraphy is recorded elsewhere as being representative of this biozone (Table 2). Mullenders (1993) demonstrated a hiatus during the deposition of the organic mud (peat) of Stratum D, indicating a gap in the depositional record between Ho. IIc and IIIb. This is based upon the absence of *Alnus* - *Corylus* - *Carpinus* assemblage. Instead there is an immediate switch to an *Alnus* - *Pinus* - *Abies* assemblage representative of Ho. IIIb, which is equivalent to that described at Marks Tey (Turner, 1970). West (1956) demonstrated continuous deposition at Hoxne in the centre of the basin (Table 2), and the transition is defined by a rise in *Pinus* and *Picea* (spruce), coupled with the appearance of *Abies* and *Carpinus* (West, 1956, diagram V).

The sharp contact at the base of the organic deposit indicates erosion, and the overlying deposits record a gradual transition back into lake deposits, palynologically representing Ho. IIIa (Figure 2). An erosional contact during a temperate period may indicate a drop in lake level. Such a drop has been identified across East Anglia during Ho. II, followed by a rise in lake levels during the transition of Ho. II and III (Boreham and Gibbard, 1995; Boreham *et al.*, 1999). The sediment clumps from this deposit consisted of organic clay clasts with red staining, probably caused by iron bacteria. This indicates dehydration, at least on one occasion, resulting in polygonal cracking. This organic deposit is interpreted as the remains of a channel which flowed across a marginal area of the lake where the drop in water table exposed the lake muds of Stratum E. These channels transported material from the nearby alder carr towards the shrunken lake. As lake levels gradually returned towards their previous levels, the channel deposits graded back into lake muds as they became inundated. Evidence of brief higher-energy depositional environments is present in the form of gravel deposits during the transition phase back towards higher lake levels (Figure 2). This is possibly a product of an individual storm event which increased the stream power. Equivalents of this localised marginal deposition may have been removed elsewhere around the basin by subsequent fluvial activity (Figure 2).

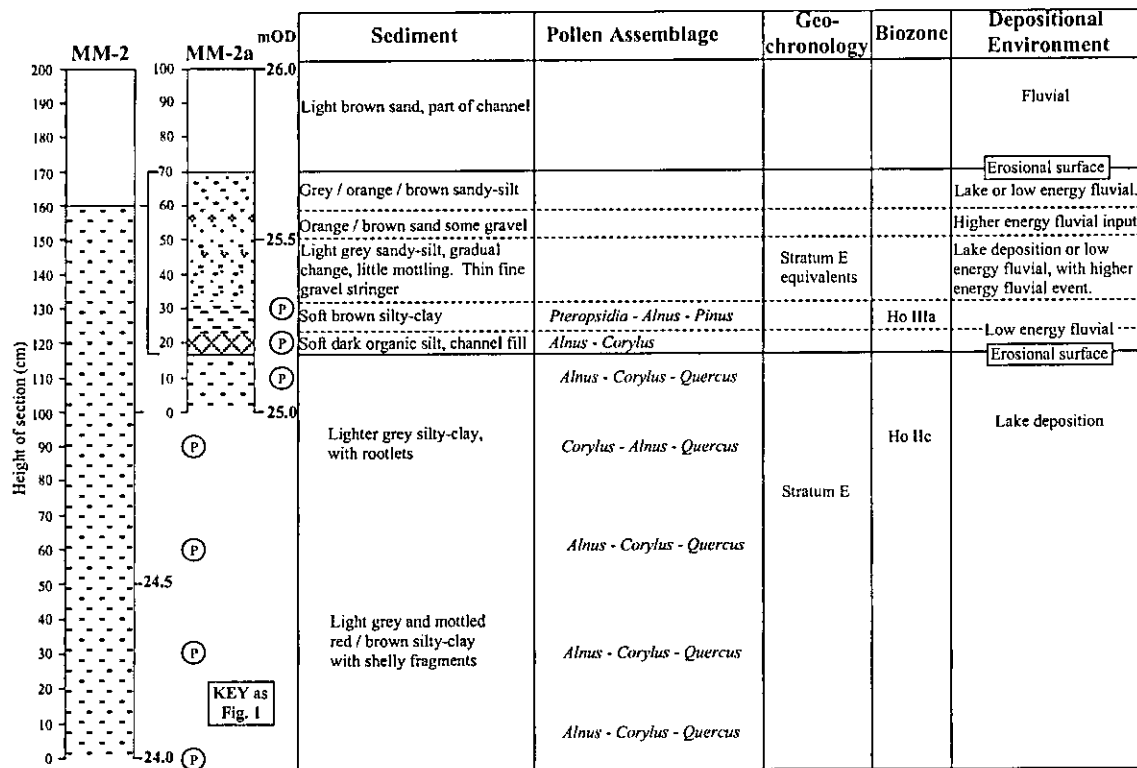


Figure 2. HOXENE 2000 SECTIONS FROM MM-2 AND MM-2a (TM 1765 7663)

Conclusions

Sedimentological and palynological data have shed light on the complex upper sequence at Hoxne and illustrated the problems of integrating stratigraphic studies. There are also interesting questions raised about the continuity of the interglacial sequences taken from lake margins due to fluctuations in lake level at Hoxne.

It is possible that the interglacial sequence present in Stratum E at Hoxne is discontinuous at the margins of the lake basin due to lake-level fluctuations during the transition between Ho. II and III. The lower water table resulted in low-energy streams extending across the exposed lake muds and transporting organic-rich clays into a smaller lake. The lake at Hoxne subsequently returned towards its previous levels, resulting in a return to low-energy deposition shown at section MM-2a, but not extending to TM 17423 76632 at the margin of the lake deposit, where Mullenders (1993) carried out palynological studies (Profile F) and found this transition to be completely absent.

The upper sequence exposed in MM-1 has been shown to comprise extremely disturbed and discontinuous sediments which were subjected to heavy oxidation and subaerial exposure. The Hoxnian deposits thin most rapidly on the north-west and south-eastern sides of the basin, indicating the possibility of feathering out against the valley sides (Gosling, 1999).

Fluvial activity of varying intensity has affected the site during the deposition of the upper sequence in post-Hoxnian cold and temperate stages (Singer *et al.*, 1993; Rowe *et al.*, 1999; Grün and Schwarcz, 2000). Climate fluctuations for this period are difficult to determine from the pollen due to poor preservation and confused signals due to reworking. The variations in lithostratigraphy, however, suggest that a number of significant climate changes took place, altering the nature of the fluvial system. One inference that can be drawn from these deposits is that the initial cool period after the Hoxnian saw some persistence of alder carr vegetation and deposition was characterised by rivers which reworked material laid down in the latter half of the interglacial. These rivers transported material which 'capped' the remaining interglacial deposits and protected the soft clay lake muds from removal by subsequent increasingly powerful rivers operating under harsher climates.

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References

- Bennett, K.D. and Birks, H.J.B. (1990). Postglacial history of alder (*Alnus glutinosa* (L.) Gaertn.) in the British Isles. *Journal of Quaternary Science*, 5, 123-133.
- Boreham, S., Field, M.H. and Gibbard, P.L. (1999). Middle Pleistocene interglacial sediments at Tye Green, Stanstead Airport, Essex, England. *Journal of Quaternary Science*, 14, 207-222.
- Boreham, S. and Gibbard, P.L. (1995). Middle Pleistocene Hoxnian Stage interglacial deposits at Hitchin, Hertfordshire, England. *Proceedings of the Geologists' Association*, 106, 259-270.
- Gibbard, P.L. and Aalto, M.M. (1977). A Hoxnian interglacial site at Fishers Green, Stevenage, Hertfordshire. *New Phytologist*, 78, 505-523.
- Gosling, W.D. (1999). *An investigation of the sedimentology, taphonomy and climatic significance of Stratum C at Hoxne, Suffolk*. MPhil Dissertation, University of Cambridge.
- Grün, R. and Schwarcz, H.P. (2000). Revised open system U-series / ESR age calculations for teeth from Stratum C at the Hoxnian Interglacial type locality, England. *Quaternary Science Reviews*, 19, 1151-1154.
- Havinga, A.J. (1964). Investigation into the differential corrosion susceptibility of pollen and spores. *Pollen et Spore*, VI, 621-635.
- Havinga, A.J. (1984). A 20-year experimental investigation into the differential susceptibility of pollen and spores in various soil types. *Pollen et Spore*, XXVI, 541-558.
- Lawson, T. and Allen, P. (2000). Quaternary Research Association annual field meeting - Norfolk and Suffolk. *Quaternary Newsletter*, 91, 15-22.
- Lewis, S.G., Ashton, N., Parfitt, S.A. and White, M. (2000). Hoxne, Suffolk (TM 176769). In: Lewis, S.G., Whiteman, C.A. and Preece, R.C. (eds) *The Quaternary of Norfolk and Suffolk. Field Guide*. Quaternary Research Association, London, 149- 153.

Mullenders, W.F. (1993). New Palynological Studies at Hoxne. In: Singer, R., Gladfelter, B.G. and Wymer, J.J. (eds) *The Lower Palaeolithic site at Hoxne, England*. University of Chicago Press, Chicago, 150-155.

Rowe, P.J., Atkinson, T.C. and Turner, C. (1999). U-series dating of Hoxnian interglacial deposits at Marks Tey, Essex, England. *Journal of Quaternary Science*, 14, 693-702.

Schreve, D.C. (2000). The Vertebrate Assemblage from Hoxne, Suffolk. In: Lewis, S.G., Whiteman, C.A. and Preece, R.C. (eds) *The Quaternary of Norfolk and Suffolk. Field Guide*. Quaternary Research Association, London, 155-163.

Singer, R., Gladfelter, B.G. and Wymer, J.J. (eds) (1993). *The Lower Palaeolithic site at Hoxne, England*. University of Chicago Press, Chicago.

