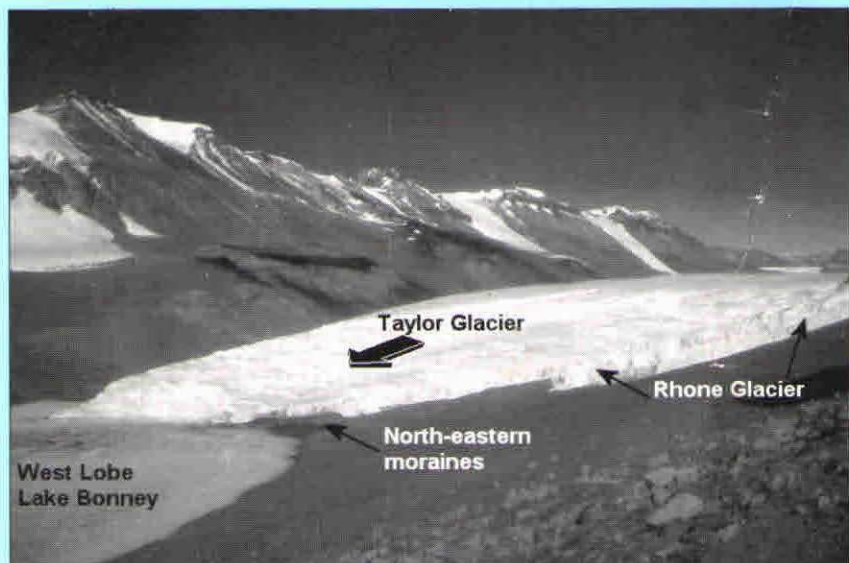

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QUATERNARY NEWSLETTER

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Instructions to authors

Quaternary Newsletter is issued in February, June and October. Articles, reviews, notices of forthcoming meetings, news of personal and joint research projects, etc. are invited and should be sent to the Editor. Closing dates for submission of copy (news, notices, reports etc.) for the relevant numbers are 1st January, 1st May and 1st September. These dates will be strictly adhered to in order to expedite publication. **Articles must be submitted at least 6 weeks before these dates in order to be reviewed and revised in time for the next issue of QN, otherwise they may appear in a subsequent issue.**

Suggested word limits are as follows: obituaries (2000 words); articles (3000 words); reports on meetings (2000 words); reports on QRA grants (500 words); reviews (1000 words); letters to the Editor (500 words); abstracts (500 words). Authors submitting work as Word documents that include figures must send separate copies of the figures in .eps format. Quaternary Research Fund and New Research Workers Award Scheme reports should limit themselves to describing the results and significance of the actual research funded by QRA grants. The suggested format for these reports is as follows: (1) background and rationale (including a summary of how the grant facilitated the research), (2) results, (3) significance, (4) acknowledgments (if applicable). The reports should not (1) detail the aims and objectives of affiliated and larger projects (e.g. PhD topics), (2) outline future research and (3) cite lengthy reference lists. No more than one figure per report is necessary. Recipients of awards who have written reports are encouraged to submit full-length articles on related or larger research projects.

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COVER PHOTOGRAPH:

A photograph of the Taylor Glacier in the Taylor Valley, South Victoria Land, Antarctica provided by Mark Lloyd Davies.

EDITORIAL

As the editorship of the *Quaternary Newsletter* passes from Julian Morton to myself, I would like to thank Julian on behalf of the QRA for his dedication and skill. Since 2000, Julian has ensured that *QN* has provided a stimulating and well-presented mix of news, research and comment.

As always, insight, debate and variety are essential to the continued success of the Newsletter. Material with these qualities will be welcomed from all ranks of the QRA. In particular, *QN* can provide an important forum to debate issues that are contentious and papers that address such problems will be most welcome. And in addition to general Quaternary matters, the Newsletter will also welcome material about education and conservation. Spreading the findings of Quaternary research to schools and the general public, and encouraging them to pursue their own Quaternary interests or research should be important to us all.

Finally, I'd like to make a plea on behalf of good illustrations. As maps, diagrams and photographs are just as important as text, please would contributors to *QN* submit illustrations that are well designed and produced.

Tim Mighall

EVIDENCE FOR A NEW HOXNIAN INTERGLACIAL SITE AT SCHOOL FIELD, TEDNAMBURY, HERTFORDSHIRE

Richard T. Betts and Steve Boreham

Introduction

This study was carried out in the summer of 2002 to investigate the temporal and spatial nature of organic deposits reported by the British Geological Survey (Millward *et al.*, 1987) at School Field, Tednambury, Hertfordshire (Figure 1). The BGS concluded that these deposits were temperate and post-Anglian, but were unable to determine which particular temperate episode the sediments represented. The presence in the area of fossiliferous silts overlying a basal grey till had been known for some time (West and Donner, 1956) but it was not until the BGS evaluation (Millward *et al.*, 1987) that the sediments at Tednambury were fully described.

Seventeen boreholes were made at School Field, Tednambury using a hand auger on a grid system across an area 150m x 100m to determine the extent and thickness of sub-surface organic deposits reported by Millward *et al.* (1987) (Figure 2). A geological cross-section through the deposits has been constructed using some of this data (Figure 3). Sediments from four boreholes (BH6, BH9, BH11 and BH17) were sampled for pollen analysis (RTB). This material also yielded plant macrofossils (identified by C. Turner, Open University), and molluscs and vertebrate remains (identified by R.C. Preece, University of Cambridge). Although comparable pollen data were recovered from all four boreholes investigated, the most complete pollen data came from BH6, from which a pollen diagram with 10 levels has been produced (Figure 4).

Site description and stratigraphy

The site at School Field, Tednambury (TL48451680) is located west of the A1184 road between Bishop's Stortford and Sawbridgeworth in north Hertfordshire, close to the border with Essex (Figure 1). The geology of the region is rather complex comprising Anglian and post-Anglian deposits overlying Chalk and London Clay bedrock. The most extensive lithostratigraphic unit in the Middle Pleistocene succession of both Hertfordshire and Essex is the (Anglian) Lowestoft Till facies of the Lowestoft Formation (Ehlers and Gibbard, 1991, Lewis, 1999) upon which the Tednambury deposits rest.

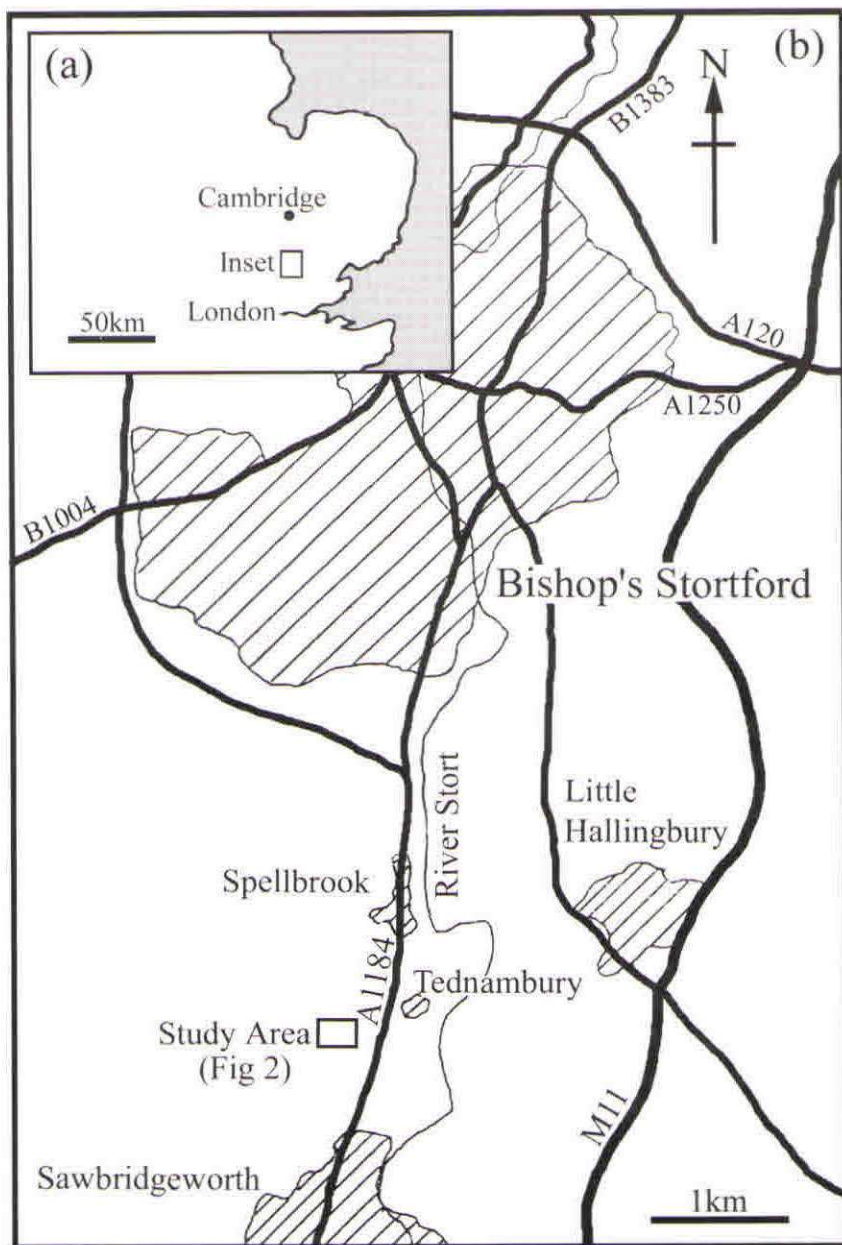


Figure 1. Maps showing (a) the position of the study site in southern England, and (b) the location of the study site near Bishop's Stortford, Hertfordshire.

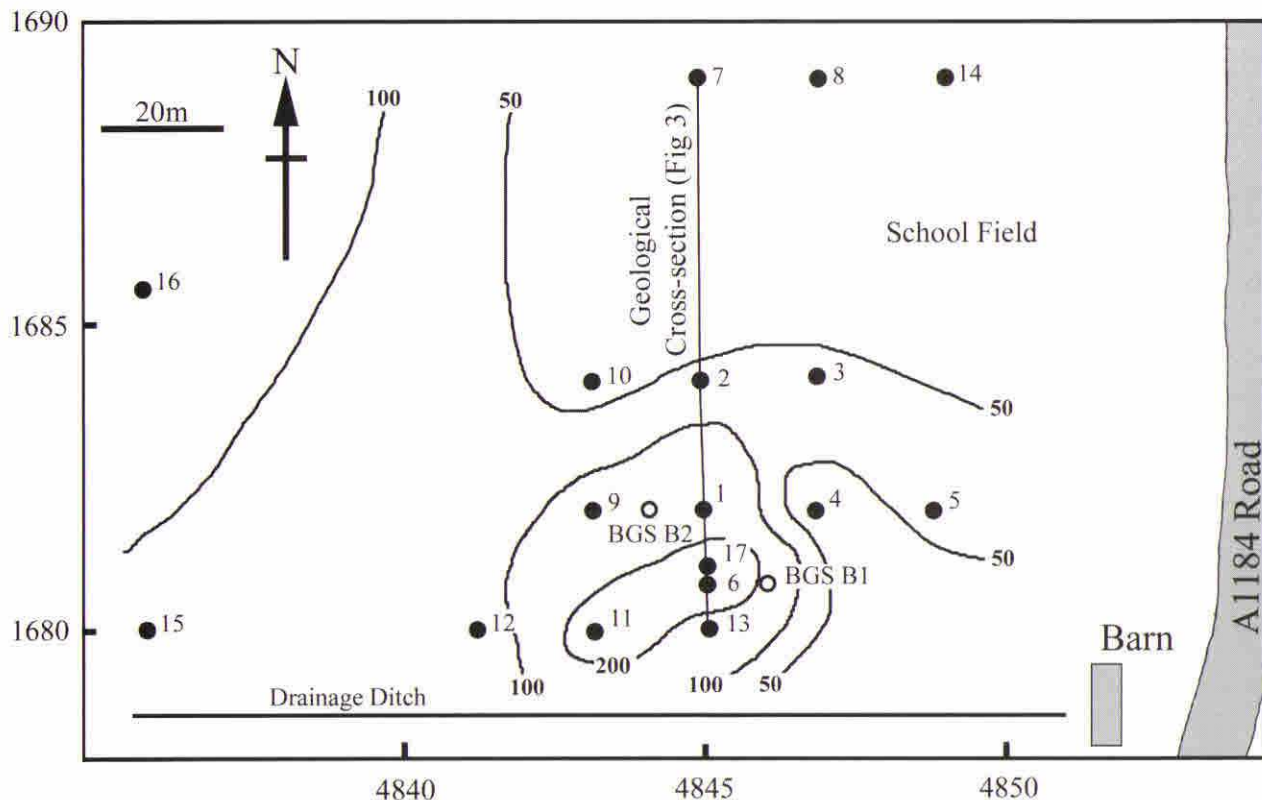


Figure 2. Location of boreholes in School Field, Tednambury, Hertfordshire, showing isopachs of silty pond sediments (50cm, 100cm, 200cm thickness) and the line of the geological cross-section shown in Figure 3.

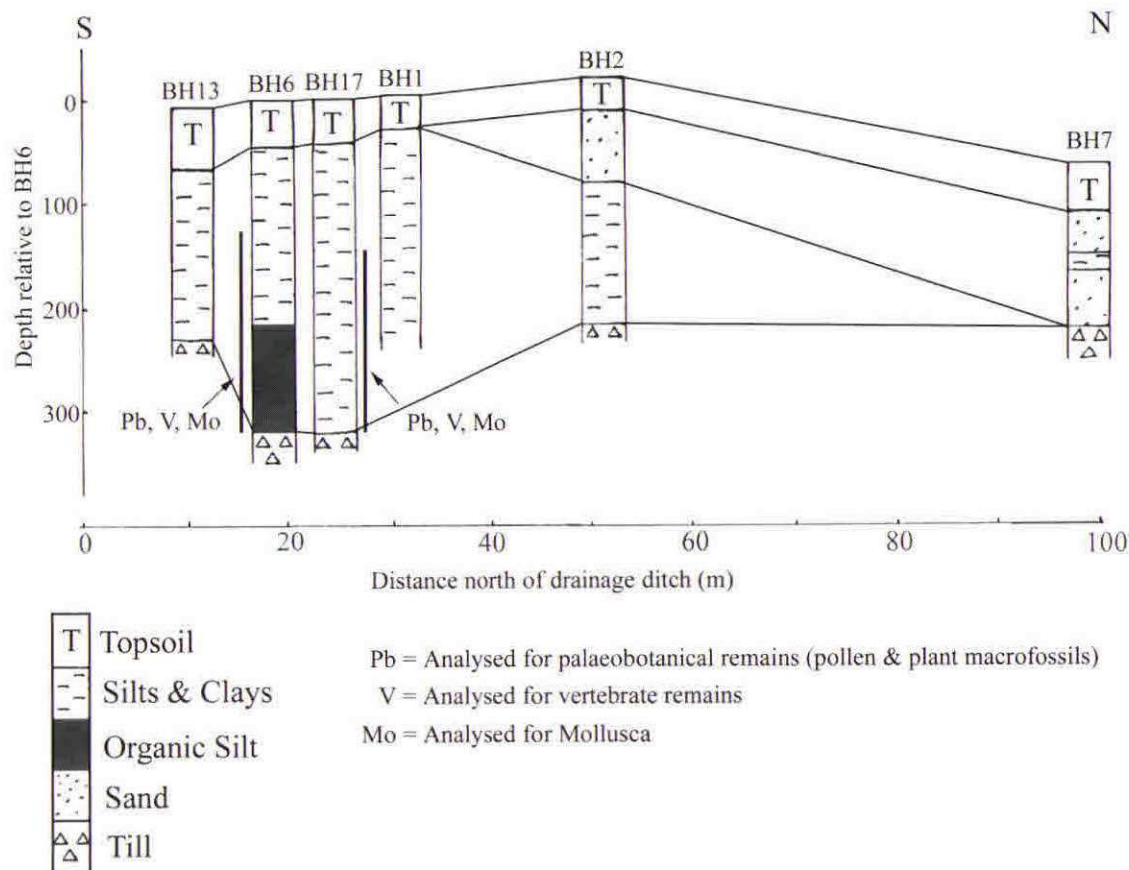


Figure 3. Geological cross-section constructed from boreholes augered across School Field, Tednambury, Hertfordshire, showing the lithology and sampling regime used for palaeobotanical, vertebrate and molluscan analyses.