Singer, R., Wolff, R.G., Gladfelter, B.G. and Wymer, J.J. (1982). Pleistocene *Macaca* from Hoxne, Suffolk, England. *Folia primatol.*, 37, 141-152.

Turner, C. (1968). A note on the occurrence of *Vitis* and other new plant records from the Pleistocene deposits at Hoxne, Suffolk. *New Phytologist*, 67, 333-334.

Turner, C. (1970). The Middle Pleistocene deposits at Marks Tey, Essex, Suffolk. *Philosophical Transactions (B)*, 257, 373-437.

Turner, C. and West, R.G. (1994). Mixed Signals from Hoxne. *Antiquity*, 68, 870-873.

West, R.G. (1953). The occurrence of *Azolla* in British interglacial deposits. *New Phytologist*, 52, 267-273.

West, R.G. (1956). The Quaternary Deposits at Hoxne, Suffolk. *Philosophical Transactions (B)*, 239, 265-357.

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REPORTS

PERIGLACIAL WORKSHOP

University of St Andrews, Scotland, 6-7 September 2000

The fourth Periglacial Workshop was co-sponsored by: (1) the *Cryostratigraphy Research Group* of the Quaternary Research Association, (2) the International Geographical Union's Commission on *Climatic Change and Periglacial Environments*, and (3) the British National Adhering Body of the International Permafrost Association. The Workshop was organized by Julian Murton and Colin Ballantyne, and comprised four themes.

Theme 1, on modelling and monitoring of cryogenic processes, began with keynote addresses by Charles Harris (Cardiff) on physical modelling in periglacial geomorphology, and Albert Pissart (Liège) on periglacial experiments and the origin of cryoturbations. Presentations were given by Colin Ballantyne (St Andrews) and Ivar Bertling (Oslo) on ploughing boulders, Michael Davies (Dundee) on centrifuge modelling of rock slope stability, Norikazu Matsuoka (Tsukuba) on micro- and macrogelivation, Julian Murton (Sussex) on physical modelling of ice segregation in bedrock, and Samuel Etienne (Nantes) on biological weathering in periglacial environments.

Theme 2, on palaeoenvironmental reconstruction, began with an evening keynote address by Colin Ballantyne on the Late Devensian periglaciation of Scotland. Presentations were given by Hanne Christiansen (Copenhagen) on nivation in the Cairngorm Mountains of Scotland, and Stephanie de Villiers (Pretoria) on South African cryogenic palaeoenvironments.

Theme 3 focussed on the mapping and monitoring of permafrost and periglacial features. Presentations were given by Dani VonderMühl (Zurich) on geophysical mapping of mountain permafrost, Nikolay Shiklomanov (Delaware) on the effects of climate variability on active-layer thickness in Alaska, Hanne Christiansen on monitoring of snow cover by automatic photography, and Martin Gude (Jena) on the microclimate of extra-alpine screes.

Theme 4 was on the interactions between permafrost and glaciers. Bernt Etzelmüller (Oslo) gave a lucid keynote address on the relation between glaciers and permafrost on Svalbard. Presentations were given by Ole Humlum (Svalbard) on the effect of supraglacial debris on glaciers in permafrost areas, Wishart Mitchell (Luton) on rock glaciers in the Indian Himalaya, Julian

Murton on basal ice and the frozen deforming bed of the Laurentide Ice Sheet, and Colin Whiteman (Brighton) on melt-out till overlying Laurentide basal ice.

Nine posters were displayed on topic spanning the four themes. Round-table discussions highlighted two key areas for future research: (1) the rheology of cold earth materials, and (2) the transient behaviour of cold-climate processes. Laboratory modelling, particularly using centrifuges such as those at Cardiff and Dundee, holds significant promise for advancing understanding of the rheological behaviour of, for example, ploughing boulders, downslope soil movements in areas of two-sided freezing, and subglacial deforming beds of permafrost. Abstracts for the Workshop may be obtained by e-mail from j.b.murton@sussex.ac.uk

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THE FIFTH ANNUAL QRA POSTGRADUATE SYMPOSIUM: ROYAL HOLLOWAY, UNIVERSITY OF LONDON

18–20 September 2000

Braving the worst that Britain's petrol blockades could throw at them, the postgraduate members of the QRA arrived at Royal Holloway for three days of debate, dispute and networking.

First, there were a variety of welcomes to Royal Holloway from Eleanor Brown, Adrian Palmer, Professor Rob Kemp (on behalf of the Centre for Quaternary Research) and Professor Tim Unwin (Head of Department). The symposium began with **Ralph Fyfe** (Exeter) reviewing the potential of alluvial sequences as a new source of palaeoenvironmental data for archaeologists. These new sites will allow many lowland areas to be exposed to palaeoecological scrutiny for the first time. Keeping with the Holocene theme, **Antony Blundell** (Southampton), opened with some unarguable photographic evidence of current climates around British mires, and then showed how a range of climatic proxies from the ombrotrophic mires of Britain could be used to reconstruct past climate. Early results from these analyses appear to show synchronous patterns corresponding to the Medieval Warm Period and the Little Ice Age from across the British Isles.

This year's chosen guest speaker was QRA President **Professor Mike Walker** (Lampeter), who gave a stimulating and thorough review of recent developments in Quaternary geochronology. He provided insights into many recent developments in fields as diverse as luminescence techniques, the calibration of ^{14}C dates in the Lateglacial and the extension of radiometric dating methods far back into the Pleistocene.

On the second day, **Stephen Thompson** (Glasgow) questioned the recently-established (Lewis, 1999) stratigraphy of the Sewerby cliff deposits of East Yorkshire, supported by stratigraphic evidence that the Basement till does not overlie the OIS 5 interglacial deposits. **Damien Laidler** (Durham) reviewed his efforts to reconstruct the inundation characteristics of isolation basins in northwestern Scotland; new results from work in the Uists indicate that salinity may be a less significant control on foraminifera populations than site-specific sedimentation characteristics. **Keith Turner** (Edinburgh) gave an entertaining tour of late-glacial Patagonia, and produced evidence from pro-glacial lake deposits suggesting synchronous deglaciation patterns in Patagonia and the Chilean Lake District. **Paul Coombes** (Southampton) outlined the methodological and philosophical problems inherent in human-impact studies

within the historic era, and possible new approaches that could resolve these difficulties.

We then turned back to the Pleistocene in the company of **Ian Candy** (Reading), who showed how micromorphological analysis of Anglian outwash sands at Leet Hill had revealed the first known cold-stage calcrete from the British Quaternary. **Jonathan Lee** (Royal Holloway) proposed a radical new palaeogeographic and stratigraphic interpretation of the Early-middle Pleistocene glaciation of Norfolk. Correlation of the Happisburgh Diamicton (Corton Formation) and Lowestoft Till (Lowestoft Formation) with terraces of the Bytham river suggests that the two diamictons were not deposited synchronously, and that the former may well be associated with a pre-Anglian OIS 16 glaciation. Moving the spotlight to contemporary glaciation, **Kim Jardine** (St Andrews) gave a finely-illustrated account of her work on freshwater glacial calving in the Italian Alps, including some exciting close-ups of calving in action.

Mark Lloyd Davies (Amsterdam) showed some breathtaking slides from Antarctica, taken during fieldwork in the Allan Hills nunatak. The "Sirius" tillites recovered from this area could provide crucial new evidence on the long-term Cenozoic stability of the Antarctic ice sheet. **Jon Barber** (Leeds) covered the evidence for Devensian glaciation from West Yorkshire, a long-neglected area that is now showing strong evidence for an independent Pennine ice sheet during the LGM. From the same era, **Lindsay Wilson** (St Andrews) outlined a project investigating the terrestrial and marine ice limits of the Hebridean ice sheet, using pioneering spectrophotometric methods to detect abrupt climatic shifts from marginal oceanic cores.

In perhaps the most original talk of the symposium, **Eleanor Brown** (Royal Holloway) turned to applied Quaternary science, and in particular the need for effective communication with the public when promoting geological conservation and an interest in earth science. **Mark Furze** (Bangor) opened with an account of the recent developments with his mollusc water-depth transfer function, and outlined some of the problems encountered. Undaunted by these challenges, he set out a strong line of evidence for the Celtic Deep's status as a proglacial lake during the last glacial maximum. Lastly, **Stuart Wilson** (Glasgow) outlined his work using digital photogrammetry and GIS to map the moraines of the Loch Lomond Stadial in Scotland. Correlation of these techniques with traditional stratigraphic methods can allow new insights into the genesis of hummocky moraines.

The day closed with a diverse and thought-provoking poster session and the wide-ranging debate continued late into the night.

Next morning **Becky Briant** (Cambridge) described a study of the Devensian fluvial sequences of eastern England. The use of OSL and high level AMS ^{14}C chronologies from these deposits may resolve current controversies over the timing of the major episodes of fluvial deposition in the Devensian. **Adrian Palmer** (Royal Holloway) revisited the classic Hoxnian site of Mark's Tey, describing the sedimentology of the mineral laminated sediments, using micromorphological techniques. This led to the unveiling of a detailed lithostratigraphic log of 7.5 cm!

We then returned to the Holocene in the company of **Stephen Davies** (Liverpool John Moores), whose study of damaged mires in north-west England suggests that climate change, rather than human impact, was the key factor controlling recent ecological changes within these systems. **Siwan Davies** (Royal Holloway) discussed the application of tephrochronology for Lateglacial correlation and outlined her discovery of a visible basaltic Vedde Ash horizon at Loch Ashik on the Isle of Skye – an unprecedented finding in the British Isles. Finally, **Jenny Schulz** (Southampton) provided an intriguing counterpoint to Stephen Davies' talk with her survey of recent ecological shifts on the mires of Borth and Tregaron.