The deposits at School Field, Tednambury generally comprised 50-60cm of topsoil, overlying up to 200cm of grey/brown clays and silts, which included some very shelly layers 20-50cm thick. The clays and silts were underlain by a light grey chalky diamict (till). An organic-rich silt overlying the till was found exclusively in BH6, and contained wood, plant and bone fragments (Figure 3). The isopachs plotted in Figure 2 show that these deposits are thickest at BH6, BH11 and BH17, and appear to occupy a depression in the surface of the till, which may have originally formed a pool or pond.

Pollen Analysis

Pollen analysis of ten samples from BH6 was undertaken to produce a skeletal pollen diagram (Figure 4). Pollen preparation, counting and identification were as described by Bennett (1983). Plant taxonomy follows Stace (1991), and incorporates the suggestions of Bennett *et al.* (1994). Where possible, a minimum of 300-land pollen and spores were counted at each level. The diagram shows an arboreal succession (from pre-temperate to fully temperate), dominated by *Betula* at the base of the sequence (zone Ted6-1), and *Alnus*, *Corylus avellana* type and *Quercus* higher up (zone Ted6-2). The organic-rich silt lying directly above Anglian till (315cm) contains c.60% *Betula*, c.27% Poaceae, and notably c.3% *Hippophaë rhamnoides* (Ted6-1a). The *Betula* curve rises to >80% (295-305cm), before falling to c.65%, accompanied by a rise in *Pinus* to c.10% (280cm) and increasing *Quercus* c.10% (Ted6-1b). Above this, *Pinus* and *Betula* decline, while *Quercus* and *Alnus* rise to c.25% and c.40% respectively, and *Corylus* is present at c.12% (Ted6-2a). The overlying sediments contain increased amounts of *Corylus* (c.50% at 225cm) and *Alnus* (c.52% at 180cm), with a smaller proportion of *Quercus*, and minor quantities of *Tilia*, *Fraxinus* and *Hedera* (Ted6-2b). Towards the top of the core, *Alnus* dominates the pollen signal (44-50%), accompanied by *Corylus* (14-24%), and subordinate amounts of *Betula*, *Quercus* and *Fraxinus* (Ted6-2c). The pollen of *Carpinus* is also a notable minor constituent (c.3%) of these deposits (125-135cm). Sediments above 135cm were barren. A similar pattern of vegetational succession was also observed from BH9, BH11 and BH17.

Mollusc analysis

Numerous molluscan remains were recovered from the lower part (230-310cm) of BH6, but the upper levels (130-210cm) produced a large quantity of unidentifiable shell debris. *Bithynia tentaculata* was the dominant species (c.52%), with *Valvata piscinalis* reaching c.40%, and *Lymnaea peregra* and *Gyraulus crista* present at low frequencies. These taxa suggest deposition in a pool or slow-moving river. Notably, c.90% of the *Bithynia tentaculata* remains were represented by opercula, indicating considerable winnowing and sediment reworking (Gilbertson and Hawkins, 1978), or perhaps selective destruction of the shells. A similar mollusc fauna, with the addition of *Valvata cristata*, was

School Field, Tednambury BH6 - Percentage Pollen Diagram (selected taxa)

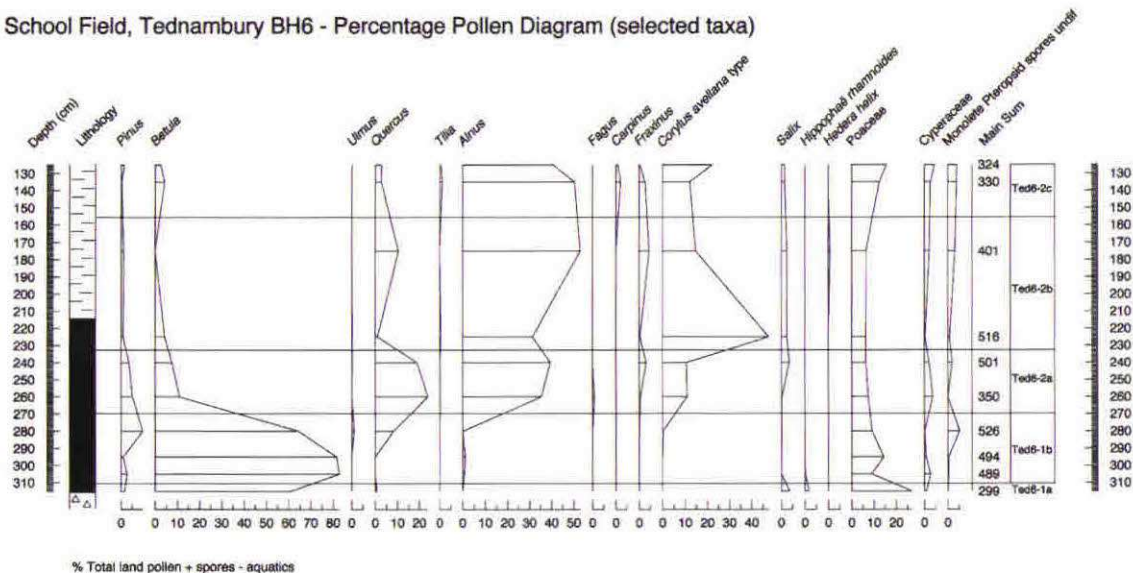


Figure 4. Skeletal percentage pollen diagram from BH6 School Field, Tednambury, Hertfordshire. The main pollen sum is the total land pollen and spores, excluding aquatics.

recovered from BH9, BH11 and BH17. Land molluscs were not found in any of the sediments analysed, which strongly suggests that if any stream entered this water body, it was small and of low-energy, since periodic flooding would be expected to introduce terrestrial molluscs.

Vertebrate and plant macro-fossil analysis

Plant macro-fossils were recovered from three levels (170cm, 230cm, 310cm) in BH6 and included abundant indeterminate wood fragments, grass and sedge remains, the leaves and stems of moss, and the seeds of *Alisma plantago-aquatica*. A similar assemblage was also recovered from 200cm in BH17. Vertebrate remains retrieved from 170cm in BH6 included 11 broken pharyngeal teeth of rudd (*Scardinius erythrophthalmus*), 6 unidentified cyprinid pharyngeal teeth and an indeterminate Mammalian tooth chip.

Discussion and Conclusions

The lacustrine deposits at School Field, Tednambury form an important stratigraphical marker since they rest directly on unweathered Lowestoft Formation till of Anglian age. Due to the presence of *Hippophaë* pollen at the base of the sequence, taken as a biostratigraphic marker (Gibbard 1977), and the lack of unconformity between the till and interglacial deposits, it is tentatively argued that these lacustrine sediments are most probably of Hoxnian (MIS 11) age. However, Thomas (2001) observes that abundant *Hippophaë* is only useful as a late Anglian/early Hoxnian marker if it can be explicitly shown not to occur in other stages.

The sediments appear to have accumulated as the infilling of a kettle-hole lake basin that formed at the very end of the Anglian Stage glaciation (MIS 12). The pool was created through the melting of dead ice, at a time when the surrounding catchment was dominated by grassland and birch scrub, with smaller areas of sea buckthorn (*Hippophaë*). In addition, willow and sedges probably grew in damper hollows and along the lake margins. This zone (Ted6-1a) is correlated with the late Anglian. With the start of the ensuing interglacial stage, the remaining areas of shade-intolerant sea buckthorn scrub were replaced by birch woodland as the canopy became more closed. Pine was the only other important component of the woodland during this pre-temperate stage of the interglacial (Turner and West, 1968). This zone (Ted6-1b) is correlated with zone Ho I at Hoxne, Suffolk (West, 1956), Marks Tey, Essex (Turner, 1970) and more locally Quendon, Essex (Baker, 1977) and Tye Green, Essex (Boreham *et al.*, 1999). As climatic conditions continued to improve, the birch-pine woodland was replaced by a mixed-oak forest (Ted 6-2a) correlated with Ho IIa. Later, this mixed-oak forest contained increased amounts of hazel, with alder becoming dominant in wetter areas. This zone (Ted6-2b) is correlated with Ho IIb. The presence of hornbeam (*Carpinus*) at the top of the sequence

(Ted 6-2c) invites correlation with Ho IIc. However, the high non-arboreal event characteristic of Ho IIc (Coxon 1993, Thomas 2001) was not detected from this sequence, making the association problematic.

A phase of increased in-wash and reworking of sediment, suggested by the lithology and molluscan remains, occurred throughout the early-temperate stage. There is some lithological evidence that the lake level was higher at this time, perhaps as a result of increased precipitation (Gibbard and Aalto 1977). Subsequently, the basin seems to have become in-filled so that late-temperate and post-temperate sediments were not deposited at the site. This is the case at some other Hertfordshire sites such as Hatfield (Sparks *et al.*, 1969) and Hitchin (Boreham and Gibbard 1995). The mollusc taxa present, the vertebrate remains and the plant macro-fossils all suggest deposition in a pool or pond, probably during the early part of the Hoxnian interglacial.

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Mr. P. D. Hughes for inestimable support and advice. Thanks also to Dr. R. C. Preece for confirming identification of the molluscs and vertebrate remains.

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RADIOCARBON DATING IN BRITAIN: THE ROLE OF THE NATURAL ENVIRONMENT RESEARCH COUNCIL RADIOCARBON STEERING COMMITTEES – ADDITIONAL GUIDANCE FOR APPLICANTS

Chris Caseldine, Alan Saville, Lin Kay and Chris Millward

Introduction

The purpose of this paper is to update information concerning the nature of radiocarbon provision in the UK, to provide an update on recent developments in the NERC-funded radiocarbon dating service, and to offer guidance to those who might be interested in applying to NERC or AHRB for radiocarbon dating support. This is of particular interest to the Quaternary and archaeological communities, but also of value to those considering the use of radiocarbon in modern process studies, especially against growing concern to quantify and understand carbon cycling in ecosystems. In particular, our aim is to explain to scientists and archaeologists how the Radiocarbon Steering Committees operate, and the ways in which applications should be constructed in order to meet the standards required by the Committees in the peer- review process.

NERC funded Radiocarbon Dating in Britain

The Natural Environment Research Council (NERC) offers radiocarbon dating support to environmental and archaeological science through two laboratories: the NERC Radiocarbon Laboratory (RCL) at East Kilbride, which provides radiometric and Accelerator Mass Spectrometry (AMS) dating for environmental samples, and the Oxford University Radiocarbon Accelerator Unit (ORAU) which provides AMS dates for the archaeological community. Following the installation of the new Scottish Universities Environmental Research Centre (SUERC) AMS facility at East Kilbride, all AMS determinations are now done in house. Applications for dating support are peer-reviewed by one of the two Steering Committees: the parent body, the NERC Radiocarbon Laboratory Steering Committee (RCLSC) which is currently chaired by Professor Chris Caseldine (University of Exeter), evaluates applications for dating of Quaternary environmental/earth science materials, while the Oxford Radiocarbon Accelerator Dating Service (ORADS) Steering Committee, under the chairmanship of Mr Alan Saville (National Museums of Scotland), deals with samples of an archaeological or archaeologically-related nature. Following agreement between NERC and the AHRB (Arts and Humanities Research Board - soon to become AHRC, Arts and Humanities Research Council), ORADSSC will also be responsible for assessing applications and providing analyses for material falling within the wider archaeological remit of AHRB, projects that do not come within the NERC Science-Based Archaeology remit.

The NERC-related provision is the responsibility of the Scientific Services and Facilities Management Team (S&FMT), with management responsibilities in the East Kilbride Radiocarbon Laboratory (RCL) being undertaken by SUERC. The RCL, in tandem with four other NERC facilities including the new Cosmogenic Isotope Analysis Facility (CIAF) and the Argon Isotope Facility, is now under the overall direction of Professor Tony Fallick. ORADS operates via a NERC contract with the Oxford University Accelerator Unit under the direction of Dr Chris Ramsey. The RCL and ORADS are two of 25 Scientific Services and Facilities run or overseen by NERC and compete for resources against these facilities. The quality of the provision in both institutions is under regular review by NERC as part of their review of services, with RCL having been last reviewed in 2002 and ORADS in 2003. The next review of both facilities will take place in 2007.

From 2004 the East Kilbride AMS facility will also be carrying out cosmogenic dating, initially, ^{10}Be , ^{26}Al , and ^{36}Cl , and applications will be handled by an augmented RCL Steering Committee within the radiocarbon application process. Thus applications may be made for dating support to the same meetings requiring the same information in the application as for radiocarbon, and will then be peer-reviewed and assessed in the same way. To provide additional expertise a new committee member has been appointed, and outside advice taken where necessary.

To cover the expanded archaeological remit of ORADSSC and to ensure close links with AHRB an academic representative has been nominated by AHRB to sit on the committee, currently Professor Graeme Barker, to be accompanied by a member of the AHRB executive.

Applications for dating support

Applications for radiocarbon and other cosmogenic isotope analytical support should be made on the appropriate form, copies of which, along with other essential details and submission dates, can be obtained from the respective Websites (also the AHRB Website) or from the Secretaries of the two Committees. Eligibility for dating support is restricted to those eligible to hold NERC or AHRB grants: members of staff in higher education institutions, or in government-funded institutes (for example, NERC Centres and Services, the British Geological Survey and national museums). The position of the staff member should be clearly stated on the form (Lecturer, Reader, Curator etc). Research students may apply for dating support, but these applications must be headed by their supervisors. Archaeological applications must identify whether they fall within the NERC or AHRB remits. An explanation of the remits of the two bodies can be obtained from the AHRB's subject coverage document (www.ahrb.ac.uk).

There are two deadlines each year and applicants should ensure that completed

forms are in the hands of the Secretaries by the closing dates that are outlined on the Websites. Late applications will not normally be considered by the Committees that meet approximately four weeks after the closing dates. Where support is required for a research student, this should be clearly indicated on the form.

The lead-time for dating will vary, but applicants should anticipate that at least six months (but usually less) may elapse between submission of samples and reporting of dates. Hence, research students and supervisors should plan well ahead when results are going to be required for the writing up of (normally) a doctoral thesis. In this respect, the Steering Committees welcome 'in principle' applications which outline a research project and give an indication of the number of dates that are likely to be required. These are essentially 'statements of intent' which will be followed at a later date by a more detailed submission. The 'in principle' application not only gives the laboratories notice of the numbers likely to be involved in future dating requests, but it also enables the Committees to provide feed-back which may strengthen (and therefore increase the chances of success of the subsequent application). The Committees also welcome applications at an early stage for either 'rangefinder' dates, enabling concentration on parts of cores or samples relevant to the question being tackled, or as a pilot study, prior to a full application once more detailed analyses have been undertaken. Such an approach can be especially helpful to postgraduates. All potential applicants are encouraged to contact the relevant laboratories at the stage of project conception and the Committees would urge all applicants to contact the respective Secretaries if they have doubts about any aspects of the application process. The preferred mode of operation is via collaborative research with facility staff, including all stages from application to interpretation and publication of results. One of NERC's criteria for renewal of service funding is evidence of scientific contribution to approved projects.

The East Kilbride and Oxford Radiocarbon Committees have some common membership. The facilities and Committees work together where appropriate - transferring proposals, projects and samples between them, seeking advice, and encouraging collaboration. Where there is strong common ground, then ^{14}C applications can be received by either Committee. Environmental archaeologists can, and do, submit to East Kilbride, especially for off-site work (e.g. pollen, molluscs, soils and tephra), while research involving a combination of on- and off-site work can be dealt with at either East Kilbride or Oxford. Samples which are environmental, but in which Oxford has a particular expertise (e.g. bone), can be dealt with through ORADS, even if the submitter is a non-archaeological Quaternary scientist.

A good application should be clear, concise and individual analyses requested must be fully justified. It should set out the background to and context of the project, explain in detail why the specific number of analyses requested are needed, and should show how the results will move the science forward. There

is a 2000-word limit for the main body of the application and, in addition, appropriate maps, diagrams, plans and section drawings are usually essential. Of particular value is a table listing the individual samples to be submitted with regard to location, type of material, sample size etc., clearly cross-referenced to any figures such as profiles, maps or stratigraphic logs. Details of the applicant's recent publications should be included. It is especially important to explain how the samples were taken and what (if any) problems might be anticipated in terms of natural contamination, as a result of sample storage etc.

Where peats and limnic sediments have been investigated, applicants should note that samples from these contexts must have been taken using a corer (such as a Russian or a Livingstone) which not only maintains sample integrity but minimises the likelihood of contamination. Unless there are exceptional mitigating circumstances, the Committee will not accept samples for radiocarbon dating that have been taken with a Hiller-type corer. It is the normal expectation of the Committees that each dated horizon should be justified. Exceptions would be, *inter alia*, where rangefinder dates are requested to establish the general age of a sequence, or where it is necessary to establish sedimentation rates, and therefore a series of dates more or less equally spaced down a profile would be required.

Archaeological samples will normally be of single entity character and obtained from documented contexts, though in certain cases (e.g. museum specimens) contextual information may be limited. Applicants are expected to furnish detailed identifications of each of the samples proposed for dating (e.g. *Equus cab. Calcaneum*). However, there is no rigid barrier to archaeologists or environmental scientists requesting multiple entity dates (e.g. on bones) from otherwise mixed or confused contexts if the project demands such an approach to the separation of materials and is shown to be important. Likewise, the dating of different organic fractions of sedimentary material (e.g. humic, humin and fulvic components) may be warranted. All such cases, however, require full and convincing justification.

In formulating a strategy it is important that applicants show understanding of what radiocarbon determinations represent in terms of their use to derive age estimates and in particular to produce age-depth curves. These issues have recently been discussed by Telford *et al.* (2004a and b), as has the application of Bayesian statistics to series of radiocarbon dates (Bronk Ramsey, 1999, 2000, 2001; Blockley *et al.*, 2004). Whilst archaeologically-related applications may not involve age-depth curves they should pay particular attention to how the requested dates provide a meaningful dating strategy within which the problem to be addressed can be progressed. The Committees would expect most applications to recognise that the development of a sound dating strategy is integral to a successful project. It is not just a case of 'needing a few dates to see when things happened....'

It should be noted that applications for up to 100 analyses can be awarded via the RCL Steering Committee, but if analyses requested are likely to exceed this, then analytical support should be sought elsewhere, e.g. via NERC or AHRB grant funding, to avoid distortion of the block-funded facility resources being allocated to one particular project.

Two other points should also be noted. First, there seems to be a general impression that applications for relatively few dates stand the greater chance of success. This is not the case. While the Committees will regard with scepticism applications for large numbers of dates where these are poorly justified, it must be stressed that it is the quality of the research rather than the number of dates requested that determines whether or not an application is successful. It is not unusual for the Committees to allocate more than 50 dates to a project that has been given a high grade in the peer-review process. Moreover, there have been numerous instances during the course of recent meetings where the Committees have awarded more dates than were initially requested because it was felt that the quality of research, as reflected in the applications, required them. It is important, therefore, that applicants are not deterred from applying for relatively large numbers of dates providing that these are fully justified by the context of the research project within which they are sought.

Second, there is a view that requests for radiometric dates are more likely to be granted than for AMS dates. While this may have been the case several years ago, it is no longer so. Indeed, the RCLSC now provides mostly AMS dates. Although radiometric dating will remain appropriate for many research projects, for example where sample homogeneity may be an issue for sub-sampling small aliquots, for others, where the quantity of sample material is limited, AMS is necessary and this is reflected in the levels of dating support provided. However, the greater expense of AMS analyses requires that requests for AMS rather than radiometric analyses are justified. Any applicant who is successful in the peer-review process will receive dates free of charge, irrespective of whether these are radiometric or AMS age measurements and the full cost of the dates can be counted as NERC or AHRB research income for the applicant.

It should be noted that some samples cannot be handled by the RCL. These include samples that contain hazardous chemicals and toxins (e.g. mercuric chloride (HgCl_2), arsenic), samples containing or likely to contain certain pathogens (e.g. Anthrax, TB) and samples imported from non-EU countries without an appropriate Department of Environment Food and Rural Affairs (DEFRA) licence. For ORADS there are similar concerns, especially regarding bone material, and applicants are advised to discuss potential problems of this nature with the laboratory. It is recommended that applicants seek advice from Committee Secretaries regarding the suitability of the proposed sample material before sample collection takes place.

Finally, we would encourage all those seeking dating support to contact the Committee Secretaries if they have a query regarding any aspect of the applications procedure. The Committees are anxious to stress that, while their primary role is to ensure that the highest research standards are maintained, both they and the Laboratories exist to provide a service to the environmental and archaeological user- communities. Interaction between these communities and the Laboratory personnel is regarded as an integral component of both the application and the dating process (see below).

Peer review

As noted above, each application is primarily evaluated on the basis of research quality. The composition of both the RCLSC and the ORADS panels is designed to reflect as broad a spectrum as possible of environmental/Earth science and archaeological research. Occasionally an application is received that falls beyond the expertise of individual panel members, and in these cases advice is sought from experts outside the respective committees. After review, applications are graded using a system based upon the conventional alpha-numeric one utilised by the NERC: $\alpha 5$ - international level science/research; $\alpha 4$ national/international science/research; $\alpha 3$ - nationally important science/research; $\alpha 2$ - science/research of regional/national significance; $\alpha 1$ - science/research of local/regional interest; β science/research of adequate quality; R - reject. Current funding levels allow projects graded at $\alpha 4$ and above to qualify for dating support, except in the case of postgraduates where applications graded at $\alpha 3$ are provided with dates. NERC, AHRB and the Committees are committed to assisting postgraduates and will often offer additional advice to applications requesting analytical support for PhD studentships. Furthermore it is strongly recommended that postgraduates (PhD students) visit the laboratories to assist with the determinations as part of their training. Those applications graded $\alpha 3$, 2 and 1, or β , may be supported but only if applicants provide funds to cover the full costs. R-graded applications will not be funded, nor will a resubmission be considered. Where the Committees are of the opinion that not all of the analyses requested have been justified, a reduced allocation may be given. Conversely, as noted above, the Committees may award additional dating support where it is deemed to be appropriate.

It is not uncommon for the Committees to grade an application R* (invited resubmission). An R* grading means that, while the Committees are not rejecting the application completely, their view is that it is deficient and cannot be supported as it stands. Deficiencies may take a number of forms: the application may lack context or focus, the sampling strategy may not have been explained, the justification for the number of dates might be inadequate, or the wider significance of the dates may not appear to have been appreciated. In the case of an R*, the application is referred back to the submitter with a full

explanation of the deficiencies, and a resubmission invited. In certain instances, for example where a student is involved and a thesis deadline is imminent, the resubmitted application may be dealt with urgently by the Committee Chairman, whose decision and grading will be reported to the next Committee meeting for ratification. As was emphasised above, both Committees encourage interaction between themselves and the user community, and applicants are invited to contact not only the Committee Secretaries but also the Committee Chairmen, particularly if they have queries related to resubmitted applications.

Dating support

Once dating support has been approved by the Committees, successful applicants will be notified (normally within two weeks), and they will be invited to submit their samples to the respective laboratories as soon as possible. Samples should be accompanied by the completed sample submission forms and a signed Data Protocol form that will be sent out with the letters of acceptance (for RCL electronic submission of sample submission forms is preferred, using the form available on the website). Turn-around times will vary depending, for instance, on the nature of the sample materials, on the size of the samples submitted, on the type of pre-treatment that will be required, on sample ages, and on whether radiometric or AMS analyses are required. Every effort is made by the Laboratories to meet any deadlines indicated on the application forms where these might relate, for example, to the writing up of a higher degree thesis or to the submission of a research report. Again the Committees are anxious to encourage contact between submitters and staff in the Laboratories who will be responsible for the processing of their samples, and who will be able to give an indication of the lead-time for the results and to keep submitters informed on progress.

Notification of results will be made to the Principal Investigator listed on the original application form, and it is assumed that s/he will communicate this information to any collaborators. The notification letter will be accompanied by a full description of the analytical results, and a form on which comment is invited on the outcome of the dating exercise. It is important that applicants respond by adding observations where appropriate before returning the forms to the respective Committee Secretaries. Ownership of the dates remains with the submitter and NERC for two years after the age determinations are issued. Dates will not be published within two years by NERC (or through the Archaeometry date lists for the Oxford dates) without the approval and co-operation of the submitters; this allows maximum exploitation of dates for publication by researchers. After this time, however, NERC may exercise its joint ownership of the results e.g. by publication in an appropriate date-list. The support of the NERC RCL, AHRB, Oxford Radiocarbon Dating Service, and the CIAF must be acknowledged in any publication in which the dates are used. Copies

of these publications, or references to the publications, should be sent to the relevant laboratory. Publications are an essential measure of the performance of the facilities and Principal Investigators are sent periodic reminders for up-to-date lists of RCL-, ORADS- and CIAF-supported publications that are included in the annual report from each facility.

Finally, although customer satisfaction questionnaires are sent periodically to applicants, both the Radiocarbon Laboratories and Committee Chairmen welcome constructive comments on possible improvements to the dating service from users and potential users alike.

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CAMBER RELATED STRUCTURES IN THE WHITE LIMESTONE FORMATION (GREAT OOLITE GROUP), CIRENCESTER BYPASS, GLOUCESTERSHIRE

Peter Worsley

Introduction

Since the seminal work in the Northamptonshire ironstone fields (Hollingworth, Taylor and Kellaway, 1944), camber, valley bulge and related structures have been shown to be widespread throughout the erosional landscapes of the central and southern England Jurassic outcrop. This apparent association with the Jurassic as such is, of course, coincidental because the primary reason for the development of these structures is the occurrence of a sedimentary sequence within which occur units of contrasting rock strength, with weak rocks underlying more competent strata. There have been a number of reports of these enigmatic structures both within and beyond the Jurassic outcrop in the literature (see listing in Ballantyne and Harris, 1994) usually arising from temporary exposures during construction projects, and particularly the excavation of dam foundations. It is not unusual for natural exposures of undercut river banks to reveal complex bedding relationships indicative of valley bulges but permanent exposures of their counterparts – cambers – are not common, simply because run-off processes on the upper parts of hill slopes are erosionally non-intensive. An exception to this generalisation is recorded in the Horsham memoir (Plate 11) where Lower Cretaceous Ardingly Sandstone displays dip fault structures (Gallois, 1993).

The purpose of this report is to document the presence of anomalous structures, related to cambering, in the road cuts of a dual carriageway. Alas, in contrast to other countries, U.K. road engineers appear not to favour maintaining sections of geological interest and instead prefer graded slopes in cuttings on the grounds of safety considerations. However, because of the rock strength, two road cuts through the White Limestone Formation along the new course of the A419 around Cirencester, have been allowed to remain as permanent exposures. Spectacular examples of large scale cross-bedding (sets 3 m thick) are exposed and the writer admits that it was these sedimentary structures which first attracted his attention. It was only after several journeys along the road that the Pleistocene-related structures became apparent!

As the Cirencester bypass swings in an arc north-westward some 3 km north of the town it has to cross the valley of the River Churn (Figure 1) a major left bank tributary of the River Thames. The Churn originates close to the crest of the main Oolite escarpment south of Cheltenham and flows down the gently

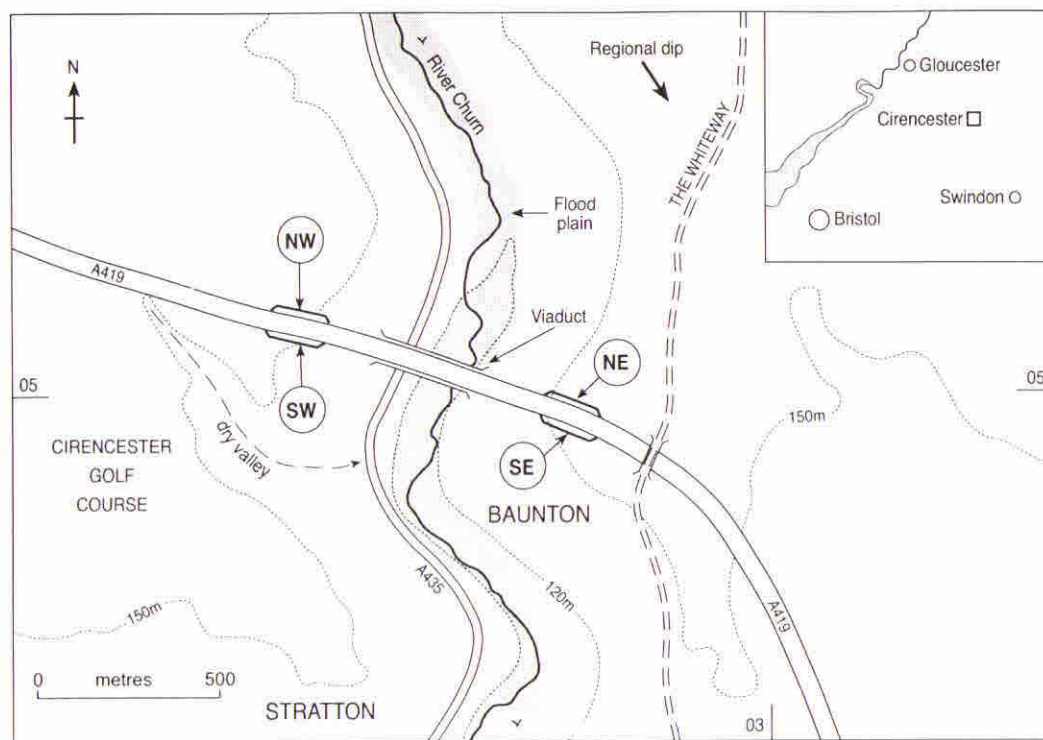


Figure 1. Map showing the location of the exposures. Apart from the Churn valley *per se*, the area is almost totally underlain by the White Limestone Formation. The Hampen and Taynton Formations crop out at the base of the valley slopes and the floodplain alluvium (horizontal lines) lies above the Lower Fuller's Earth Formation.

inclined plateau-like dip slope in an incised sinuous valley. At the A419 road crossing, the flanking valley sides typically have slopes of 10°, there being a height difference of some 40 m to the west and 35 m to the east between the Churn alluvium and the plateau surface. To accommodate this relief contrast, the road design featured deepening cuttings on the valley approaches before opening out on to a viaduct which towers almost 20 m above the valley floor. Two sets of anomalous structures crop out where roadway enters the cuttings on both upper valley flanks. These four sections will be designated NE, SE, SW and NW respectively. The mid points between each pair i.e. the median of the dual carriageway lies at NGR SP 0245 0490 and SP 0170 0520. Fortunately, these sections are almost normal to the valley side slopes so the exposed bedding plane dips are reasonably close to true ones.

Geological succession

The most recent published geological mapping of the area was undertaken by Albert Horton (in 1985) whilst contributing to the revision of the Cirencester British Geological Survey 1: 50,000 scale sheet 235 (published 1998). The relevant 1:10,000 sheets are numbered SP 00 NW and SP 00 SW. The critical road cuttings lie across the boundary between these two sheets and since the road construction post dates the maps the new road is not shown.

The local bedrock succession underlying the Churn valley is entirely in the Great Oolite Group of the Bathonian Stage and consists of the following formations (with average thickness in brackets):-

Forest Marble Formation – interbedded mudstone and limestone (20 m)

White Limestone Formation – limestone and thin clays (25 m)

Hampen Marly Formation – limestone, marl and mudstone (5 m)

Taynton Limestone Formation – limestone (7 m)

Lower Fuller's Earth – mudstone with thin limestones (22 m)

Below the Great Oolite Group is the Inferior Oolite but normally this is too deep to be exposed (but see later).

On either side of the Churn viaduct, the uppermost cutting walls are graded slopes typically 3 m high. Below lies the White Limestone Formation, consisting of mainly oolitic shell-detrital, spar-cemented grainstones, with magnificently developed cross sets on a variety of scales indicating a dominant palaeoflow to the south west. This facies probably represents a high energy marine depositional environment of tidally influenced shoals. The regional dip is very low averaging 1 – 2° SE. Within the limestone, well developed joints have two prominent trends - 335°N and 65°N and these, in conjunction with the near-horizontal bedding planes, create a stepped cubic structure with face edges of around 1 m in length.

In the locality, readily identifiable Quaternary deposits *per se* are limited, being restricted to the Holocene alluvium of the Churn, a terrace and a head consisting of pebbly loam at the bottom of a dry valley coming in from the west, south of the A419. The terrace is present below the viaduct on the east side of the Churn some 10 m above the river but dies out to the north within 400 m. There is no corresponding terrace on the opposite side of the valley. On the west facing flank of the Churn valley, 3 km to the north, an area of landslip has been identified. Of particular significance is that on his map, Albert Horton records the possibility that Inferior Oolite might be present in a valley bulge structure beneath the Churn alluvium, just over 1 km north of the viaduct.