Many thanks must go to the organisers of the symposium – Eleanor Brown, Siwan Davies, Jonathan Lee and Adrian Palmer – for their flawless management. Such was the success of the symposium that, for the first time, two bids were received to host the next Postgraduate Symposium. In the subsequent voting, St Andrews triumphed, delegates apparently being won over by the unbeatable combination of a new departmental accommodation and liberal Scottish licensing hours. Our congratulations to Lindsay Wilson, Kim Jardine and all others at St. Andrews - and we hope for another fine celebration of Quaternary culture next year.

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**IGCP PROJECT 437 MEETING IN PATAGONIA,
31 OCTOBER TO 3 NOVEMBER 2000,
FOLLOWED BY POST-CONFERENCE FIELD EXCURSION
TO TIERRA DEL FUEGO, 4-7 NOVEMBER 2000**

Coastal Interactions during Sea-level Highstands

Four participants from the UK joined representatives from some 13 countries in this diverse and stimulating meeting on Coastal Interactions during Sea-Level Highstands. The meeting was sponsored by IGCP with additional co-sponsorship from the Centro Nacional Patagonico (CENPAT) in Puerto Madryn, the Argentine Committee for IGCP, the INQUA Commission on Shorelines and IGU Commission on Coastal Systems. The aims of IGCP 437 are to co-ordinate comparative investigations between the Holocene and earlier eustatic highstands, both in terms of sea-level behaviour and the sedimentary responses to sea-level and climatic forcing. The post-conference field excursion to Argentine Tierra del Fuego explored this theme in some depth, with excellent comparative landform-sediment assemblages covering a number of sea-level cycles. The conference was organised by **Enrique Schnack** (Universidad Nacional de La Plata), a seminal figure in Argentine sea-level studies, and **Colin Murray-Wallace** (Wollongong), the leader of IGCP 437. It would be impossible to review here all the many impressive contributions and mention of a few personal highlights must suffice.

Richard Peltier (Toronto), in a paper with K. Rostami, gave a thorough overview of his glacio-hydro-isostatic modelling work with special reference to model-data intercomparisons, including some notable misfits, along the Argentine coast. This provided an excellent update for the sea-level community on the latest work and thinking from the modelling community. The authors found Peltier's discussion of the problems of interpreting sea-level and water-depth index points from Patagonian shelf sequences particularly interesting. **Colin Murray-Wallace** gave an extremely well-illustrated and clear account of the southern Australian sea-level record, and **John Grindrod** (Monash) a stimulating account of palynological evidence for Holocene mangrove and saltmarsh successions in northeast Queensland. **Helmut Brückner** (Marburg) gave an account of his work with G. Schellmann on Late Pleistocene and Holocene shorelines on Spitsbergen. Very detailed geomorphological mapping and dating indicates the presence of isostatically-uplifted Late-glacial and later Holocene beach ridge shorelines in northern Andréeland. However, an intriguing lacuna of bare bedrock with an absence of beach ridges characterises the Younger Dryas interval. Brückner and Schellmann convincingly interpret this

as a product of intense sea-ice preventing littoral dynamics linked to absence of warm Atlantic water during thermohaline slow-down or shut-down. Such work therefore provides a basis for palaeoceanographic interpretations from isostatically-uplifted Arctic coasts.

Patagonia is an extraordinary land. No wonder that Darwin in his autobiography looked in retrospect on "the great deserts of Patagonia and the forest-clad mountains of Tierra del Fuego" as amongst the most sublime of his Beagle experiences. The "great deserts" are indeed arid, far more so than we had expected. When subject to the near-constant westerlies which rage down from the Andes, the sparsely-vegetated gravelly and sandy plains, punctuated by saline depressions, are subject to intense deflation. The dust gets into everything and much of it ends up in the southern Atlantic. S. Bidart (Bahía Blanca, Argentina) and colleagues gave an account of this aeolian dust flux from Patagonia to the SW Atlantic which stimulated an interesting discussion on the implications of this flux for iron fertilisation and ocean productivity.

On a free day between the conference and the post-conference excursion, we visited Peninsula Valdés, some 90 km to the east of Puerto Madryn - an unforgettable experience. The most striking impression of the horizontal Miocene strata at Punta Piramides were the hugely abundant coquinas full of *Ostrea maximus*, characteristic of the shell beds which run the length of the Patagonian coast and which had also so impressed Darwin, testimony to the long-term tectonic stability of this passive margin. We observed southern right whales which return between July and December each year to the sheltered bays here in order to breed, abundant obese halibut bull elephant seals defending their even more abundant harems from intruding males and the occasional Magellanic penguin.

We then attempted to fly to Tierra del Fuego by LAPA Airways. *lapa* is the Spanish for limpet, and Limpet Airways seemed an apt epithet given the reluctance of its aeroplanes to take to the air. The wait was, however, worth it because the arrival by air into Ushuaia, the southernmost city in the world, which lies on the northern shore of the Beagle Channel, was another of the most striking memories of the meeting. Having acclimatised to the flat dusty opacity of Patagonia, we were now plunged into a profound Alpine landscape bathed in cool, pellucid light. The excitement of the aerial descent which closely skirts the astonishingly precipitate peak of Mount Olivio just a kilometre or two from the city was replaced by a sense of awe arising both from the majesty of the landscape and the historical resonance of standing on a shore which, for any Darwinians, is hallowed ground indeed. To those of us used to reciting the connections between Darwin and the geomorphology of Cwm Idwal to generations of students, to stand opposite the Murray Passage which leads to

Woollya Cove where the “civilised savages” Jemmy Button, York Minster and Fuegia Basket had been returned by Captain Fitzroy to their native lands, was profoundly moving. We took our first lunch on top of one of the ubiquitous shell middens where Darwin had been so shocked by his first encounter with raw naked savages.

The field excursion was led by **Gustavo Bujalesky**, **Andrea Coronato** (both of CADIC-CONICET, Ushuaia) and **Iñaki Isla** (CONICET, Mar del Plata) and ranged in scope from recent coastal morphodynamics on gravel beaches to uplifted beach terraces and glacial advances of the Middle Pleistocene. The work of these three over the past few years, and their colleagues, deserves the greatest commendation. Few in number and working in difficult terrain under testing conditions, they have produced convincing and first-rate interpretations of diverse phenomena: Bujalesky largely on coastal morphodynamics, Coronato on glacial geology, and Isla on sea-level change and marine geology.

The first afternoon was spent examining the uplifted Holocene gravel beach ridges of Playa Larga on the shore of the Beagle Channel. Tierra del Fuego straddles the transform junction between the Scotia Plate in the south and the South American Plate in the north. Seismic activity along this strike-slip boundary is felt particularly in the deformed terrain of the Patagonian Andes and probably accounts for the uplift of these gravel beach ridges late in the Holocene. To the authors one of the most striking aspects of the Quaternary of this region is the lack of uplifted Late-glacial and early Holocene shorelines. These we had expected, and their absence testifies to either relatively thin ice or early isostatic recovery, or both. Deglaciation appears to have been terrestrial from all the exposures investigated. Presumably marine stages in the deglaciation of the Cordilleran ice sheet are preserved offshore in the deeper parts of the Beagle Channel. All the evidence for high sea-levels date from the mid-Holocene and show a marked regressive tendency from then until the present day. In passing on this first afternoon we also examined fantastic sections through thick (>30 m) deltaic fills in kame terraces marginal to the Beagle Channel glacier.

On the second day we visited several sites which provide evidence that Lago Roca, a large freshwater lake, was, during the early-mid Holocene, part of an extensive palaeofjord system extending to Bahía Lapataia on the Beagle Channel. Subsequent uplift has isolated the lake and stranded shelly marine deposits across the intervening emergent valley system. **Mónica Salemmé** (CADIC-CONICET, Ushuaia) gave an enthralling account of the history of the peopling of this “uttermost part of the earth”, of the two main tribal groupings involved, of their transitory lifestyle and co-existence in Tierra del Fuego

during the Late-glacial with many of the extinct large vertebrates, including American horse (*Hippidion* sp.), ground sloth (*Myodon* sp.) and a small camelid (*Lama gracilis*).

During the first day one of the guides had pointed out, from a moving bus, Darwin's fungus (*Cyttaria darwinii*) growing on *Nothofagus*. Darwin had noted this fungus, "Indian bread", being eaten raw by the natives. We observed large pale green bauble-like growths hanging down from the branches and assumed, in all innocence, that this was the famous fungus. It didn't look much like fungus, but then as mere geologists who were we to argue? A number of the party sampled this growth on the second day and declared it rather "acid". Later in the day, on foot, the same guide pointed out big puffballs on the trees and said, in passing, "more Darwin's fungus". An awful moment of realisation passed over those who had partaken when they realised that they had been eating some kind of inedible parasitic mistletoe-like plant. Fortunately it appeared to have been merely unpleasant rather than toxic or hallucinogenic.

We then travelled by bus into the mountains to cross over to northern Tierra del Fuego. This took us through huge peaks, mantled by corrie glaciers in their higher parts, and clothed in the neatly-zoned succession of the three *Nothofagus* species flanking the valleys. To those of us from the northern hemisphere, to experience an Alpine landscape devoid of conifers was one of the more subtle pleasures of the excursion. We then travelled towards the plate boundary at Lago Fagnano. A very large elongated lake fills a depression along the boundary and, from a vantage point above the eastern shore, we viewed a large gravel barrier created by seismic seiche during the 17 December 1949 earthquake. This same earthquake produced a fault scarp which extended from the lake to the Atlantic coast some 60 km away. Erosion on the southeastern shore has revealed an excellent section through another large glacio-deltaic complex with astonishingly clear bottomset-foreset-topset relations. ^{14}C dating of organics within the topsets have yielded effectively infinite ages, which poses a problem since the sequence lies within the limit of the Lago Fagnano LGM ice lobe and must have therefore been overridden; there are strangely no indications of glacio-tectonics within the sequence that might provide evidence for this.