Access

Most traffic through the cuttings is travelling at high speed but as the A419 is designated as a 'clearway' no stopping is permitted in any case. However, all the sections both east and west of the Churn can be viewed from the top of the cuttings. A bridge over the eastern cutting (SP 027 048), where a minor road called 'The Whiteway' crosses it on a bridge, gives good overview of the main White Limestone exposure. With care, it is possible to walk west close to the southern lip of the cut to a point directly across the roadway from the NE section. This is best undertaken after the vegetation has died back. Its counterpart the SE section, can be viewed from the field by the cutting boundary. Across the Churn, a private concreted track leads from the A435 to the north side of a golf course and an overlook of section NW. On the opposite side of the A419, another concreted track, a public right of way leads to an overlook of section SW.

The sections with anomalous dips and faults

The regional dip is prominently displayed by flat bedding planes within the White Limestone Formation and to the unaided eye it appears horizontal. It can be readily traced as a consistent feature throughout the cuttings, save for where the valley side slopes of the Churn are approached. All four sections under discussion are characterised by bedding plane dips which are greater than the regional one. To the east of the Churn these dips are contra to the regional dip whereas those to the west are conformable to the regional dip but generally have significantly greater values. The limits of each section away from the Churn are exposed and are placed where the first anomalous dips can be detected. In the descriptions of the sections which follow, each works from this limit towards the valley axis until slope grading obscures the exposures.

NE. This section (Figure 2) extends for some 55 m and can be divided into 4 blocks, each separated by fault zones. Starting in the east, there is initially a fracture extending through the entire *in situ* limestone and then commences a block extending for 5 m before a semi-vegetated zone of relatively fine-grained

talus arising from extensive rock disintegration possibly associated with multiple fractures. Next is a major block some 10 m wide with clear westwards dips of between 15 - 18°. The limestone of this block is heavily fractured with open voids between the constituent joint blocks and these extend down well below the level of the road in the adjacent drainage ditch. In contrast, the next block, some 13 m wide, has only a slight westward dip and apart from one fracture appears largely to retain its original integrity. A zone 2 m wide follows with a prominent blocky structure which passes into a block 25 m wide with a westward dip of 10 - 12°. Six bedding units are clearly present in this block, with the joints being defined by open cavities. A graded slope ends the section.

Just beyond the end of the section at a lower level is a road runoff drainage sump excavated into the 10° slope of the valley side. The walls of this excavation show abundant evidence of open fractures and an element of the runoff into the sump becomes subterranean because of these.

SE. Some 55 m beyond the section's east limit, within the *in situ* limestone of the cutting, is a gull trending 235° N and after a further 61 m there is a second one with a similar trend. The gulls are on average 0.6 m wide and infilled with angular limestone clasts in a red/brown silty matrix. These gulls are present in the cutting walls on the opposite side of the roadway.

The disturbed strata extend for some 70 m and start with an abrupt increase in dip angle beyond which there is a complex zone 12 m wide of anomalous dips and a stack of near horizontal limestone joint blocks each around 1 m high. This is followed by a block 27 m wide with a westerly dip of 15° and this in turn is bounded by a fault beyond which there is a block of limestone with a very low dip to the west until the limit of the exposure. Projection westwards of a marker bed in the *in situ* limestone across the 70 m wide disturbed section suggests a total lowering of about 4 m at the far limit of the exposure.

SW. This section is just over 90 m in length. After a rather obscure normal fault zone, the first block is a coherent mass nearly 45 m wide with a 10° dip to the east. A further fault zone separates it from a more or less horizontal block 25 m wide. This is terminated by simple normal fault which defines the start of a 16 m wide block with an average dip of 6° east. Finally, there is a block dipping east at 25°. Only a minimum width of 5.5 m can be given since its eastward extension is obscured by a graded slope.

NW. This section displays the most extensive exposure of cambered strata and extends for almost 140 m. The first block, possessing an 8° east dip, is some 18 m wide. It is uniquely defined by infilled gulls at the western and eastern limits. There then follows a series of 6 blocks between 5 and 36 m wide, with varying dips up to a maximum of 10°. Each is separated by extensional faults. The last block is only exposed for 4 m before being obscured by vegetation. However, with a dip of 33°, it has the highest dip value of all the sections.



Figure 2. Photograph of section NE taken from section SE showing how fault fractures within the White Limestone Formation have produced dip and fault blocks with varying dips, all contra to the regional dip. The latter is at a very low angle from left to right.

Note that its counterpart on the opposite side of the carriageway displays the second highest dip of those recorded.

Discussion

In all four exposures there is a strong similarity in the style of extensional failure. The White Limestone Formation has fractured to form a number of discrete blocks and these have moved independently of each other, with some still maintaining an attitude similar to the *in situ* material further away from the valley wall but, of course, not their original altitude. The overall dip pattern clearly suggests that there has been movement towards the valley axis. Unfortunately, lack of exposure gives uncertainty as to the cause of this style of response. Previous work, e.g. Horswill and Horton (1976), has described 'dip and fault' structures exposed at the Empingham Reservoir dam site in Rutland, where a multi-fractured competent bed had been carried towards the valley axis, due to extensive creep in the underlying incompetent material (Lias clay), the latter culminating in a valley bulge structure beneath the valley floor. Cambering and valley bulges associated with the Lias have been reported from the Cotswolds by a number of workers including Ackerman and Cave (1967), Chandler *et al.* (1976) and Hutchinson and Coope (2002). At the Churn Viaduct, the valley floor is underlain by Lower Fuller's Earth Formation mudstones which geotechnically are likely to behave in a similar way to those of the Lias clay. However, the local succession is more complicated since intervening between the White Limestone and the Lower Fuller's Earth formations are the Hampton Marly and Taynton Limestone formations. Clearly, at least in theory, an element of creep might have been accommodated within the marls and mudstones of the Hampton Marly Formation. Yet the restricted thickness of these weak strata suggests that they are likely to be of limited significance when the *circa* 22 m thick, mudstone dominated Lower Fuller's Earth Formation is considered. Regionally, the Fuller's Earth Formation outcrop is associated with both active and degraded landslips leaving little doubt that this formation is the one within which the creep failure was the most extensive. The suggestion by Horton, that a valley bulge structure might be present beneath the Churn alluvium a short distance to the north of the viaduct site, is consistent with this view.

Although where it forms the plateau surface the White Limestone Formation outcrop is regarded as being *in situ* and essentially undeformed, as noted above, it does contain several gull structures. Apart from the obvious gulls, many of the joint networks in the limestone are open and the walls are covered in thin sheets of speleothem. This makes it unlikely that the observed joint widening is an artefact of excavation, rather they are a response to stress release as the cambers developed.

Hitherto, palaeoclimate as a factor in the genesis of the structures has not been mentioned in this discussion for one very good reason. No evidence from the

site *per se* can be unambiguously interpreted as an indicator of former climatic conditions except to the extent that the structures are apparently not active at the present day. The Upper Thames basin is relatively rich in evidence of former permafrost within the fluvial succession (Worsley 1999). Viewed in the context of similar features elsewhere and the speculations regarding their development, it may be tentatively suggested that creep associated with former ice-rich permafrost within the fine grained sediments is likely to be implicated in their formation. Although this is the preferred interpretation it cannot be ruled out that simple erosion of the valley floor by the River Churn has induced valley bulge formation in unconfined Fuller's Earth and in turn has been the principle cause of the cambering.

Conclusion

The camber related 'dip fault structures' exposed in the road cuts of the Cirencester by-pass are expected to be exposed for many years to come. They demonstrate the kind of failure which occurs when a competent bed, in this case the White Limestone Formation, has been deeply incised by a river system down into an incompetent bed. The key to the style of failure is the occurrence of the Lower Fuller's Earth Formation towards the base of the slope and beneath the alluvium. During those parts of middle and late Pleistocene cold stages when permafrost was widespread, the fine grain size characteristics of Fuller's Earth may well have encouraged the development of excess ground ice. This would have been subject to permafrost creep and induced gull formation. Upon permafrost decay, thaw consolidation processes associated with this ground ice would have produced a low strength material amenable to viscous flow failure and this in turn would have caused the overlying limestone to fracture, rotate and be rafted down the upper valley slopes.

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SELECTED CASE STUDIES OF COLD-BASED GLACIERS, SOUTH VICTORIA LAND, ANTARCTICA

Mark Lloyd Davies and Sean Fitzsimons

Introduction

Conventional thinking among glaciologists and geomorphologists is that cold-based glaciers are basally inactive because basal sliding does not occur (Boulton, 1972; Paterson, 1994; Drewry, 1986). However, as research into modern cold-based glaciers gathers momentum, there is a developing tension between glaciologists, modellers and geomorphologists. On the one hand glaciologists and modellers maintain that cold-based glaciers are incapable of basal activity and preserve the landscape (Paterson, 1994; Dowdeswell and Siegert, 1999; Näslund *et al.*, 2003) whereas a recent number of geologists and geomorphologists have begun to report cases of cold-based glacial erosion, deposition and tectonism (Atkins *et al.*, 2002; Bennett *et al.*, 2003; Waller, 2003). We define a cold-based glacier, as a glacier in which basal temperatures are permanently below the pressure melting point (Paterson, 1994; van der Veen, 1999). The lack of net basal melting justifies the assumption that no basal sliding, erosion, bed deformation and debris entrainment takes place. Instead the glacier is frozen to its substrate (Boulton, 1972) and moves only by slow internal deformation (Paterson, 1994), having minimal or no influence on the landscape.

However, speculation as to whether rock fragments or sediment could be entrained into cold glacial ice began in the 1970s. Mercer (1971) reported that the cold-based McCarthy Glacier in the central Transantarctic Mountains (TAMS) contained "granitic fragments from gravel through to boulders 3 m in diameter...(that) must have been quarried beneath the glacier". He also observed striated clasts in ice-cored moraines on the east side of Buckley Island nunatak in upper Beardmore Glacier. Holdsworth's (1974) landmark paper regarding observations in the basal zone of the cold-based (-17°C) Meserve Glacier, Antarctica triggered interest when he described a basal 'pavement' of large boulders cemented together by ice, clay and silt. These field observations were later accompanied by theoretical proposals that liquid water might exist between ice and foreign bodies at sub-freezing temperatures (Gilpin, 1979). Since the mid 1980s research into processes operating within the subglacial and marginal environments of cold-based glaciers has been on the increase. Both Shreve (1984) and Fowler (1986) postulated that basal sliding was theoretically possible at sub-freezing temperatures. This was supported by field observations of basal sliding and subglacial deformation at sub-freezing temperatures in the cold-based Urumqi Glacier No.1 in China (Echelmeyer

and Zhongxiang Wang, 1987); although their measured temperature of $\sim -5^{\circ}\text{C}$ prevents direct comparison with the Meserve Glacier's temperature of -17°C for debris-rich basal ice (Holdsworth, 1974).

Aims and scope of the paper

The premise of landscape preservation by cold-based glaciers has resulted in the concept of 'relict landscapes'. These are landscapes that have been geomorphologically unaffected despite glacial overriding, with examples reported from Scandinavia (Clarhäll and Kleman, 1999; Kleman *et al.*, 1999) and North America (Clarhäll and Jansson 2002). This brought about the term 'palimpsest landforms' (Kleman, 1992; Stea, 1994), which are landforms that are identifiable despite later overprinting by younger glacial landforms. The acceptance of cold-based glacial protection of the landscape has resulted in all glacially modified landscapes being 'automatically' equated to temperate ice. Such an assumption must be challenged if examples are provided for cold-based subglacial activity. The aim of this paper is to harness this challenge, by reviewing three examples of cold-based glacial activity from South Victoria Land, Antarctica (Figure 1). However, we would like to stress that we recognise that many landscapes are also preserved under cold-based glacial ice, and we are not proposing that cold-based glaciers are interacting with their substrate all of the time.

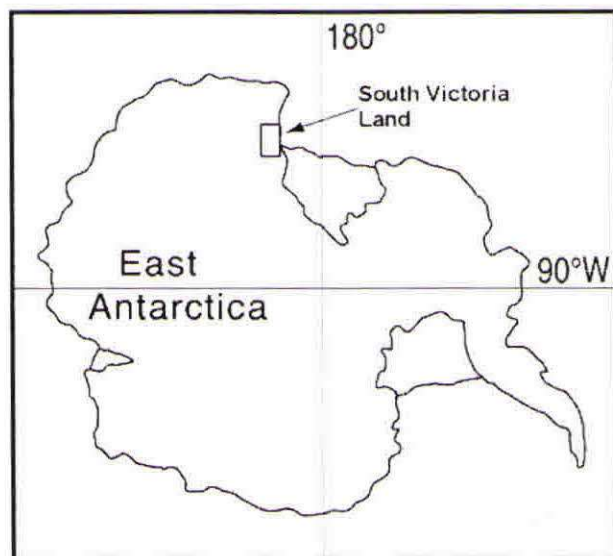


Figure 1. South Victoria Land, Antarctica. All three case studies described in this article feature from this relatively small, but ice free region of Antarctica.

The first case study is the Meserve Glacier, Wright Valley where Cuffey *et al.*, (1999; 2000) published evidence for cold-based glacial sliding and entrainment at the nanometre scale, which is manifested at the metre scale in terms of entrained debris. The second case study is from the Suess Glacier, Taylor Valley, where Fitzsimons (1996) and Fitzsimons *et al.*, (1999; 2001) report subglacial deformation at the cm-scale as well as thrust-block moraines dm long. The third case study (Atkins *et al.*, 2002) documents erosional striae on bedrock and relatively large-scale depositional features ($>10\text{m}^2$) in the forefield of the Manhaul Bay Glacier (informal name), Allan Hills.

The Meserve Glacier, Wright Valley, Antarctica

The Meserve Glacier is an alpine glacier, flowing northward from an elongated cirque in the Asgard range of South Victoria Land. The glacier is about 8 km in length and terminates at an elevation of ~ 400 metres above sea level (masl). Cuffey *et al.*, (1999) built upon the field work and observations of Holdsworth (1974), theoretical work of Shreve (1984) and Fowler (1986), and laboratory work of Dash *et al.*, (1995) by observing glacier sliding and ice segregation beneath Meserve Glacier and attributing this to the role of thin brine films. The brine films are thought to occur at the ice-rock interface, and vary between 20–40 nm in thickness depending on pressure, rock type, surface morphology and ice solute content (Hooker *et al.*, 1999). They argue that these brine films play an important role in ice deformation processes at the base of the Meserve Glacier and facilitate sliding and entrainment of basal fine-grained sediments. Their proposed mechanism is that interfacial films affect the bulk mechanical properties of ice (Cuffey *et al.*, 1999) thereby inducing particle entrainment (Cuffey *et al.*, 2000). This is achieved by supercooled liquid occurring between ice and immersed particles, which is 'allowed' to exist because of the interfacial free energy afforded by separating of the two solid interfaces (Wettlaufer *et al.*, 1996). The supercooled liquid or brine films then permit slip at the ice-rock interface and subsequent entrainment (Cuffey *et al.*, 2000) of silt and sand explaining their occurrence in the basal layers of the Meserve Glacier (Holdsworth, 1974). It is appreciated that this case study is not a perfect analogue for large ice sheets, but it does provide an excellent first hand account of cold-based glacier erosion and particle entrainment, which over the time scale of millennia has the potential to considerably alter the landscape. For example, ice thickness measurements by radar along the middle portion of the Meserve Glacier revealed a U-shaped trough (Cuffey *et al.*, 2000), suggesting significant landscape modification.