The change of landscape as we crossed from the Scotia Plate to the South American Plate was extreme. Within 10 km we had moved from highly-deformed tectonically-active mountainous terrain back into the flat plains of Patagonia, for the northern part of Tierra del Fuego, though south of the Magellan Strait, is geologically part of the stable passive margin that characterises the coast to the north. Here the geological focus was on Holocene and older gravel beach ridges and coastal morphodynamics. The coast of northern Tierra del Fuego is characterised by a palaeo-cliffline and vegetated gravel beach

ridge plain related to the mid-Holocene sea-level some metres above present sea-level. Older, higher, gravel terraces, such as the La Sara Formation which is attributed to Oxygen Isotope Substage 5e, only occur outside the limits of the Bahía Inutil ice lobe which is thought to have occupied a similar location during successive glaciations. There are a number of factors that make the northern Fuegian landscape so beguiling for Quaternary research. The aridity, lack of vegetation and soil, and absence of slopes, create a landscape which favours the preservation of coastal and glacial landforms-sediment associations. We were conscious of examining a moribund landscape in which events of the past were writ large and clear. Not that there were no problems to solve. We examined the extraordinary granodiorite boulders of the Río Cullen Drift at Punta Sinai, attributed to the OIS 12 advance of the Bahía Inutil lobe, and yet outside the moraine limit the OIS 11 marine terrace indicates a sea-level that should have drowned the moraine. Holocene coastal erosion has led to the removal of the moraine across the present shelf, so why not in the past ? Certainly more geochronology is needed, and cosmogenic dating of the supraglacial boulders should help resolve this issue.

For those particularly interested in gravel beach morphodynamics, notably **Julian Orford** (Belfast), this last part of the excursion was a feast. Modern and Holocene morphodynamics were examined in some depth in the Río Chico, Bahía San Sebastián, including the evolution of the Péninsula el Páramo, and Cabo Peñas-Punta Popper areas. In Bahía San Sebastián chenier ridges correlate well with gravel beach stages; not only were these chenier ridges shelly, they were also whaley, with lots of bone and carcasses.

The excursion in northern Tierra del Fuego was based in Río Grande. This unfortunate place did indeed seem a plate boundary away from Ushuaia and has not been blessed by its mayors. Not only have they disrupted sediment supply in the Río Grande inlet-Punta Popper spit system by constructing, and refusing to move, some coastal hard engineering, but they have also erected mile after mile of what can only be described as multicoloured metal pipes down the middle of all the main streets. Apparently this has been done in the cause of civic pride and modern art.

All in all this was an overwhelmingly interesting meeting and all those involved in its planning and organisation are to be thanked for their efforts.

James Scourse and Mark Furze
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**QRA ANNUAL DISCUSSION MEETING
MODERN ANALOGUES AND THEIR VALUE FOR THE
INTERPRETATION OF PAST ENVIRONMENTS.
'THE KEY TO THE PAST IS THE PRESENT'**

Cardiff, 3-5 January 2001

The QRA Annual Discussion Meeting 2001 was held at the National Museums and Galleries of Wales, Cardiff. The theme of the meeting was the use of modern analogues to interpret fossil material. This was a relatively small conference with approximately 80 people registered.

Wednesday 3 January

Mike Tooby (Director of the Museums and Galleries) welcomed participants to Cardiff before **Mike Walker** (University of Wales, Lampeter) chaired the first session, on pollen and plant macrofossil research. **Mike Field** (Coventry University) gave a paper on the *'Incorporation of plant parts into a modern temperate lacustrine basin and the implications for the interpretation of plant macrofossils from palaeolakes in analogous environments'*, suggesting that the maximum accumulation of macroscopic plant remains occurs at the margins of water bodies and that sampling of fossil lake material should also be located near the margins. **Robert Marchant** (Hugo de Vries Laboratory, Amsterdam) discussed *'A reconstruction of Colombian biomes derived from modern pollen data along an altitudinal gradient'*, showing that it is possible to delimit the altitudinally-induced changes in vegetation composition from Andean forest associations, open forest and shrub grassland complex through to high-altitude grass lands. **Sheila Hicks** (University of Oulu) gave a paper on *'Annual pollen deposition as a proxy of temperature: records from northern Finland'*. Pollen trapping suggests that annual pollen deposition reflects the temperature of the growing season of the previous year rather than just the presence/absence and density of tree species in the area surrounding the pollen monitoring site.

Jane Bunting (University of Hull) discussed on-going work on wetland and upland vegetation communities in Canada and Britain: *'Beyond the woodland edge: pollen-vegetation relationships in open communities'*, research focusing on non-tree-dominated landscapes and the development of analogues for interpreting late Holocene landscapes. **Will Gosling** (University of Leicester) discussed the *'Characterisation of Amazonian forest and savanna ecosystems by modern pollen spectra'*, setting out preliminary results of a project that aims to determine the pollen signatures of present-day Amazon ecosystems in order to improve pollen-based reconstructions of forest and savanna ecosystems.

Brian Huntley (University of Durham) gave the inaugural Wiley Lecture on

'Using the contemporary ecology and biogeography of organisms as the basis for reconstructing Quaternary palaeoenvironments'. He emphasised that the scale of study was important for robust and reliable reconstructions because the macro-climate as measured by meteorologists may be quite different from the micro-climate conditions experienced by for example, beetles. A buffet reception was later held in the Main Hall of the Museum.

Thursday 4 January

Richard Preece (Cambridge University) chaired the morning session which dealt predominantly with faunal studies. **Huw Griffiths** (University of Hull) gave a paper on *'Combining ecology and palaeoecology: Balkan Lake Dojran'*, describing a multi-proxy study of this rapidly-shallowing lake. The evidence suggests that the lake will be severely degraded unless a management plan is implemented soon. **Chris Gleed-Owen** (University of Coventry) discussed *'Converting herpetofaunal remains into a palaeotemperature proxy'* and suggested palaeotemperatures for sites going back to OIS 11/13 where amphibian and reptile remains had been found.

Jane Reed (University of Hull) presented a paper on *'The application of diatom-based transfer functions'* for reconstructing pH, nutrient status and salinity in studies of lake acidification, eutrophication, lake level and climate change. **Gavin Simpson** (University College London) presented results from an on-going project, *'Multi-proxy analogue matching and baseline reference sites for acidified upland surface waters'*, that aims to improve the modern analogue transfer function for reconstructing acidified upland surface waters. The results show that a more robust reconstruction is possible using combined diatom and Cladocera data than either proxy in isolation. **Jeff Blackford** (Queen Mary, University of London) spoke on *'Surface samples of fungal spores from woodland and upland heath environments in the UK'*, considering the methodological/ecological issues and results from studies that aim to identify the fungal spore assemblages in modern environments for comparison with subfossil data. **Steve Brooks** (Natural History Museum) spoke to the rather alarming title of *'What they didn't tell you about chironomid-inference models'*, suggesting that factors other than air temperature (pH, water temperature, dissolved oxygen, water depth from which cores are extracted) may need to be considered in using chironomids as palaeoecological indicators. **Dan Charman** (University of Plymouth) concluded the session with a paper entitled *'Modern analogues and the reconstruction of surface wetness changes on ombrotrophic peatlands'*. This research compared hydrological reconstructions from ombrotrophic mires using plant macrofossil and testate amoebae and discussed the pros and cons of various quantitative techniques.

Phil Gibbard (Cambridge University) chaired the first session of the afternoon on Landscapes and Processes. **Geoff Boulton** (University of Edinburgh) opened with a thought-provoking review entitled *'Scaling up from modern*

valley glaciers to continental ice sheets' and reminded us of the need for analogues because 'the past is dead'. **David Evans** (University of Glasgow) then set out the use of '*Modern glacial landsystems as analogues for Quaternary ice sheet reconstructions*' and discussed the use of terminology for describing glacial features. **Brian Whalley** (Queen's University of Belfast) discussed '*The importance of plateau icefields in the interpretation of glaciers in deglaciated areas*', suggesting that some Norwegian blockfields revealed by retreating plateau ice show deeply weathered surfaces of Pre-Glacial age.

After a tea break, **Colm ó Cofaigh** (University of Bristol) turned our attention to '*Fjord sedimentation associated with fast flowing outlet glaciers, East Greenland: implications for the ancient glaciomarine record*', challenging the current interpretation of sedimentation processes in glaciomarine successions. A paper by **Julian Murton** (Sussex University) on '*Field observations and laboratory simulations of thawing ice wedges*' showed how experimentally-formed tunnels and involutions resemble natural ones observed above partially-thawed ice wedges in sand in the Mackenzie Delta area, Canada. **Brice Rea** (Cardiff University) presented a paper on '*The structural geology of Bruarjökull, and the origin of diamict ridge*'. The ridge network found in front of Bruarjökull (an Icelandic surging glacier) was compared to similar networks of ridges found in the Canadian Prairies, and from these comparisons, inferences were made about the dynamics of the Laurentide Ice-sheet. Overall, the session was extremely well illustrated and generated some good discussions.

Friday 5 January

With **James Scourse** (University of Wales, Bangor) as Chair, **Charles Harris** (Cardiff University) discussed '*Geotechnical centrifuge experiments to simulate periglacial slope processes (gelifluction, mudflows and detachment slides)*', experiments designed to model the response of a silty sediment to active-layer thawing. Charles also discussed the potential of modelling periglacial slope processes for exploring environmental histories of slope deposits. **Paul Davies** (Bath Spa University College) gave a paper ('*Linking the past and the present: the molluscan experience*') which examined the ecology and palaeoecology of molluscs from floodplain sequences in central southern England. **Brian Whalley** (QUB) discussed '*Rock glaciers – what do they signify?*', suggesting that they are glacial not periglacial features and depend on both ice flux and available debris, which means that we may need to reconsider their climatic implications. Perhaps, therefore, the term 'grotty glacier' may be a more appropriate. **Danny McCarroll** (University of Swansea) delivered a very informative and well-illustrated paper on '*Whispering trees: the potential of multiproxy dendroclimatology*', concluding that a multiproxy approach gives better calibration results and higher r values, and limits results biased towards the mean of the reconstructed value. **Ian Fairchild** and **Anna Tooth** (Keele

University) discussed '*Modern cave environments and speleothem geochemical records of climatic change*'. Studies of Crag Cave, western Ireland, show that the modern environment is at one extreme of the Holocene record. **John Stewart** (Cambridge University) spoke on '*Northern refugia, do they explain the non-analogue mammalian communities of the late Pleistocene?*', setting out the argument that such refugia for thermophilous and plant taxa existed in NW Europe during OIS 3 and discussing the possibility that they partially explain the non-analogue mammalian communities of the Late Pleistocene.

Martin Head (Cambridge University) chaired the afternoon session on Marine Environments, which opened with **Yongqiang Zong** (University of Durham) discussing '*Approaches and applications of reconstructing sea-level changes using modern analogues*', specifically based on diatom-based transfer functions. **Ben Horton** (University of Durham) presented research on '*Environmental modelling and quantitative palaeoenvironmental reconstructions of Holocene sea-level data, eastern England*', which included computer modelling of sea-level change in the Humber Estuary. **James Scourse** followed with '*Benthic foraminifera and stable isotopes as palaeostratification indicators in shelf seas*', suggesting that the isotopic evidence from modern forams from the Celtic Sea supports the assertion that seasonal effects are important as different species calcify their tests at different times of the year, and therefore in water of varying temperatures. **Fabienne Marret** (University of Wales, Bangor) discussed '*Seasonal changes in the modern dinoflagellate cyst distribution in the Celtic Sea*', presenting preliminary results which suggest that five assemblages can be recognised that may facilitate interpreting this area's Holocene record. **Bill Austin** (University of St Andrews) discussed '*Oxygen isotopes and benthic foraminifera: some new challenges*'. He set out a brief history of the study $\delta^{18}\text{O}$ from carbonate fossils for reconstructing palaeotemperature and suggested that 'Seasonality is the new challenge in palaeoceanography' - an excellent paper with which to end the meeting.

The meeting covered an extremely broad range of topics, and, for once, speakers concentrated on the conference theme, such that for those attending the majority of talks, a very clear picture emerged of where Quaternary science is in terms of the analogue/calibration issue - it is clear that there is still plenty to do and many cherished interpretations may suffer as a result. **James Scourse** thanked all the speakers and the conference organisers Mary Seddon, Heather Pardoe and Elizabeth Walker of the National Museums and Galleries of Wales for organising this small but successful meeting.

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QRA RESEARCH FUNDS

AWARDS IN THE FIRST YEAR

Members of the QRA should be aware that we have three different kinds of research awards to promote Quaternary research:

- a) the Quaternary Conference Fund, to support increased participation in meetings in the UK and overseas;
- b) the Quaternary Research Fund, to promote any aspect of Quaternary research activities;
- c) the New Research Workers' Awards, to promote Quaternary research by postgraduate members.

Awards are made three times a year, in January, May and September; full details are available in the QRA circular and on the web site (<http://www.qra.org.uk/awards.htm>). The intention is to regularly list in *QN* new awards and reports on previous ones. Two rounds of awards have been completed so far and their details are listed below. The awards are currently administered by Dan Charman, University of Plymouth, to whom all enquiries and applications should be directed (please check the details on the web site or in the circular first). We encourage all members to consider how the QRA grants could assist their own activities and to apply for an award.

Dan Charman
Department of Geographical Sciences
University of Plymouth
Plymouth
Devon PL4 8AA

New Research Workers' Awards

| | | £ | Project |
|------------------|--------------------------------------|-----|---|
| Anette Engelmann | Cheltenham and Gloucester CHE | 300 | Application of the new radioluminescence dating method to samples of Upper Pleistocene and Holocene aeolianites from the Sharon and Carmel Coastal Plains of Israel |
| Jonathon Lee | Royal Holloway, University of London | 200 | Contribution to costs of publication of colour figures |
| Mark Stephens | Royal Holloway, University of London | 170 | Investigation of loess-palaeosol sequences in Moldova, Eastern Europe |
| Michelle Clarke | University of Wales Swansea | 300 | Extreme storm events and long-term soil erosion in primary tropical rain forest in Sabah (Malaysian Borneo) |
| Paul Stupples | University of Manchester | 300 | Long term processes and controls on intertidal sedimentation |
| Stewart Williams | Queen's University of Belfast | 170 | Investigation of a plateau-valley glacier system in north Norway |
| Stuart McQuarrie | University of Sheffield | 170 | Luminescence dating of fluvial deposits |
| William Gosling | University of Cambridge | 300 | Characterisation of Amazonian forest and savanna ecosystems by their modern pollen spectra |
| Zoe Hazell | Royal Holloway, University of London | 150 | A Late Holocene lake diatom and atmospheric pollution record from the Massif Central, France |

Quaternary Conference Fund

| | | | <i>To present:</i> |
|-----------------|-----------------------------|-----|---|
| Mary Gagen | University of Wales Swansea | 150 | 'Stable isotope dendroclimatology: a tool for reconstructing Little Ice Age climate using pine trees from the southern French Alps' at the 15 th International Dendroecological Fieldweek 2000, Masun, Slovenia. |
| Siobhan McGarry | The Open University | 250 | 'A multiproxy study of speleothems' at Climate Changes - The Karst record II, Krakow, Poland, August 2000 |

Quaternary Research Fund

| | | | <i>Project:</i> |
|------------|-------------------------------|-----|---|
| Ben Horton | University of Durham | 330 | The development and application of microfossil-based transfer functions in Holocene sea-level studies, New South Wales, Australia |
| Helen Roe | Queen's University of Belfast | 330 | Precision dating of saltmarsh sediments: an integrated approach using historically dated pollen markers and industrially emitted particles, |

| | | | |
|-------------------------------------|-----------------------------------|-----|---|
| | | | Connecticut, USA |
| Jason Kirkby | University of Hull | 330 | The recovery of late glacial/ early Holocene deposits at Tilling Green, Rye, using a drilling rig |
| Simon Carr | Oxford Brookes University | 270 | Glaciotectonised sediments at Mullaghmore, County Meath, Ireland: evidence of a large-scale re-advance during ice-sheet deglaciation? |
| September 2000 awards | | | |
| <i>New Research Workers' Awards</i> | | £ | Project |
| Ian Lawson | University of Cambridge | 180 | The Lateglacial and early Holocene environmental history of Greece |
| <i>Quaternary Conference Fund</i> | | | To present: |
| Adrian Tams | University of Edinburgh | 213 | 'Soil micromorphology of occupation deposits from Iron Age dwellings in the Western Isle, Scotland' at Archaeological soil micromorphology workshop, University of Milan, Italian Council of Research, December 2000. |
| Chris Gleed-Owen | English Nature | 170 | 'Converting amphibian and reptile remains into a palaeotemperature proxy' at QRA Annual Discussion Meeting, Cardiff, January 2001. |
| Mark Furze | University of Wales (Bangor) | 250 | 'Sea level rise on the NW European continental shelf' at 'Coastal interactions during sea-level highstands', Patagonia, Argentina, IGCP Project 437, November 2000. |
| Russell Coope | Tighe na Cleirich, Perthshire | 250 | 'The quantitative estimation of Late Glacial climates based on MCR using coleopteran remains' at INTIMATE International workshop, Kangeslussuaq, Greenland, August 2000 |
| S.E. Collinge | UCL | 250 | 'The Pleistocene mammal community of Britain - effects of a changing environment' at 60 th Annual Meeting of the Society of Vertebrate Paleontology, Mexico City, October 2000 |
| <i>Quaternary Research Fund</i> | | | Project |
| Iain Robertson | University of Wales (Swansea) | 470 | $\delta^{13}\text{C}$ of tree-ring lignin as an indirect measure of climate change |
| 5 Neil Glasser | University of Wales (Aberystwyth) | 250 | Reconstructing the Late Devensian glaciation of the Irish Sea from erosional evidence |

REVIEWS

GEOLOGY OF THE COUNTRY AROUND LOWESTOFT AND SAXMUNDHAM: MEMOIR FOR 1;50,000 SHEETS 176 AND 191 (ENGLAND AND WALES)

B.S.P. Moorlock, R.J.O. Hamblin, S.J. Booth and A.N. Morigi

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This memoir describes the geology of a district that comprises coastal Suffolk from Lowestoft to Aldeburgh, extends up to ~ 25 km inland, and includes a small part of southern Norfolk to the north of the river Waveney. The district is a dissected plateau consisting mainly of glacial tills which rise to ~ 50 m above sea level in the west, separated by valleys and tracts of coastal marshland. Almost all the area is underlain by marine Plio-Pleistocene Crag deposits, the focus of extensive study during the 19th century, because they contained fauna well preserved and easily excavated. The Crag deposits comprise mainly sands with silts, clays, and locally gravels that overstep the Palaeogene (>70 m thick under Lowestoft) to rest directly on the Upper Chalk in the western half of the district. Thus, the chapter on concealed strata is concerned not only with geophysical interpretations and the nature of the Lower Palaeozoic basement beneath the mid-Cretaceous unconformity but also with these formations that outcrop in the rest of southeast England.

Quaternary deposits are normally termed by the British Geological Survey 'Drift' deposits. However, the Crag Group is classified as part of the Solid on account of the lithified nature of the material. Conversely, the higher terraces of the Kesgrave and Bytham gravels, which were deposited by rivers flowing into the area from the southwest and west respectively, are probably equivalent in age to the youngest Crag but are considered to be Drift. Furthermore, due to their poor and limited outcrops they are undifferentiated from later Anglian sands and gravels on the published geological maps. In spite of these technicalities, all these pre-Anglian gravels are dealt with in the chapter on the Crag, because towards the end of this period the sea regressed and the boundary

between these marine and fluvial sediments must have been diachronous. The chapter describes in some detail the different members of the Red and Norwich Crag and provides clear photographs of typical sections from local gravel pits.