Suess Glacier, Taylor Valley, Antarctica

Suess Glacier descends from 1750 m on the Asgard Range, terminating within Taylor Valley, which is part of the McMurdo Dry Valleys, a relatively ice free, polar desert in South Victoria Land (Figure 2a). The climatic conditions of

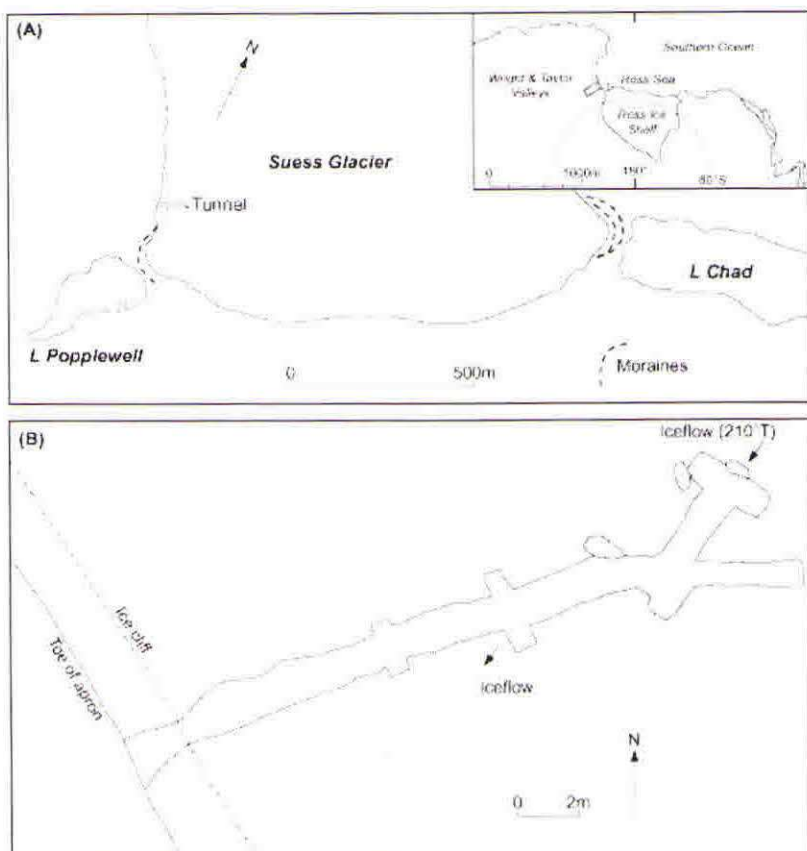


Figure 2(a). Location map of Suess Glacier in Taylor Valley. 'L' as in 'L Chad' stands for lake. **(b).** Position of the subglacial tunnel within Suess Glacier, Taylor Valley.

the Dry Valleys are unique with summer temperatures rarely above 0°C and the mean annual temperature $\sim -17^{\circ}\text{C}$ (Keys, 1980). Snowfall is between $5\text{-}10\text{mm yr}^{-1}$ on the valley floors (Lewis *et al.*, 1998), rainfall unknown and most of the area experiences a moisture deficit (Hooker *et al.*, 1999). Suess Glacier itself is an alpine glacier with a basal temperature of -17°C , well below the pressure melting point, hence its classification as cold-based (Fitzsimons *et al.*, 1999, 2001). During the Antarctic summer season in 1996 a tunnel (2 m x 1.50 m x 25 m)

was excavated through part of the Suess glacier basal zone using chainsaws and a demolition hammer. The tunnel was extended in 1997 and a vertical shaft 4.5 m high was cut at the end of the tunnel to expose the entire debris zone underneath the glacier (Figure 2b). For further information on the methodology see Fitzsimons *et al.* (1999, 2001). Key observations of the basal ice debris zone in the tunnel made by Fitzsimons *et al.* (1999) were that parts of the basal substrate had been entrained into the ice and that in many cases this occurred without disaggregation. This observation supports Cuffey *et al.*'s (2000) concept of cold-based sediment entrainment, but is further elaborated because deformation of the entrained sediment was also noted. Fitzsimons *et al.* (1999) observed two styles: (1) the more common ductile structures associated with basal ice having low debris concentrations, such as folds and boudinage (Figure 3a-b) and (2) brittle deformation within areas of high debris concentration owed to broken blocks of frozen sediment (Figure 3c). Direct shear tests also conducted showed that the substrate had almost double the average peak shear strength (2.53 Mpa) of the basal ice (1.28 Mpa) and glacial ice (1.39 Mpa) samples (Fitzsimons *et al.*, 2001) complicating any clear explanation as to the subglacial process of erosion and entrainment by Suess Glacier. However, spatial and temporal variation in the structural strength of the basal ice and

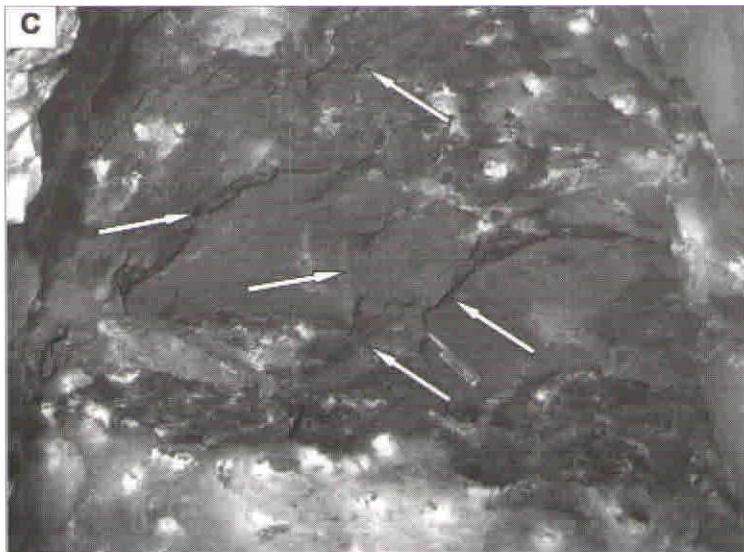


Figure 3. The Suess Glacier tunnel.

a. Ductile deformation: entrained and folded sediment in the debris-rich basal ice layer of the cold-based Suess Glacier.



b. Ductile deformation: Boudinaging of entrained sediment (arrows) in the debris-rich basal ice layer of the cold-based Suess Glacier. The boudinaging points towards extensional deformation.



c. Brittle deformation: Note the tension cracks (arrows) in the debris-rich portions of the basal ice. The knife is ~12.5 cm long.

its substrate cannot be discounted; for at times peak shear strength readings for basal ice and the substrate were closely matched (Fitzsimons *et al.*, 2001). Fitzsimons (1996) also observed well developed (thrust-block) moraines (Figure 4) at the margins of Suess Glacier, which have important implications when considering the ability of cold-based ice in modifying ice-marginal landscapes (Ehlers, 1996). Moreover, the processes responsible for such features should be considered, as conventional explanations such as an elevated pore-water pressure or Weertman's (1961) ice-debris accretion hypothesis require abundant subglacial meltwater. Three proposals made by Fitzsimons (1996) for the formation of these thrust-block moraines are: (1) sediment block entrainment linked to frozen-bed deformation, (2) entrainment by overriding and accretion of debris aprons and marginal ice and, (3) temporary wet-based conditions as Suess Glacier flowed into one of its ice-marginal lakes. Certainly, the two former conclusions are significant when considering the fact that cold-based ice masses may in themselves (without an external input such as water from a lake) entrain, deform and deposit their substrate, which in turn alters their ice-marginal geomorphology.

The Allan Hills, Antarctica

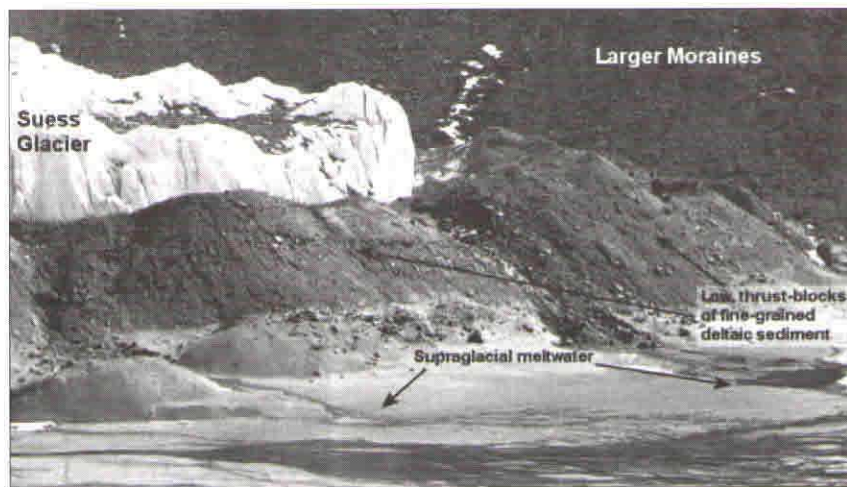


Figure 4. Part of the north-east snout of the cold-based Suess Glacier. The smaller moraines (~4 to 5 m high) in front of far larger ones are low sandy ridges consisting of blocks of planar-bedded sand inferred to be thrust-blocks of fine-grained deltaic sediment (Fitzsimons, 1996).

The Allan Hills are a low lying nunatak located high in the TAMS of South Victoria Land (1600–2100 masl). The centre of the nunatak is occupied by the cold-based Manhaul Bay Glacier (informal name), which is approximately 6 km long and 200 m thick. It flows into the centre of the Allan Hills from the north and exposed areas of its snout are bubble rich and fractured. This points towards former glacial advance by ice block apron overriding (Shaw, 1977); a common observation for other cold-based glaciers in South Victoria Land (Chinn, 1985, 1989, 1991). Atkins *et al.*, (2002) reported four types of erosional and depositional features, which they attributed to an advance of the Manhaul Bay Glacier at the Last Glacial Maximum (LGM). ‘Type I broad scrapes’ occurring on sedimentary bedrock, are up to 500 mm wide, 40 mm deep and 1200 mm long (Figure 5). They are unweathered and consist of many smaller striae cms and mms in width. On several occasions the abrading tool is also observed at the striae terminal wall, and cm-scale levees occur along the sides of the abrasion marks. ‘Type II individual striae and grooves’ are linear, often isolated and typically cms in width and dm long. Some have a ‘nailhead’ morphology or maintain a more tapered form with veneers of crushed sandstone on local bedrock surfaces. ‘Type III are unweathered scrapes’ found on the stoss side of lodged, weathered dolerite boulders within or upon the Sirius Group tillite. The scrapes are thin, but a striking contrast to the ventifacted varnish of the weathered boulder. ‘Type IV ridge and groove lineations’ are fine parallel lineations displaying a sheen similar to slickensides and are found in carbonaceous layers of sedimentary bedrock. Type I and II erosional features are only found close to the snout of the Manhaul Bay Glacier, whereas types III and IV are more widespread throughout the Allan Hills.

The depositional landforms are more varied in form and distribution than the erosional structures. ‘Type I’ are ‘sandstone and siltstone breccia’ that are unlithified, friable deposits <30 cm thick and <3 m across and are recognisably composed of the immediate sedimentary bedrock (sandstone and siltstone). The deposits are usually found on up-glacier escarpments or vertical walls and occasionally have a linear form tapering away from the glacier snout. ‘Type II isolated boulders’ are up to 3 m in diameter and dispersed throughout the Allan Hills, up to >2 km away from the Manhaul Bay Glacier. On the lee side of several promontories the boulders form a train. ‘Type III ice-cored debris cones’ have been observed as far as 1 km inland from the Manhaul Bay Glacier and range in size from 3 m high to 7 m in diameter. In each instance, the ice-cored cone is covered in loose bedrock debris (ranging in size from sand to boulders). The ‘type IV sandstone debris on lee slopes’ (Figure 6) is crushed and toppling bedrock on the lee side of bedrock promontories or northern face of depressions. The scale of the features range from <1 m through to 10 m²+, and are characterised by extensional fractures sub-parallel to the margin of the Manhaul Bay Glacier.

Atkins *et al.*, (2002) followed the principal of Drewry (1986) and inferred

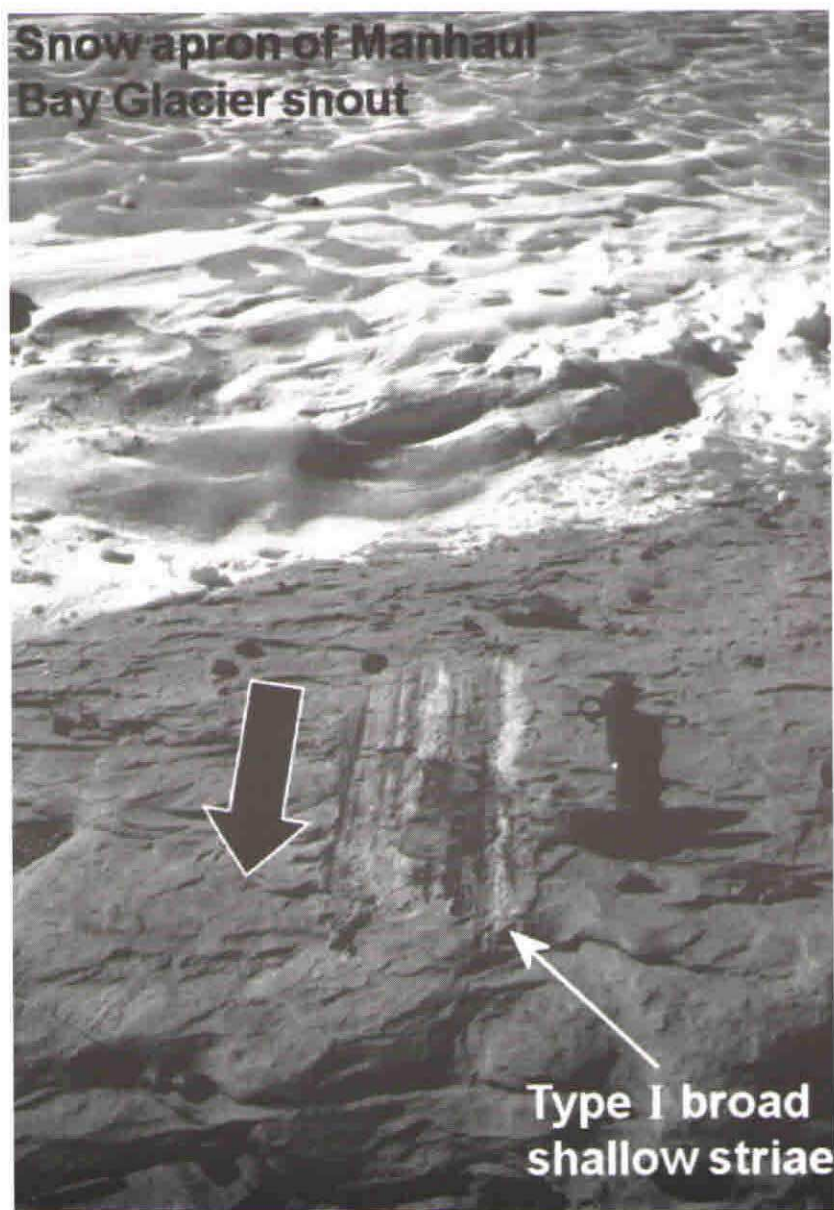


Figure 5. An example of the broad, shallow type I erosional striae reported by Atkins *et al.*, (2002). The thick black arrow indicates inferred LGM ice flow direction. Rock hammer is 33 cm long.

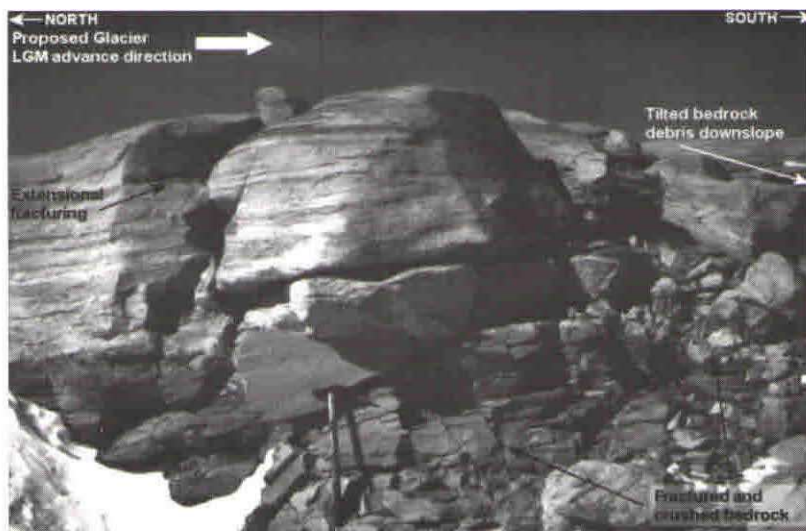


Figure 6. An example of type IV sandstone debris on lee slopes (Atkins *et al.*, 2002). Note the extensional fracturing and fractured, crushed bedrock and in places tilting.

that the type I and II striae are the result of glacial ice dragging debris over or upon the bedrock as a result of basal slip or forward movement. The abrading particles were observed to be the same lithology as the bedrock, with little contrast in hardness explaining the broad shallow form of the striae and presence of broken, crushed fines that are likely to be sheared remnants of the former striating tool. These have survived because no meltwater has washed them away. A similar process was inferred for the type III forms where basal debris came into contact with wind-polished boulders lodged in tillite and projecting upglacier. The fastened status of the boulders meant they were not entrained, but nonetheless abraded and occasionally overturned. Fourthly, the type IV were interpreted by Atkins *et al.*, (2002) to be a glacitectonic structure formed by differential slip on the thin and weaker carbonaceous siltstone layers within the bedrock in response to increased shear stresses on the lee side of bedrock promontories.

The type I depositional debris, is local failure and crushing of up-ice bedrock promontories, which is proposed to constitute a form of glacitectonite (Pedersen, 1988; Benn and Evans, 1998). The type II scattered boulders are the result of glacial plucking and passive englacial transport, because no abrasive marks are associated with the boulders, as might be expected if they were basally transported. The type III ice-cored cones are interpreted to be passive deposition

features formed by retreating glacial ice being covered in loose debris that have subsequently been preserved in the cold and hyper-arid climate in the Allan Hills. The final type IV depositional structure is interpreted to be glacitectonic in origin, where cavities on the lee side of bedrock promontories facilitated tensional fracturing and toppling of bedrock knobs or promontories downslope and down-glacier.

Summary

This paper has reviewed three Antarctic case studies which illustrate cold-based glacial sliding, entrainment, erosion, deformation and deposition at increasing scales of impact. The smallest scale is demonstrated by Cuffey *et al.*'s study (1999, 2000) where brine films 20 and up to 40 nm thick are responsible for particle by particle entrainment of silt and sand fines into basal ice. On a marginally large scale, Fitzsimons *et al.* (1999) provide a first hand account for ductile and brittle deformation of such entrained basal debris, even though the mechanism for this remains elusive, because of the substrate's higher shear strength when compared to basal or clean glacial ice (Fitzsimons *et al.*, 2001). At a larger scale, mechanisms for thrust-block moraine formation by the Suess Glacier were proposed by Fitzsimons (1996) and the geomorphological potential for cold-based glaciers realised. The largest scale, and one that involves lithified bedrock as opposed to soft sediment substrate, is illustrated by Atkins *et al.*, 2002. Here mm and cm scale striae are found in conjunction with depositional landforms $>10\text{m}^2$ in size.

In an oral presentation to the Antarctic Earth Science community, Lloyd Davies *et al.* (2003) stated that the preservation potential of the above cold-based glacial features is very low beyond polar climates, such as Antarctica, because of the rapid weathering in sub-polar and temperate regimes. They argued that this explains the perceived absence of cold-based glacial activity in the Pleistocene record of today's temperate regions which most likely experienced cold-based glaciation during past glacial maxima. Examples include the apparently palimpsest landscapes of Scandinavia and North America. The vast majority of research and theories to date concerning the subglacial environment are derived from observations and measurements made from temperate-based glaciers (Hart and Rose, 2001). However, it is hoped that this paper will prompt other earth scientists to shift attention towards the cold-based subglacial environment, especially as its character appears to differ significantly from temperate-based glaciers.

Conclusion

There is a developing tension between glaciologists, modellers and geomorphologists regarding the ability of cold-based glaciers to interact with their substrate and ice marginal environment, so to result in landscape

modification.

There is a momentum of evidence pointing towards cold-based glacial erosion, entrainment, deformation and deposition on both soft substrate and lithified bedrock. Therefore, any glacial geological record, however inconspicuous, might be attributed to cold-based glacial ice (keeping in mind all other variables such as the sedimentology and environmental context).

We accept that many landscapes may experience significant periods of cold-based coverage with no or minor modification. However, the universal assumption that cold-based glaciers are utterly inert and their landscapes completely unscathed should be abandoned. This, in particular, has implications for modelling ice sheet dynamics (cf Näslund *et al.*, 2000; 2003) or automatically equating glacially modified landscapes to temperate-based glaciers only.

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REPORTS

THE QUATERNARY OF THE CENTRAL GRAMPIAN HIGHLANDS

QRA Short Field Meeting, Newtonmore, 20th - 23rd May 2004

Introduction

I have lost count of the number of times I have driven along the A9 through the Pass of Drumochter, risking the loss of complete concentration on the road while I steal more than passing glances at the spectacular array of glacial landforms and wonder if anyone has "looked at this stuff". I have even brought students here to study "hummocky moraine" and lamented the fact that the most recent work was a map by Brian Sissons, dating from 1974 and covering only part of the pass. I know that many glacial researchers are of the same opinion, but for all of us the frustration is over - the guide edited by **Sven Lukas, Jon Merritt and Wishart Mitchell** addresses the problems of glaciation style and history in the central Grampian Highlands. However, the guide is not without controversy and the short field meeting was billed as a potentially contentious affair as the participants assembled at Craigerne Hotel in Newtonmore.

To put the controversy in context, the central theme of the meeting was the reconstruction of Dimlington and Loch Lomond Stade glacier margins in a complex upland terrain that comprises numerous plateaux and deep mountain passes. Of significance are plateaux to the east (Gaick Plateau) and west of Drumochter Pass, upon which Sissons (1974) proposed that plateau icefields developed during the Loch Lomond Stade which were independent of the easterly flowing margins of the main west highland glacier complex. Recent mapping had highlighted the nature of glacier recession in the area, and we were introduced to this most welcome flurry of research activity throughout three stimulating and enjoyable field days. In the red corner, **Jon Merritt, Wishart Mitchell** and **Sven Lukas** provided their evidence for a westerly recession of the west highland glacier complex and highlighted the lack of chronological control on the glacial geomorphology. In the blue corner, **Doug Benn** and **Colin Ballantyne** outlined the case for plateau icefield glaciation during the Loch Lomond Stade. Our appetites were sharpened by the unusual exchange of views between the two teams provided in print in the field guide.

Day one

The major breach (Gaick Pass) through the Gaick Plateau was the destination for the first day. After finding ourselves in the unusual position of trying to convince **David Jarman** that the slopes of Sgor Dearg had been subject to rock slope failure, we were introduced to the morainic evidence for valley glaciers that had receded southwards and westwards. Although **Jon Merritt** had reconstructed regional southwesterly ice recession based upon this evidence, a critical site appeared to be at the watershed of the Gaick Pass where proximal glacialacustrine deposits had been glactectonized by ice moving from the south and from the north; the corollary was that ice lobes had flowed into the pass and had dammed lake water between their snouts. While most of the party got out the spades and scrapers and assessed folds and faults, a small RSF group were led around the impressive failure features on A'Chaoirnich by **David Jarman** who provided compelling evidence for glacial watershed breaching and plateau dissection aided by rock slope failures. Our conclusion on the style of glaciation was that ice had indeed receded southwards and westwards. But was this the margin of a large icefield located in the west or were we seeing the deposits of piedmont lobes receding onto surrounding plateaux? We agreed that we needed to see the evidence in the Edendon Valley on the following day.

Day two

After a brief overview of the moraines in the Edendon Valley and more discussion on their ice source (i.e. plateau icefield versus regional ice cap), the group were taken to an excellent section through an alluvial fan, presented by **Colin Ballantyne** as an example of delayed paraglacial sediment reworking. The sediment succession is remarkable in that it contains *in situ* peat layers, thereby providing chronological control on fan development over the last 3ka. Discussions on moraine provenance then continued after the group had assembled on top of one of the numerous moraine ridges in the middle part of the valley. From this vantage point it was clear that moraines ascended on to the plateau directly above us to the west. This fuelled the plateau icefield lobby, led enthusiastically by **Doug Benn**, who appealed to modern analogues of plateau icefield glaciation styles to explain the distribution of the Edendon Valley moraines. The afternoon was spent in the Pass of Drumochter, largely on its SW facing slopes and in the valley of Coire Mhic-sith. Here **Sven Lukas** introduced us to his evidence for an ice-dammed lake. Most prominent from our highest vantage point were numerous horizontal trimlines that could be traced around the head of the valley to a series of kame terraces and meltwater channels. Sven explained the landform assemblage as the products of a lake dammed by ice in the Pass of Drumochter, the trimlines being lake shorelines and the kame terraces and meltwater channels recording the drainage of lake water around the glacier margin. Some earnest debates ensued, involving the

alternative interpretations of the trimlines as bedrock structures and the melt channels/kame terraces as slope failures or "gulls". If the geomorphology appeared to be ambiguous then the sedimentary evidence for a former lake in the valley certainly was not. A fine section in the valley bottom had been nicely cleaned up for the group to inspect glacialacustrine rhythmites that had been glactectonized and capped by till. The final site of the day was at the "Drumochter Mast", an area of hummocky moraine that all geomorphologists who have travelled through the Pass of Drumochter would instantly recognize. **Wishart Mitchell** and **Sven Lukas** explained that this remarkable landform assemblage records the former coalescence of glaciers that receded onto surrounding high ground from the pass. Small exposures reveal that deposition was predominantly as stacked debris flows in ice-contact ramps or fans.

Day three

Our final day was spent in the highland terrain to the SW of the Pass of Drumochter or the West Gaick. The appetites had been whet the previous evening by presentations by **Wishart Mitchell** in support of regional ice sheet deglaciation and by **Doug Benn** proposing a plateau or local icefield style of glaciation. It was agreed by all that the crucial site was in Allt Ghlas, to the west of Loch Ericht, where a clear Loch Lomond Readvance moraine demarcates regional ice terminating in the middle of the valley. **Wishart Mitchell** and **Jon Merritt** suggested that moraines outside this limit also record regional ice receding westwards from the West Gaick. Conversely, **Doug Benn** presented evidence for moraines deposited by outlet lobes that receded northeastwards onto the surrounding highlands. A model of Loch Lomond Stade plateau icefield glaciation presented by **Doug Benn** and **Colin Ballantyne** linked the moraines in the upper part of Allt Ghlas to the moraines and ice-contact deltas in Loch Garry to the northeast. Again, those members of the party that had observed modern plateau icefields conceded that the model of local upland glaciation was compelling but the lack of dates along most of the length of proposed Loch Lomond Readvance glacier limits hampered palaeoglaciological reconstructions. Staring wistfully at numerous large boulders perched on the regional moraine in Allt Ghlas, we all agreed that some serious cosmogenic isotope dating was overdue.

Overall the field meeting was a thoroughly enjoyable experience. Of course the weather co-operated which always helps, especially in the majestically beautiful surroundings of the Scottish Highlands, but the array of field evidence provided everyone with an insight into the local mountain geomorphology and the problems inherent in its interpretation. There was controversy and debate but it was always conducted in a thoroughly professional and good-natured atmosphere – protagonists and antagonists at every site remained in good humour throughout. This speaks volumes for the QRA, a professional body

at whose meetings people feel comfortable in exchanging views, offering constructive criticism and creating a productive learning environment for all involved. Final thanks go to Sven Lukas, Jon Merritt and Wishart Mitchell for organizing splendid accommodation and access to some fine landscape. And if you are travelling through the Pass of Drumochter, the field guide is an essential purchase.

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DEVELOPING THE TEPHROSTRATIGRAPHY OF AN LOCH MÓR, INIS OÍRR, WESTERN IRELAND

Background and rationale

The lake of An Loch Mór, on Inis Oírr, Aran Islands, western Ireland, was the focus for multi-proxy investigations of its Holocene sediment sequence in the EC-funded project TIMECHS, led by Prof. Michael O'Connell, National University of Ireland (O'Connell *et al.*, 2000a, b; Molloy and O'Connell, 2004). Three parallel cores had been taken, and these had been matched visually using conspicuous bands in the sequence. Most of one of the cores, MOR2, had been sampled contiguously for tephra. During the course of this work, several tephra horizons were encountered that appeared to date from the First Millennium AD. However, cross-correlation with the other, parallel cores showed that there might be a small gap in sediment recovered in MOR2.

The missing sediment was some half metre below tephra shards that matched geochemically with tephra from the AD 1104 Hekla (H-1) eruption. Geochemically similar shards (though different in shard size and number), which possibly indicated a previously unrecorded eruption of Hekla in the late First Millennium AD, were found in loose sediment at the top of the next 2-metre drive. Core cross-correlation indicated that some sediment, perhaps c. 20 cm that should have been at the base of the preceding drive, immediately above this tephra, was missing. Hence, there was concern about the integrity of the tephra-containing material. Fortunately, a 2-metre drive from parallel core MOR1 was intact through this part of the sequence. Contiguous 1-cm samples of this core were prepared and examined for tephra.

Results

Examination and geochemical analysis of the prepared samples confirmed the presence of the additional, Hekla-attributable tephra recorded in the other core and also helped to clarify the sequence of late-Holocene tephras at the site. A summary of the tephras found in the relevant period, AD 800–1104, is given in Table 1. Their estimated ages are based on a composite deposition-rate curve, compiled by MO'C and KM, based on data from TIMECHS members.

Significance

A significant finding is the confirmation of two, geochemically similar, Hekla-derived tephras from the mid-9th and the early 12th Centuries AD. This emphasises the possibility for confusion between different Holocene tephras

Table 1. Tephtras of Icelandic provenance recorded from An Loch Mór, Aran Islands, and dating to the period AD 800–1104 (adapted from Chambers *et al.*, 2004).

Age	Tephra local name	Correlative
AD 1104	MOR-T3	Hekla 1 (H1)
c. cal. AD 1000	MOR-T4	<i>new tephra?</i>
c. cal. AD 890	MOR-T5	Possibly equivalent to AD 860A tephra
c. cal. AD 840	MOR-T6	Possible relationship with Tjörnuvík A?

See Chambers *et al.* (2004).

that have similar geochemistry, and of the need to be cautious in using records of single tephtras as isochronous marker horizons. A discussion of the issues associated with distal tephtra representation of Hekla eruptions in the latter half of the first millennium AD is in preparation by Hunt *et al.*

For a full report of the tephtra investigations of An Loch Mór, including an account of the methods, results and the implications for tephtra records in the north-east Atlantic region, see Chambers *et al.* (2004).

Acknowledgements

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GLACIAL LAKE KNOCKANDO AND ITS BEARING ON THE TIMING AND SEQUENCE OF THE LAST DEGLACIATION IN STRATH SPEY, NORTHEAST SCOTLAND

The former existence of a large glacial lake in the valley of the River Spey around Knockando (NJ180430) was first recognised by the Geological Survey (Bremner, 1934; Hinxman and Wilson, 1902) on the basis of former shorelines (at up to 189 m OD) and from thick sequences of glaciolacustrine deposits. Glacial Lake Knockando (GLK) has potential significance for the reconstruction of the timing and mode of deglaciation in Strath Spey for several reasons:

- It may record a period when two major ice streams, the Moray Firth and Strath Spey ice streams, were uncoupling (Sutherland, 1984).
- GLK appears to represent the damming of lower Strath Spey was a result of a readvance of ice from the Moray Firth. This event was thought to have been contemporaneous with an advance of ice in middle Strath Spey to the southern shore of GLK (Sutherland, 1984). If correct, this raises the possibility of climatic forcing related to Heinrich events.
- Ice limits linked to GLK can be correlated with others inferred for lower Strath Spey (Bremner, 1934) and, especially, with moraine systems up-valley against the northern flanks of the Cairngorms (Brazier *et al.*, 1998; Bremner, 1932; Everest and Golledge, 2004).
- It provides potential to link with the complex sequence of Devensian glacial events recorded to the northeast and east in Morayshire, Banffshire and Buchan (Merritt *et al.*, 2000; Merritt *et al.*, 2003).

Recent fieldwork indicates that GLK did not exist as a single, large body of water. A smaller lake, with an area of a few km², can be identified around Upper Knockando from exposures of water-lain and locally horizontally-bedded sands. Many sections show deformation structures (possibly glactectonic), including deformed and faulted sand beds, and also intercalated and water-lain diamicts, implying ice-proximal deposition. Other thick sequences of water-lain sands occur in the Avon valley for 6 km upstream of Bridge of Avon and relate, in part, to prograding delta sequences built up in front of the retreating ice front as the Avon glacier retreated. Large parts of the intervening ground lack evidence of lacustrine sedimentation, however, and the slip-off slope of the Spey below Phones (NJ193406) displays only coarse terrace gravels. Some supposed terrace fragments, such as at Georgetown (NJ 191383), are inclined towards the valley axis and cut across till. More generally, there is little evidence of former valley-wide horizontal lake terraces, with sequences of terraces sloping down-valley at different elevations in the valleys of the Avon, Spey and Knockando Burn.