The text then tentatively discusses the chronostratigraphy of these complex sediments. However, it becomes confusing when the correlation of offshore equivalents is attempted without fully considering the key evidence produced by the magnetisation of these sediments. Thus, in Table 5 the reversely-magnetised Westkapelle Ground Formation should only be correlated with the uppermost Thurnian Red Crag and not with the older Thorpeness and Sizewell members that are normally magnetised. The chapter also dates the international Plio-Pleistocene boundary, which is towards the end of Crag deposition, at 1.64 Ma instead of using the now revised figure of around 1.81 Ma. However, the chapter correctly places the whole of the Crag in the Lower Pleistocene as is standard Anglo-Dutch practice, above the base of the Pre-Ludhamian, which is now considered to be ~ 2.6 Ma.

The next chapter considers all the deposits from the Anglian to the Devensian. Anglian deposits predominate, with glacial tills covering almost all the higher ground in the district. While a clear distinction is made in the text between the Corton Formation, which was derived from a Scandinavian ice sheet, and the later Lowestoft Till Formation, which was deposited by a British ice sheet during the Anglian, there is no figure to summarise the probable stages of glaciation in East Anglia; it would have been appropriate to have updated the figure reproduced in the Norwich memoir (Cox *et al.*, 1989). The text contains a significant amount of well-reported detail about the composition and provenance of these complex Anglian deposits and comes into its own with a conductivity map of the area south of Aldeburgh that clearly picks up a series of melt-water channels. This shows the potential for combining such geophysical surveys with more traditional techniques such as augering when surveying features otherwise difficult to delineate. The gravels above the Lowestoft Till around Lowestoft and to the east along the Waveney valley are attributed to late Anglian ice-marginal channels. The limited occurrences of Hoxnian and Ipswichian interglacial deposits are described only briefly, as they have only been found in a few temporary excavations. Details are given of the local river terraces that developed after the Anglian, when the present drainage pattern was established.

The chapter on the postglacial (Holocene) deposits has a good introduction that outlines the combined effects of global sea-level rise and crustal movements associated with the melting of the major ice-sheets on the palaeogeography of the study area and the southern North Sea in general. The marine deposits associated with this marine transgression are described next. There is a clear

schematic section showing the inter-relationships of these recent deposits from inland to marshes, beaches and then offshore. While there is an interesting section on the valley deposits and associated peats and soils, it is a pity that the text does not make it clear that the quoted radiocarbon dates are uncalibrated. This part is followed by useful notes on the nature of ground affected by human activity, including landscaping, quarrying and landfill.

After a short, out-of-place chapter on the structure of the district, there is an extensive chapter on economic geology, including hydrogeology - significantly, over half the abstracted water comes from either Drift deposits or the Crag. But surprisingly little attention is paid to engineering geology and erosion on one of Britain's fastest retreating coastlines: for example, Dunwich, a major mediaeval port, has been washed into the North Sea. This contrasts with the series of figures illustrating the coastal evolution around Great Yarmouth (Arthurton *et al.*, 1994) in an adjoining memoir. Compared to this earlier account, the memoir for Lowestoft and Saxmundham has fewer figures and apart from the frontispiece the photographs are in black and white rather than colour. In general the text is rather dated, and it is telling that there is not a single reference to any publication after 1996 when the geological maps it describes were published. While this might be regretted, the overall cost of this memoir combining two 1:50,000 sheets has been kept down and provides a far more detailed and rounded account of the local geology than will be possible in future Sheet Explanations (see *Quaternary Newsletter*, 92, 58-61).

References

- Arthurton, R.S., Booth, S.J., Morigi, A.N., Abbott M.A.W. and Wood, C.J. 1994. *Geology of the country around Great Yarmouth*. Memoir of the British Geological Survey, Sheet 162 (England and Wales). 138 pp. ISBN 0 11 884491 1 £50
- Cox, F.C., Gallois, R.W. and Wood C.J. 1989. *Geology of the country around Norwich*. Memoir of the British Geological Survey, Sheet 161 (England and Wales). 38pp. ISBN 0 11 884410 5 £12

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ABSTRACTS

SOME ASPECTS OF THE GEOLOGY AND ENGINEERING PROPERTIES OF THE HOLOCENE DEPOSITS AT THE BOTHKENNAR SOFT CLAY RESEARCH SITE

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This thesis describes the sedimentology and engineering geology of the Holocene sediments of the Claret Formation at the EPSRC Bothkennar Soft Clay Research Site, near Grangemouth, Scotland. The composition, fabric and geotechnical characterisation of these deposits have been described using detailed borehole logging, X-ray densimetry, X-radiography, XRD, SEM and soil mechanical techniques. These factors have been related to changes in the relative sea-level in the Bothkennar area during the period 5,000 - 3,000 ¹⁴C yrs BP. In particular, the water-depth history has been quantified by a comparison of the published sea-level curve (corrected to MSL) with a novel seabed curve constructed from ¹⁴C dated shell samples. In both sea-level and seabed curves the elevation of the index points has been corrected for autocompaction, using a method based on the geotechnical profile at the point in question.

At Bothkennar the deposits record a period of falling sea level during which the conditions of deposition changed from subtidal (~20 m water depth below contemporaneous MSL) to intertidal, as indicated by the facies succession and by the gross sedimentology of the deposits. The detailed sedimentology and the SEM microfabric studies indicate that deposition was not continuous and that these hiatuses have generated features of geotechnical importance.

The sediments are almost entirely silty clays or clayey silts with a sand content usually less than 5%. They contain a mixed mineral suite that comprises mainly quartz, feldspar, mica (illite) and chlorite, all of which are typical of the mixed rock suite from which the Claret Formation has been ultimately derived. On the basis of their primary sedimentary structures, and the nature and extent of bioturbation, three principal macrofacies, termed the bedded, mottled and laminated facies, can be recognised across the site. Biogenic features occur throughout all these facies and were probably produced by an invertebrate infauna similar to that of the intertidal mudflats of the present-day Forth estuary. The SEM microfabric can be categorised into three types, termed the aggregated, the cumulate and the granular, which correlate broadly with the macrofacies: the cumulate microfabric appears more frequently in the mottled facies and the granular in the bedded facies, the aggregated being found in both facies.

The sediments contain up to 5% of organic material that occurs mainly as mucal sheets or amorphous coatings. These cement individual soil particles into larger aggregates or pellets. The organic material has a low C:N ratio and is probably derived from estuarine organisms, rather than from a terrestrial source. Its composition can be characterised in terms of three gross fractions: monosaccharide residues, Kjeldahl nitrogen and a methanol-toluene extractable fraction. When plotted on a ternary diagram, the composition in terms of these fractions falls along a line of constant nitrogen to monosaccharide weight ratio.

In the pore water the concentrations of sodium, potassium and magnesium conform to depth profiles of an approximately parabolic shape. Their relative proportions show that, although the pore water is likely to have originated as estuarine water trapped during deposition, it has probably undergone subsequent modification as a result of long term diffusion and the breakdown of potassium-bearing minerals.

In its natural state the sediment is of medium to high plasticity (liquid limit = 50% - 80%). This is greater than expected from its clay mineralogy and differs little between the bedded and mottled facies. There is a positive correlation between the liquid limit and the concentration of the sodium, potassium and magnesium cations and also with two of the organic compositional fractions (the monosaccharide residues and Kjeldahl nitrogen).

The water content does not reduce uniformly with depth, but shows many small high-frequency perturbations and reaches a maximum value about one-third down the depth profile. This suggests that the later stress history was not one of simple selfweight consolidation. The liquidity index shows fewer perturbations, which in turn suggests that the local variability in water content is caused by variation in the liquid limit. A similar conclusion is reached from the void index profile, which also suggests that the sediment has a level of geotechnical structure that varies with position in the profile, leading to the conclusion that it is governed by geological events such as rate and continuity of deposition, development of intradepositional surfaces (hiatuses) and secondary ageing of the material.

The results from Bothkennar are compared with those published from other Holocene estuarine clays at Belfast (Northern Ireland), Brean (Severn Estuary, England) and Drammen (Norway). This comparison indicates that it is possible to identify a limited number of key factors which have determined both their overall architecture and their level of geotechnical structure. These factors include the initial depositional level within the tidal frame, subsequent changes of relative sea level, the composition of the clay-sized fraction, the presence of amorphous organic material and the ionic composition of the pore water. These factors together suggest a possible framework within which to understand the geotechnical properties of estuarine clays.

SEDIMENTOLOGICAL, PALAEOGEOGRAPHICAL AND STRATIGRAPHICAL ASPECTS OF THE MIDDLE PLEISTOCENE GEOLOGY OF THE PETERBOROUGH AREA, EASTERN ENGLAND

**Harry E. Langford (Doctor of Philosophy)
Department of Geography, Anglia Polytechnic University**

A sedimentological study of Middle Pleistocene deposits in the Peterborough area has been undertaken in order to determine their genesis and to develop palaeogeographical and stratigraphical models. The deposits were divided into two categories on the basis of published descriptions:

- (i) Anglian chalk-rich diamictons, which locally may overlie deep sequences of lacustrine muds, sands, diamictic muds and matrix-supported diamictons;
- (ii) post-Anglian sand and gravel bodies forming fluvial terrace aggradations.

The Anglian sequences are interpreted to have been deposited subaqueously in a lake that at times may have covered the present-day area of the Fen Basin. Contrary to prevailing models of Anglian glaciation, there is no unequivocal evidence for glacial overriding of the Peterborough area from the northeast, and the timing and origin of the breaching of the Chalk escarpment at The Wash remains equivocal. Triassic-rich phases suggest that the easterly limit of ice advancing from a westerly direction during this stage was closer to Peterborough than prevailing models suggest, although it appears to have remained to the west of Peterborough.