Fine sequences of arcuate moraines, kame terraces and meltwater channels occur between Upper Knockando and the Lossie watershed. The landforms can be traced for a further 5 km W of Loch of the Cowlatt and record the withdrawal of Moray ice from Strath Spey and its retreat across the high ground to the west. A series of small ice marginal lakes and spillways formed as ice retreated. The moraines appear to carry only small erratic boulders unsuited to exposure age dating using cosmogenic radionuclide concentration but boulders derived from ice-marginal, rock-cut meltwater channels may offer more potential.

The earliest evidence of deglaciation in the area is provided by the delta kame near Lynemore (NJ 290358) at 380 m OD in Glen Rinnes. Meltwater issuing from the Glack of Hornes channel beneath Ben Rinnes deposited ~20 m of gravels and sands at a time when the upper glen was at least partly free of ice and the lower valley was dammed by ice, probably at Lynemore itself.

This reconnaissance survey has shown that this part of Strath Spey has high potential for unravelling the sequence of uncoupling and retreat of ice up the valleys of the Avon and Spey and back towards the Moray Firth. The complex morphostratigraphic assemblages in the main valleys and in the Knockando basin require detailed study. It is unlikely that Glacial Lake Knockando existed as a single, large lake. Instead, a series of marginal ponds and lakes existed related to the retreat of ice north and west towards the Moray Firth and southwestward up Strath Spey.

Acknowledgement

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PALAEOLIMNOLOGICAL EVIDENCE FOR RECENT ENVIRONMENTAL CHANGE IN TROPICAL ALPINE AFRICA: ASSESSING THE PALAEOLIMNOLOGICAL EVIDENCE FROM LAKE BUJUKU, RWENZORI MOUNTAINS NATIONAL PARK, UGANDA

Introduction

The alpine aquatic ecosystems on the Rwenzori Mountains (which straddle the border between Uganda and the Democratic Republic of Congo) are supplied, in part, by the second largest snowfield in tropical Africa, yet are in a period of rapid transition, due mainly to rapid glacial recession. Figure 1 highlights that in 1990, glaciers had receded to only 40% of their 1955 extent, and to less than 25% of their extent recorded by the Duke of Abruzzi in 1906 (Kaser and Osmaston, 2002). Due largely in part to civil unrest in the Democratic Republic of Congo, an up-to-date assessment of glacier retreat has not been possible until a major expedition took place to the Rwenzori Mountains in June and July 2003, involving University College London, Makerere University (Uganda), Water Resources Management Development (Uganda), University of Innsbruck (Austria), Uganda Wildlife Authority, and Rwenzori Mountaineering Service.

Objectives

To meet the overall project's aim, three objectives were highlighted:

- assess the magnitude of current glacial recession.
- assess the impact of glacial recession on the hydrology of the Mubuku River Basin.
- extract sediment cores from a range of lakes from which to investigate the impacts of recent change on alpine lacustrine ecosystems.

Radiometric analysis of recently deposited lake sediments

In order to investigate the final objective, three lakes were visited (Lake Bujuku, Lower Kitandara Lake and Lake Mahoma), and multiple sediment cores of up to 50 cm long extracted from each. A multiproxy approach is being taken to reconstruct environmental change from these lakes, including both biological (e.g. pollen grains, diatoms) and atmospherically deposited pollutants (such as trace metals and spheroidal carbonaceous particles) in the sediment cores. The QRA contributed to the costs of dating one of these cores extracted from Lake Bujuku, using radiometric ^{210}Pb and ^{137}Cs dating. ^{210}Pb is derived from radon gas being released into the atmosphere, has a half-life of c. 22 years, and so allows the dating of lake sediments deposited in the last 150 years or

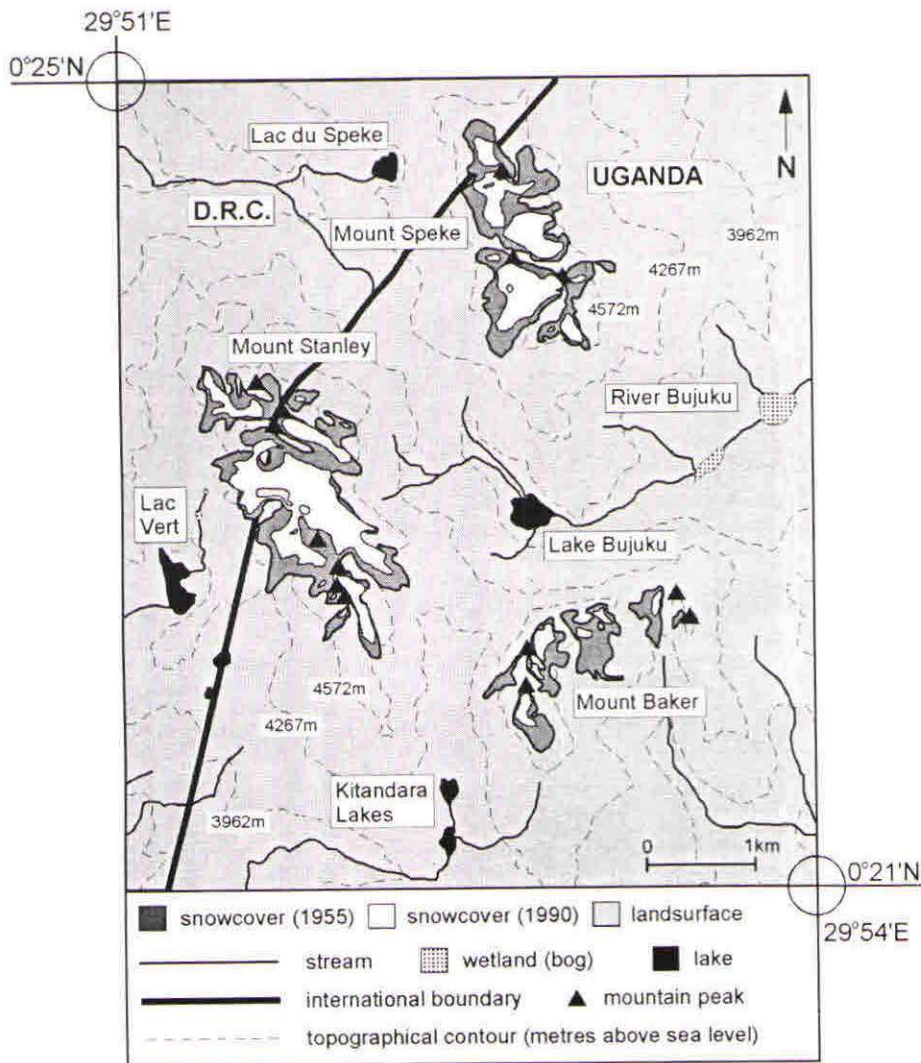


Figure 1. The Central Rwenzori Massif showing alpine lakes, wetlands, streams and extents (1955, 1990) of glacial snow cover (redrawn and adapted from Osmaston and Kaser, 2002).

so. ^{137}Cs is derived from atomic weapons testing, and acts as a marker date for 1963 AD (corresponding to the global peak in weapons testing), while also providing an essential control on the ^{210}Pb chronology. A clear subsurface maximum in ^{137}Cs activity at 10 cm depth in core Buju3 is interpreted as the 1963 AD date. This date is consistent with an exponential decline in ^{210}Pb activity with depth, thereby suggesting an average sediment accumulation rate at this site of c. 2.9 mm per year (range 2.5 – 3.4 mm per year). Applying these findings to our core suggests that that base of the core can be dated to about c. 140 years old (i.e. can be dated to c. 1863 AD). This timeframe suggests that we have an excellent resolution with which to reconstruct recent events, and is all the more notable because the last 140 years or so marks two important periods in terms of past change: recent global warming, and increases in atmospheric contamination since the onset of industrialisation. Multiproxy analyses of these cores is currently underway, and data will be available for publication later this year. Project updates can be found at: http://www.geog.ucl.ac.uk/~rtaylor/data_disk/rwenzori/rwenzori.htm

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QUATERNARY DRAINAGE EVOLUTION IN MOROCCO: AN INVESTIGATION INTO THE CREATION OF TRANSVERSE DRAINAGE

Introduction 6

With the support of the Quaternary Research Fund, a field reconnaissance of the Late Cenozoic river terrace and strath landforms of the River Draa, in South-Central Morocco (Figure 1), was undertaken during May 2004. This work forms a case study as part of an ongoing, broader investigation into the mechanisms and timing of fluvial incision, and the creation of transverse drainage within tectonically active landscapes (e.g. Stokes and Mather, 2003). Through reconstruction of long-term Cenozoic drainage records the research aims to address two key questions:

- 1) Are transverse drainage primarily created by river capture-induced drainage network reorganisations in response to differential surface uplift (as opposed to antecedence and superposition)?
- 2) Are many of the world's transverse drainage relatively youthful features within contemporary landscapes, created in response to a pulse of tectonism during the Plio-Quaternary (leading to regional tilting, head wards erosion and river capture)?

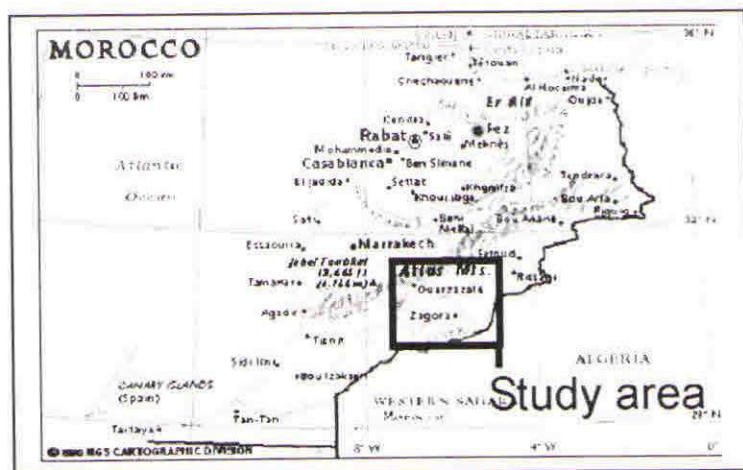


Figure 1. Location of the of the River Draa, South-Central Morocco.

Transverse drainage

Transverse drainage are rivers that cut across tectonically controlled geological structures (e.g. faults, folds and orogenic mountains). Within contemporary

tectonically active landscapes transverse drainage can form spectacular features as they often occupy pronounced canyons that cut through prominent topographic barriers. Once established, transverse drainage often forms an important link between sedimentary and hydrological basins across structural highs often acting as significant conduits for routing sediment-water fluxes away from mountain belts into adjacent basins. Knowledge of the origin and development of transverse drainage is essential in order to enhance our understanding of the fluvial system, long-term landscape development, sedimentary basin evolution and mountain belt development.

The River Draa

The Draa is largest drainage in Morocco, some 1200km in length (Figure 1). It originates in the High Atlas Mountains and flows southwards into the Sahara Desert, cutting a spectacular and deeply dissected (>200m) transverse route across the Anti Atlas Mountains (~2km high), some 180km in length, before turning west to join the Atlantic Ocean in the Western Sahara region (Figure 1). The reconnaissance focussed upon two key areas:

- (1) the Ouarzazate basin and,
- (2) the Draa Gorge (between the towns of Ouarzazate and Zagora) (Figure 2).

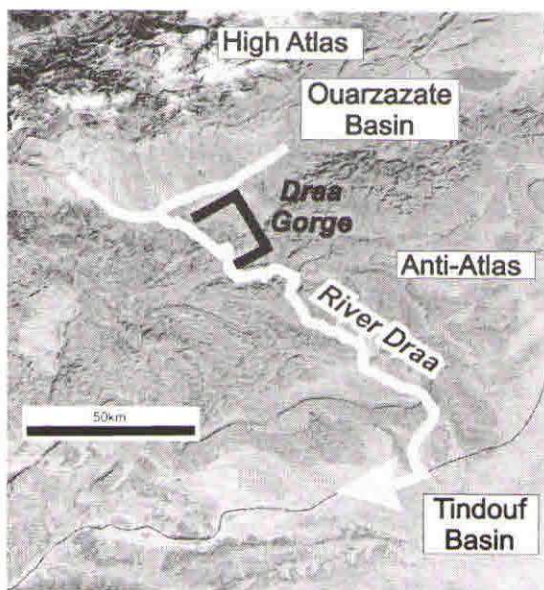


Figure 2. Annotated Landsat satellite image outlining the key physiographic components of the study project area.

Ouarzazate Basin

The Ouarzazate basin forms the main foredeep on the southern side of the High Atlas Mountains formed by flexural loading and thrust migration of the High Atlas Mountain system. The basin fill comprises a thick sequence of Mio-Pliocene alluvial and lacustrine deposits (Figure 2) that appear to correspond to an early stage of internal, endoreheic drainage evolution prior to the creation of the River Draa as a transverse drainage across the Anti-Atlas Mountains. Research into these basin fill sediments is limited (e.g. Gorler *et al.*, 1988; El Harfi *et al.*, 2001) and simply provides a stratigraphic framework and some insights into sedimentary processes and environments. A series of Plio-Quaternary pediment and river terrace levels are cut into the Mio-Pliocene fill of the Ouarzazate Basin (Figure 2) and correspond to a period when a southwards routed external, exorheic drainage into and across the Anti-Atlas Mountain was established. Research into the geomorphological development of the Ouarzazate Basin is also limited (e.g. Stablein, 1988; Schmidt, 1992) providing a useful but basic stratigraphic framework and simply alluding to the creation of the Draa as a transverse drainage.

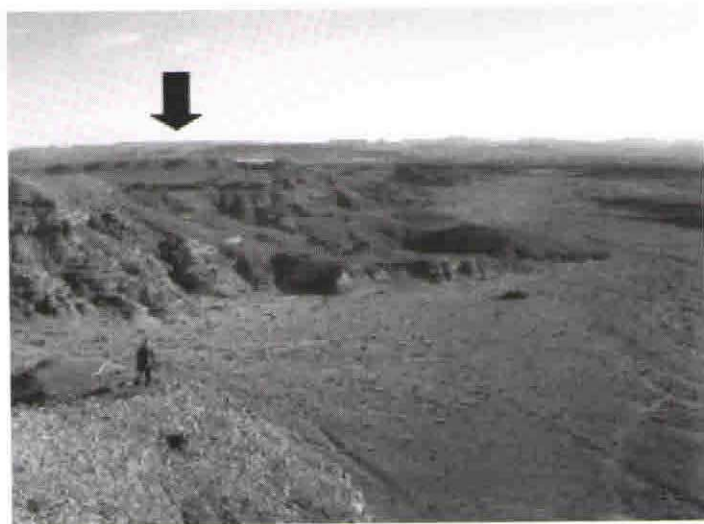


Figure 3. Southwards view across Mio-Pliocene lacustrine / alluvial sediments and inset Plio-Quaternary pediment and terrace landforms of the Ouarzazate foredeep. The site is located 8km east of Ouarzazate town. Arrow denotes the position of the Draa Gorge, marking the southerly exit of High Atlas and Ouarzazate drainage into and across the Anti-Atlas Mountains as a transverse drainage.

The Draa Gorge

The Draa Gorge forms the only exit point for drainage derived from the High Atlas Mountains and the Ouarzazate foredeep basin. The gorge between the towns of Ouarzazate and Agdz contains at least 3 levels of Quaternary(?) river terrace and strath landforms that records the capture and development of the River Draa as a transverse drainage (Figure 4). There is no existing literature on the Quaternary of the Draa Gorge.



Figure 4. Quaternary gravels overlying Proterozoic basement exposed on the west bank of the River Draa north of Agdz town.

Future work

The field reconnaissance was a great success allowing a series of key sites for future data collection (mapping, sediment description etc) to be identified. A return visit in late 2004 / early 2005 funded by the Royal Geographical Society is planned to begin field data collection. Preliminary data collection involving the integration of field reconnaissance information along with published literature, maps and remotely sensed data strongly suggest a Plio-Quaternary capture-induced drainage network reorganisation. Active and passive tectonic controls appear to be key driving mechanisms for long term drainage evolution and the creation of the Draa as a transverse drainage.