Sequences in post-Anglian deposits suggest major Middle Pleistocene reorganization of fluvial networks in the Fen Basin. Southerly-directed meltwater flow from a post-Anglian, but pre-Devensian ice sheet to the north of the Fen Basin deposited a fluvial sequence to the north of Uffington and formed the Southorpe dry valley. Formation of an alluvial fan at the southern end of the dry valley impounded waters of the former Nene river to create a lake at Elton. The origin of some of the River Nene 3rd and 2nd terraces, and some of the incised bedrock meanders, can be explained by the presence of the lake at Elton and by flow through the Southorpe dry valley. Formation of the River Welland during this phase diverted flow from the Southorpe dry valley.

Stratigraphical interpretation of fluvial sequences at King's Dyke and Sutton Cross, based on age-estimates from the former, suggests that the major drainage reorganization occurred during Oxygen Isotope Stage 8.

RECONSTRUCTING THE LATE DEVENSIAN GLACIATION HISTORY OF THE SOUTHERN IRISH SEA BASIN: TESTING OF COMPETING HYPOTHESES

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The question whether the last deglaciation of the southern part of the Irish Sea basin occurred under terrestrial or glacialmarine conditions has been debated for more than 150 years. The answer is critical for interpreting the role of environmental factors in triggering and controlling deglaciation and also for defining the sensitivity of the crust to the last glacial cycle. The controversy is due to differing interpretations of fossil glacialgenic sediments, especially glacialgenic diamicts with Irish Sea affinity, and has been compounded by the often uncritical approaches taken in the past and ignorance of deformation structures. In this thesis a falsification approach is formalised for the interpretation of fossil glacialgenic sediments, based upon the testing of competing hypotheses.

Glacialgenic successions were investigated in detail at six key sites around the southern Irish Sea basin: at Rotherlslade, West Angle Bay, Druidston, Abermawr and Traeth y Mwnt (all in Wales) and in Killiney Bay (Ireland). At Rotherlslade, Gower Peninsula, evidence is found for the existence of an unstable glacialfluvial paraglacial fan system. At West Angle Bay abundant evidence for recent anthropogenic activity associated with clay winning for Castlemartin brick making has been identified. The contention of the oldest till of Wales being present here is severely questioned. At Abermawr, Pembrokeshire, the most complete sedimentary succession has been identified recording glacial advance, glacial fluctuation during retreat and later paraglacial sediment flow activity. At Traeth y Mwnt the best exposure in Wales has been identified showing density driven deformation induced by higher density glacialfluvial gravels sinking into lower density flow tills (Rijdsdijk, 2001; Hindmarsh and Rijdsdijk 2001). At Killiney Bay, Ireland, evidence is present for syndepositional glacialtectonic deformation by the Irish Sea ice sheet, leading to the deposition of diachronous lithological units. Here evidence is found for hydrofracturing of tills (Rijdsdijk *et al.*, 1999).

The results are combined with previous studies and synthesised to produce a model of land-system evolution during the Late Devensian deglaciation. It is concluded that there is no exclusive evidence of glacialmarine deposition and that the sedimentary successions were formed during the melting and retreat of a terrestrial ice-sheet. Most of the glacial successions of the southern Irish Sea

basin were laid down during the last ice-retreat, and mainly comprise accumulations of ice-proximal and distal paraglacial glacifluvial sediments and sediment flows. The southern Irish Sea basin was thus much less sensitive to the last glacial cycle than is implied by the glacialmarine hypothesis. Sea levels were not raised glacio-isostatically above the present margins and deglaciation was not triggered by seawater invading the basin from the south.

References

Hindmarsh, R.C.A. and Rijdsdijk, K.F. (2000). Use of a viscous model of till rheology to describe gravitational loading instabilities in glacial sediments. In: Maltman, A.J., Hubbard, B. and Hambrey, M.J. (eds) *Deformation of Glacial Materials*. Geological Society Special Publication, No. 179.

Rijdsdijk, K.F. 2001 (*in press*). Density-driven deformation structures in consolidated glacial diamicts: examples from Traeth y Mwnt, Cardiganshire, Wales, Great Britain. *Sedimentary Research*.

Rijdsdijk, K.F., Owen, G., Warren, W., McCarroll, D. and Van der Meer, J.J.M. (1999). Clastic dykes in over-consolidated tills: evidence for subglacial hydrofracturing at Killiney Bay, eastern Ireland. *Sedimentary Geology*, 129, 111-126.

THE GEOMORPHOLOGY OF PALAEO-ICE STREAMS: IDENTIFICATION, CHARACTERISATION AND IMPLICATIONS FOR ICE STREAM FUNCTIONING

Chris R. Stokes (Doctor of Philosophy)
Department of Geography, University of Sheffield

Ice streams are the dominant drainage pathways of contemporary ice sheets, and their location and behaviour are viewed as key controls on ice-sheet stability. Identifying palaeo-ice streams is of paramount importance if we are to produce accurate reconstructions of former ice sheets and examine their critical role in the ocean-climate system.

Many workers have invoked palaeo-ice streams from a variety of former ice sheets, despite a limited understanding of their glacial geomorphology. This thesis addresses the problem by predicting several diagnostic geomorphological criteria indicative of ice-stream activity. These are developed objectively from the known characteristics of contemporary ice streams and can be summarised as:

- large flow-set dimensions (>20 km wide and >150 km long),
- highly convergent flow patterns,
- highly attenuated subglacial bedforms (length:width $>10:1$),
- Boothia-type dispersal plumes,
- abrupt lateral margins (<2 km),
- ice-stream marginal moraines,
- evidence of pervasively deformed till, and
- submarine sediment accumulations (marine-terminating ice streams only).

Collectively, the criteria are used to construct conceptual landsystems of palaeo-ice stream tracks. Using satellite imagery and aerial photography to map glacial geomorphology, identification of the criteria is used to validate the location of a previously hypothesised ice stream and identify a hitherto undetected palaeo-ice stream from the former Laurentide Ice Sheet. Implications for ice-stream basal processes are explored and their ice-sheet wide significance is assessed.

On Victoria Island (Arctic Canada) five of the geomorphological criteria are identified and the extent of the marine-based M¹Clintock Channel Ice Stream is reconstructed at 720 km long and 140 km wide. The ice stream (operating between 10,400 and 10,000 yr BP) was located within a broad topographic trough, but internal glaciological processes, rather than properties of the bed

controlled the margin locations. It eroded into pre-existing unconsolidated sediments and left a spectacular pattern of subglacially-produced landforms, recording a snapshot view of the bed prior to ice-stream shut-down. Sediment availability appears critical to its functioning (deformable bed?) and the debris flux of the ice stream is inferred to have been high. Frictional shut-down occurred once down-cutting through sediments reached hard bedrock close to the terminus.

The presence of four of the geomorphological criteria are used to identify a terrestrial ice stream which drained the Keewatin Sector of the Laurentide Ice Sheet between ca. 10,000 and 8,500 yr BP. Its size is reconstructed at > 450 km long and 140 km wide, and it left behind a subglacial bedform pattern consisting of highly attenuated drumlins (length:width ratios up to 48:1) displaying exceptional parallel conformity. This represents an isochronous bedform pattern, and variations in lineament elongation ratio are thought to be a useful proxy for ice velocity. Highest elongation ratios occur immediately downstream of a topographic step where the ice stream entered a sedimentary basin. It is inferred that the ice stream was triggered by climatic warming which altered the ice-sheet configuration and the thermal state of the bed. A switch from cold to warm-based conditions probably triggered rapid basal sliding. The ice stream (and a tributary) shut down when it ran out of ice, causing widespread thinning of the ice sheet and subsequent deglaciation.

These ice streams denote considerable ice-sheet instability over both hard and soft (deformable) beds and emphasise the enormous effects that ice streams had in controlling the deglaciation of the Laurentide Ice Sheet.

NOTICES

1. GLACIAL INTERGLACIAL SEA-LEVEL CHANGES IN FOUR DIMENSIONS: SEA-SURFACE CHANGES AND COASTAL FLOOD HAZARDS IN EUROPE

University of St Andrews, Scotland, 31 March – 5 April 2001

The central theme of the conference will be addressed under the instrumental, historical and a geological points of view and particular emphasis will be given to the meso- to microscale approaches to coastal flooding, including the effects of high-energy single events of either meteorological or seismic origin. Given the intrinsic value and occupation of the European Coastal Fringe the links between the scientific and the management approaches will also be addressed.

The conference will include keynote talks by invited speakers and flexible sessions. The latter consist of short presentations of the research work being carried out by participants and aim to encourage discussion between young and senior researchers and transnational exchange of recent scientific developments. Participants are strongly encouraged to contribute with their experience or results to fulfil the spirit of the meeting. The in-door programme will be followed by a short field trip.

For information, please contact:

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On-line information at: <http://www.org/euresco>

2. QRA POSTGRADUATE SYMPOSIUM

University of St Andrews, 10-12 September 2001

Oral and poster contributions are invited for presentation at the QRA annual postgraduate symposium to be held at the University of St Andrews. The symposium constitutes an ideal forum for postgraduate students to present and discuss their research findings and for new research students to introduce their proposed topics of study in an informal and relaxed environment. The symposium

will cover all aspects of Quaternary research. A keynote speaker will be announced in early 2001.

The conference dinner will be on the evening of day 1. Oral and poster presentations will take place on days 1 and 2. This will be followed by a short field meeting, on day 3, around the local area. A fieldguide will accompany the meeting.

Organisers: Lindsay Wilson, Kim Jardine, Alix Cage, Eleanor Haresign, Kat Hands and Lindsey Nicholson (University of St Andrews).

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Registration forms will be available online from February 2001 at

<http://www.st-andrews.ac.uk/~ljw4/qra2001/registration.htm>

3. CHANGING WETLANDS: NEW DEVELOPMENTS IN WETLAND SCIENCE

University of Sheffield, 11-13 September 2001

A joint, international meeting between the Mires Research Group of the British Ecological Society and the Society for Wetland Scientists, hosted by the Sheffield Wetlands Research Centre (SWeRC)

The conference aims to bring together researchers from the many disciplines involved in wetlands research (e.g., ecology, hydrology, biogeochemistry, palaeoenvironmental reconstruction) and to provide a forum to share and exchange ideas on recent developments in wetland science. The programme will include invited lectures, contributed sessions and workshops organised under a number of broad, interdisciplinary themes. We aim to publish selected papers in special issues of *Wetland Ecology & Management*, *Hydrological*

Processes and The Holocene. Post-conference field trips are planned to the blanket mires of the Flow Country in Caithness and Sutherland (Scotland) and to the fens of Broadland in East Anglia (England).

See the web site at <http://www.shef.ac.uk/~g/wetlands> for updates on the conference and for instructions on submission of abstracts. The deadline for abstracts is **Friday 23 February 2001**. The deadline for registration is **Friday 22 June 2001**.

Please direct all enquiries to:

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4. JOURNAL OF QUATERNARY SCIENCE

Forthcoming papers

Rapid communication

Davies *et al.* Identification and significance of a visible, basalt-rich Vedde Ash layer in a Late-glacial sequence on the Isle of Skye, Inner Hebrides, Scotland

Research papers

Nesje & Dahl. The Greenland '8200 cal. BP' event detected in loss-on-ignition profiles in Norwegian lacustrine sediment sequences

Hardardóttir *et al.* Seismostratigraphy and sediment studies of Lake Hestvatn, southern Iceland; implications for the deglacial history of the region

Hunt & Hill. Tephrochronological implications of beam size - sample size effects in electron microprobe analysis of glass shards

Andrews *et al.* Changes in marine and terrestrial Neoglacial (~4 ka) environments in Reykjarfjordur, Iceland: climate and/or settlement

Edwards. Mid to Late Holocene relative sea-level change in the Hampshire

Basin, UK: new data from Poole Harbour

Larsen *et al.* Geochemistry, dispersal, volumes and chronology of Holocene silicic tephra layers from the Katla volcanic system, Iceland

Gehrels *et al.* Foraminifera, testate amoebae and diatoms as sea-level indicators in UK saltmarshes: a quantitative multi-proxy approach

Kirkbride & Dugmore. The timing and significance of mid-Holocene glacier advances in northern and central Iceland

Narcisi. Palaeoenvironmental and palaeoclimatic implications of the Late Quaternary sediment record of Vico volcanic lake (central Italy)

Sejrup *et al.* Late glacial - Holocene environmental changes and climate variability; evidence from Voldafjorden, western Norway

Hongyan *et al.* Detecting Holocene movements of the woodland-steppe ecotone in northern China using discriminant analysis

Bos *et al.* Vegetation and climate during the Weichselian Early Glacial and Pleniglacial in the Niederlausitz, eastern Germany - macrofossil and pollen evidence

Lewis & Illgner. Late Quaternary glaciation in southern Africa: moraine ridges and glacial deposits at Mount Enterprise in the Drakensberg of the Eastern Cape, South Africa

Khatwa & Tulaczyk. Microstructural interpretations of modern and Quaternary subglacially deformed sediments: the relative role of parent material and subglacial processes

Lyså & Lønne. Moraine development at a small high-arctic valley glacier: Rieperbreen, Svalbard

5. A CARTOGRAPHIC AND PHOTOGRAPHIC RECORD OF BREIDAMERKURJÖKULL, ICELAND

The Department of Geography and Topographic Science at the University of Glasgow in collaboration with the Department of Building and Civil Engineering at Loughborough University have just completed the re-mapping of one of the world's most famous and accessible glaciers - Breidamerkurjökull in southeast Iceland. The new 1998 map and two selected aerial photograph stereo-triplicates, in addition to the previously published 1945 and 1965 maps, are now available for teachers and researchers.

The high quality maps are at a scale of 1:30,000, printed in full colour and include the surficial geology and geomorphology. The 1998 map includes the original orthophotographic image over the glacier surface, thereby providing a clear impression of crevasse and supraglacial moraine patterns. The contour interval is at 10 m on all the maps, allowing reconstructions of glacier surface profiles through time and assessments of glacial landform morphologies. Stereo-triplicates of the 1998 aerial photographs cover most of the proglacial area, allowing the viewing of features in 3-D through the use of standard stereoscopes. The pre-1998 glacial geomorphology has been augmented by extra process-form classifications which are based upon recent advances in glacial research. These features make the maps and photographs ideal tools for the teaching of glaciology and glacial geomorphology.

For further information and an order form see:

<http://www.geog.gla.ac.uk/~mshand/Breida>

Department of Geography & Topographic Science (Breida map)

University of Glasgow

Glasgow

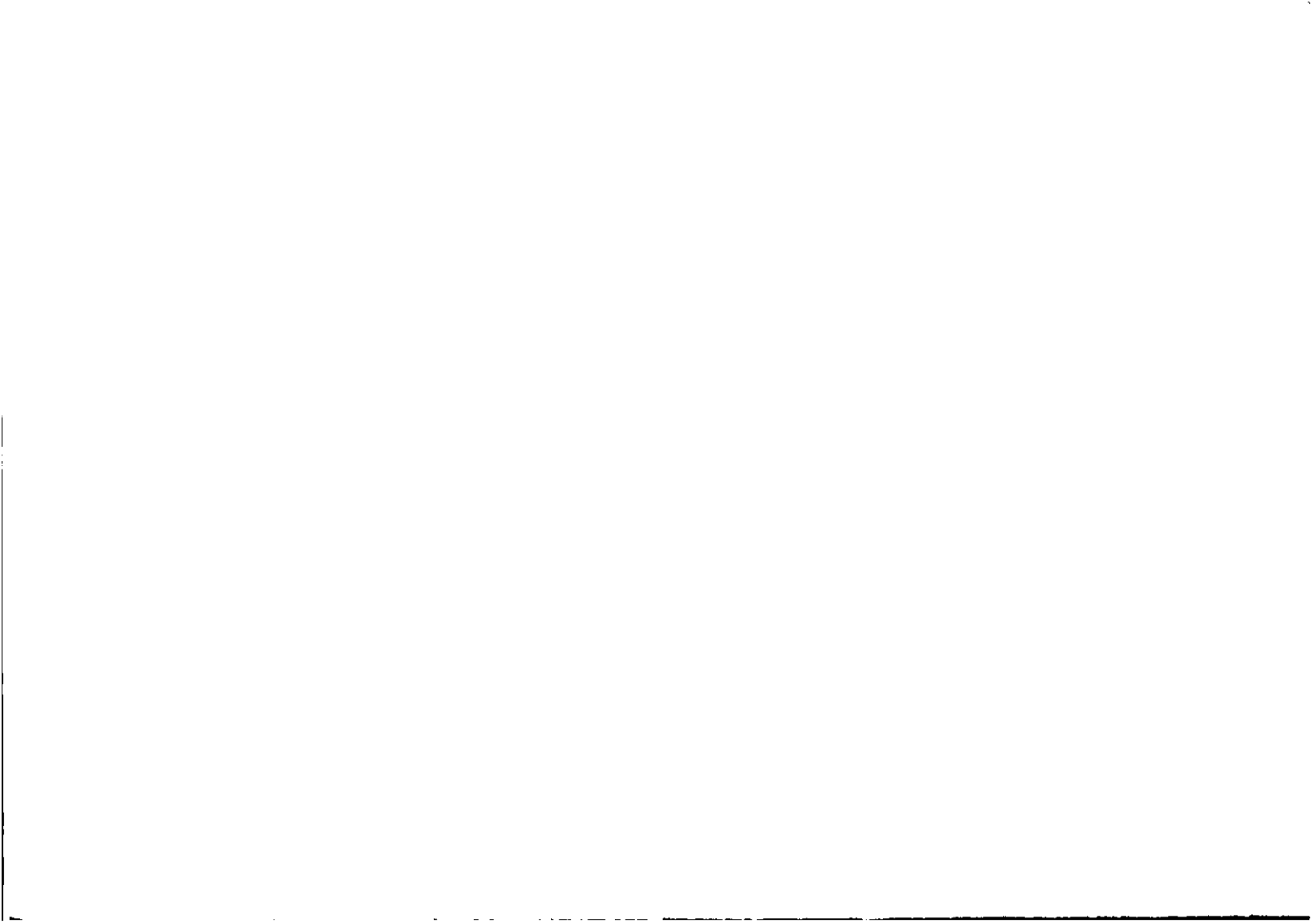
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QUATERNARY RESEARCH ASSOCIATION

The Quaternary Research Association is an organisation comprising archaeologists, botanists, civil engineers, geographers, geologists, soil scientists, zoologists and others interested in research into the problems of the Quaternary. The majority of members reside in Great Britain, but membership also extends to most European countries, North America, Africa, Asia and Australasia. Membership (currently c. 1,000) is open to all interested in the objectives of the Association. The annual subscription is £15 with reduced rates (£5) for students and unwaged members and an Institutional rate of £25.

The main meetings of the Association are the Annual Field Meeting, usually lasting 3-4 days, in April, and a 1- or 2-day Discussion Meeting at the beginning of January. Additionally, there are Short Field Meetings in May and/or September, while Short Study Courses on techniques used in Quaternary work are also occasionally held. The publications of the Association are the *Quaternary Newsletter*, issued with the Association's *Circular* in February, June and October; the *Journal of Quaternary Science*, published in association with Wiley, incorporating *Quaternary Proceedings*, with eight issues per year, the Field Guide Series and the Technical Guide Series.

The Association is run by an Executive Committee elected at an Annual General Meeting held during the April Field Meeting. Current officers of the Association are:

- President:** *Professor M.J.C. Walker*, Department of Geography, University of Wales, Lampeter, Dyfed, SA48 7ED
(e-mail: walker@lamp.ac.uk)
- Vice-President:** *Dr R.C. Preece*, Department of Zoology, University of Cambridge, Downing Street, Cambridge, CB2 3EJ
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