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TOWARDS AN INTERPRETATION OF THE LATE HOLOCENE FAUNAL RECORD FROM ANDEAN HIGHLAND LAKE SYSTEMS

Background And Rationale

The Andean highland region of South America is justifiably famous for its geological, climatic, cultural and biological diversity. Indeed, the region is increasingly becoming the focus for detailed palaeoenvironmental investigations as researchers examine the links between millennial-scale climatic variability and cultural change. Ongoing research into a suite of recently-acquired cores from a range of lacustrine sites in the region is coupling palynological, sedimentological, stable isotope and invertebrate faunal data (ostracods and gastropod molluscs in particular) to construct a detailed Late Holocene palaeoenvironmental history for the Urubamba Valley in the south-central highlands of Peru (e.g. Chepstow-Lusty *et al.*, 1998; 2003; 2004). However, almost nothing is known of the ecological preferences, taxonomic status or biogeographical pedigree of the invertebrate taxa recovered from such records. Most existing data-sets for the region come from Lake Titicaca, located approximately 200 km to the south and almost all of these relate to modern fauna; see, for example, references in the reviews of Dejoux (1992) and Martens & Behen (1994). In addition, with its 4 million year old record of profligate endemism and biological diversity, Titicaca is unlikely to be 'typical' with respect to any patterns of past faunal diversity or climatic response and is therefore not necessarily the ideal point of reference for palaeoenvironmental studies from other lake basins. What is needed is a better understanding of the ecological and habitat requirements of the fauna from 'ordinary' lake systems in the region.

To this end, fieldwork was undertaken in the Cusco region during August 2003 to sample a suite of lake sites of different character (including altitude, area, depth, bathymetry, vegetation cover and proximity to anthropogenic influence) from which cored sedimentary material had previously been obtained. Modern invertebrate material was collected from a variety of micro-habitats at each lake site; basic water chemistry parameters were also measured.

Results

Twelve different lake sites were sampled in the Cusco region at altitudes ranging from ~2900 to 4200 m above sea-level (Figure 1 and Table 1). As expected in a region dominated by volcanic bedrock, measurements of pH varied from 5.0 to 7.0; other water chemistry parameters were similarly unremarkable for highland lake systems such as these. Taxonomic evaluation of the recovered faunal material is still ongoing, though notable amongst several cosmopolitan taxa of ostracod is a (probably undescribed) species belonging to the *Penthesilenula*

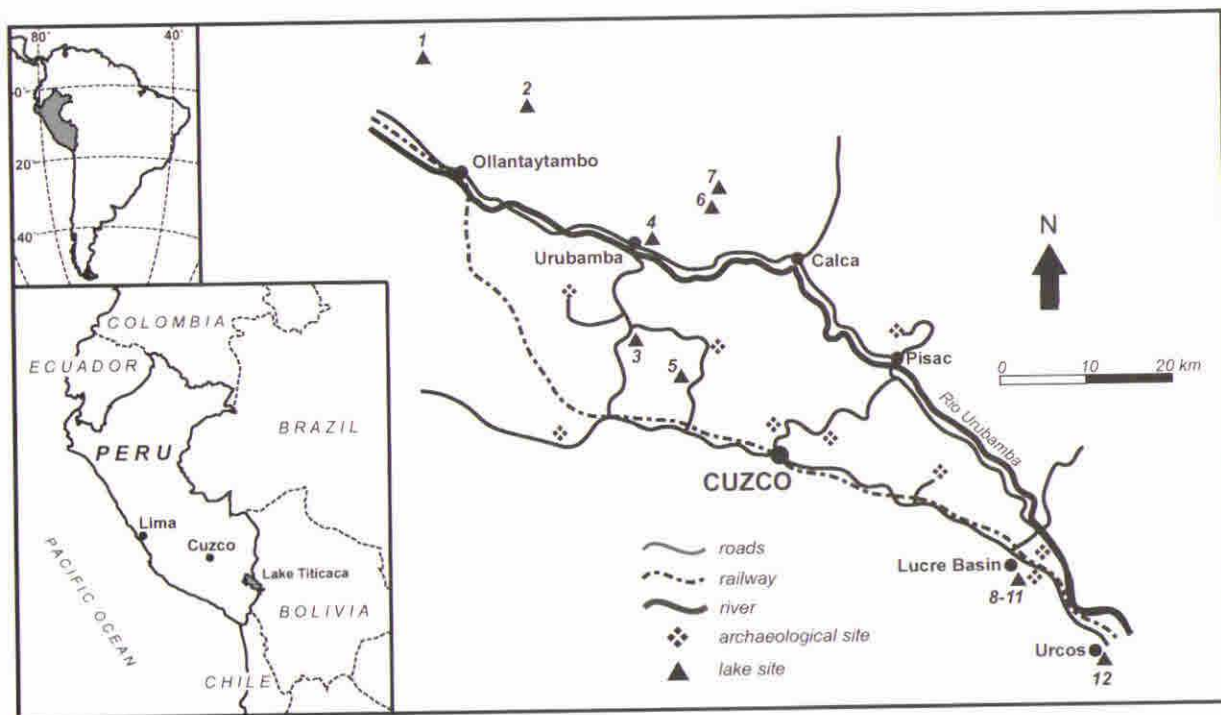


Figure 1. Location map; sample sites are designated by numerals (see also table 1).

	Site	Longitude	Latitude	Altitude m above sea-level
1	Chiricocha	S 13°08'	W 72°20'	3900
2	Marcacocha	S 13°13'	W 72°12'	3355
3	Huaypo	S 13°24'	W 72°08'	3547
4	Huachac Marsh	S 13°19'	W 72°06'	2872
5	Chaperacocha	S 13°26'	W 72°04'	3760
6	Yanacocha	S 13°18'	W 72°03'	3940
7	Quellacocha	S 13°17'	W 72°03'	4176
8	Inkacocha	S 13°36'	W 71°44'	3107
9	Laguna Lucre	S 13°38'	W 71°45'	3110
10	Huascar Grande	S 13°38'	W 71°44'	3108
11	Huacarpay	S 13°38'	W 71°44'	3102
12	Urcos	S 13°41'	W 71°38'	3174

Table 1. Sample sites (see also Figure 1).

incae-group of darwinulids, which are found only in South America and New Zealand (Rossetti & Martens, 1998). The aquatic molluscan fauna similarly contains several ubiquitous taxa, though special taxonomic attention will be required in the case of at least one subspecies of the planorbid *Taphius montanus* and several species of the hydrobiid *Littoridina*.

Significance

These are probably the first collections of invertebrates and water chemistry measurements from many of these Peruvian lake systems. The results of this study will therefore enhance the rather poorly documented body of knowledge concerning freshwater invertebrate taxa in this region. Perhaps more importantly, however, once analyses are completed the data will provide the basis of much-needed confidence in the ongoing palaeoenvironmental interpretation of late Holocene sedimentary records from these lakes.

Acknowledgements

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SEA-LEVEL RECONSTRUCTION AND DEGLACIATION OF NW ICELAND AND ITS IMPLICATIONS FOR OCEAN CIRCULATION

Background and rationale

Iceland occupies an important position in the North Atlantic close to the major areas of deep water formation at the present day key to the global thermohaline circulation system (THC). The climate history of Iceland is, therefore, heavily influenced by ocean circulation. Deglaciation of the Icelandic ice sheet at the end of the last glaciation, however, may also have had an influence on the ocean circulation through the flux of meltwater to this sensitive area of the ocean. In recent years there have been a number of studies investigating the deglacial history of the Icelandic ice sheet and also the maximum extent of the ice sheet (e.g. Andrews and Helgadóttir, 2003). There are still uncertainties over the size of the LGM ice sheet; relatively restricted glaciation (e.g. Hjort *et al.*, 1985) or extensive glaciation (e.g. Andrews *et al.*, 2000). A greater understanding of the sea-level history of Iceland will help to inform this debate – the amount and pattern of crustal rebound can be used to estimate the relative size and configuration (one large ice sheet, or a separate ice cap over the NW peninsula) of the Icelandic ice sheet.

There have been relatively few studies investigating the relative sea-level (rsl) history of Iceland in general and the NW peninsula (Vestfirðir) in particular (eg. Norddahl and Einarsson, 2001). The majority of sea-level studies in Iceland are based on raised shoreline evidence (e.g. Norddahl and Hjort, 1993), few studies use biostratigraphy to accurately constrain the sea level history (an exception being Rundgren *et al.*, 1997). The aim of this current project is to use the isolation basin methodology to provide detailed information on rsl changes from the Vestfirðir Peninsula.

This current project is essentially a pilot study with the aim of identifying and sampling isolation basins from the Reykholar area on the south Vestfirðir coast, examining the biostratigraphy of these sequences to elucidate the rsl history of this area (Figure. 1).

Results and significance

During the fieldtrip in summer 2003 a total of 11 sites were visited and sampled. Preliminary diatom analysis of a number of isolation basins from the south coast of the Vestfirðir Peninsula has identified rsl falling in the area during the early Holocene. Three sites, Hafrællvatn (altitude of sill 24.7 m above mean sea level, msl), Hrísholsvatn (40 m above msl) and Berufjardarvatn (49.9 m above msl) show transitions from a blue grey silty clay with brackish and marine

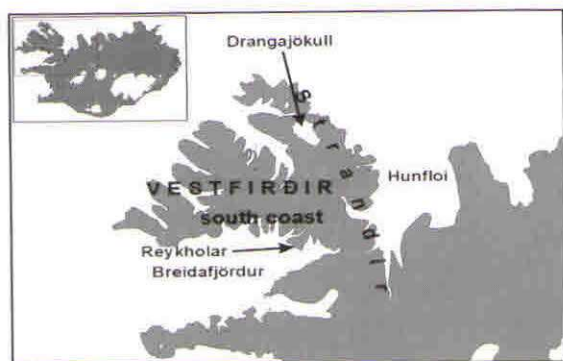


Figure 1. Location of study area, Reykholar, on the south coast of Vestfirðir.

diatoms at the base of the sampled core to organic rich silty clay dominated by freshwater diatoms. These three sites document the fall in rsl from above 49.9 m to below 24.7 m. This fall in sea level has not yet been accurately dated. The presence of a thick (5–7 cm) Saksunarvatn age tephra layer in the freshwater section of the cores from Hríshólsvatn and Berufjardarvatn suggests the fall in sea level from above 50 m to below 40 m took place earlier than 9.2 ka C¹⁴ yrs BP. No tephra layer was found in the core from Hafrafellvatn. If we assume the tephra is below the depth of sampling at Hafrafellvatn (the core was not sampled to bedrock) then this site was isolated sometime after the Saksunarvatn tephra fall. Based on this assumption sea level fell below 24.7 m some time after 9.2 ka C¹⁴ yrs BP.

These initial results provide the first biostratigraphically constrained evidence for rsl change from the southern coast of the Vestfirðir Peninsula near Reykholar. The pattern of rsl fall we have identified is in broad agreement with the reconstruction of Hansom and Briggs (1991) based on raised beach deposits from the SE coast of Vestfirðir. The timing is slightly different, Hansom and Briggs suggest rapid fall in rsl to below 10 m by 10.4 ka C¹⁴ BP, while our data suggests a rather later fall in rsl below 24 m some time after 9.2 ka C¹⁴ BP. The chronology of these sites, and further sites to be analysed, will be improved using radiocarbon dating and detailed tephrochronological analyses. This initial research has highlighted the potential for further detailed rsl investigations based on the isolation basin methodology from the Vestfirðir Peninsula.

Acknowledgements

The Quaternary Research Fund grant contributed to the cost of the fieldwork for 3 weeks during the summer 2003. The fieldwork costs were also supported by a grant from the Department of Geography, University of Durham. We would like to thank Dr. Hreggvidor Norddahl, of the University of Iceland and also

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TWENTIETH-CENTURY CHANGE IN GLACIERS OF THE BENDOR AND SHULAPS RANGES, BRITISH COLUMBIA COAST MOUNTAINS

Introduction

Recent mountain glacier wastage has been almost universal, but punctuated by readvances in some regions: c.1965-85 in the Alps, Caucasus and Iceland, and in the 1990s in Norway and New Zealand. The degree of recession has varied both regionally and with glacier size and position. Thus it is useful to make regional studies, to complement the annual monitoring of a small sample of glaciers (Haeberli *et al.* 1998).

The southern Coast Mountains of British Columbia (Ryder, 1981) form a glacier region (Østrem, 1966) almost as extensive as the Alps but with relatively little published information other than for two glaciers monitored for mass balance (Sentinel and Place Glaciers, near Pemberton), and several glaciers near Whistler ski resort whose termini are checked annually by Karl Ricker. Topographic maps published at 1/50k in the 1970s and 1/20k in the 1990s omitted many small glaciers and show errors in interpretation due to snowbanks and debris cover: late summer air photography and/or fieldwork is necessary for accurate delimitation of small glaciers. Though very poorly known, these are important as they respond rapidly to climatic changes, especially increased temperature.

Methods

On the landward side of the Coast Mountains, west of Lillooet and northeast of Pemberton, the Bendor and Shulaps Ranges of the Bridge River District had some 131 small glaciers and glacierets, based on my interpretation of 1947 and 1951 air photographs (Evans, 1977; 1990). The latest air photographs are from 1997 but show too much snow to define glaciers shorter than about 1 km. Thus the glaciers were remapped from September 1993 Forest Service air photographs, which have very low snow cover.

The fieldwork supported by the QRA was undertaken in August 2003 to reoccupy as many photo stations as possible and take ground photos comparable to those from 1965 and 1966, giving 38 years of change. Despite access problems, this was successful for the northern and western Bendor Range and the central Shulaps Range.

Results

All these glaciers have suffered net loss, both 1965-2003 and 1951-1993, but few have disappeared entirely. Glaciers which were thin and deteriorating in

1965 are still present. Some steep north-facing glaciers have receded very little since 1951, but those over 1 km long have lost hundreds of metres of their tongues. On Whitecap Mountain (2918 m), the length of the east-facing glacier, initially 1880 m, diminished by 760 m 1951-1993, while its neighbour facing northeast lost only 180 m of its initial 2020 m. Keary Glacier lost 160 m of its 1940 m length, and the bottom 50 m of its initial 750 m height range. Immediately northwest of Mount Truax in the northern Bendor Range, two lakes have enlarged considerably and the glaciers are no longer in contact with them. One glacier has lost 240 m of its 1250m length, the other, 260 of 600 m. The hanging glaciers on Shulaps Peak (2880 m) have lost very little. In general, where the 1/20k maps, based on 1988 air photographs, had accurately identified glacier margins, there was little change by 1993.

A multi-temporal inventory of these glaciers is being produced, including their Little Ice Age (LIA) extents. Analysis of this will relate length and snout altitude change to glacier size, gradient, altitude and aspect. West of the Bendor Range and east of the Bridge - Lillooet Ice Field, there are numerous larger glaciers: these appear to be continuing their rapid post-LIA wastage. Their 1993, 1951 and LIA extents have been mapped and will provide useful comparisons with the small glaciers farther east.

Significance

These small glaciers have shared the global trend of recession in the second half of the twentieth century, as shown also by negative mass balances for the Sentinel and Place Glaciers. However, it is not the smallest that have lost most either relatively or absolutely. The data will contribute to development of a model for differential response of glaciers to recent climatic change, in relation to size, altitude, aspect and detailed position.

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PALAEOMAGNETIC ANALYSIS OF EARLY MIDDLE PLEISTOCENE SEDIMENTS AT NORTON SUBCOURSE, NORFOLK

Background and rationale

Norton Subcourse, Norfolk (NGR TM 403 994) lies some 15km inland from the present North Sea coast on the low relief till plateau, adjacent to alluvium of the River Yare. It lies within the Neogene Crag basin, which contains Pliocene to early Middle Pleistocene marine, estuarine and freshwater sediments of the Norwich Crag, Wroxham Crag and Cromer Forest-bed Formations. These were deposited at the western margin of the southern North Sea basin. Pre-Anglian fluvial sediments of the Ingham Formation, part of the Bytham river system, overlie these coastal formations. These are overlain by the regionally extensive glaciogenic sediments of the North Sea Drift and Lowestoft Formations (terminology of Bowen, 1999), which are generally attributed to Marine Isotope Stage (MIS) 12 (but see Hamblin *et al.* (2000) Rose *et al.* (2000; 2001)). Following discovery of the site by members of the Norfolk RIGS group in 2001, field work was undertaken in order to establish the lithostratigraphic succession, the depositional environments and fauna and flora of these deposits.

The sedimentary succession at the site consists of basal gravels (beds 1 and 2) consisting mainly of rounded flint pebbles, deposited in a shallow marine environment. An increase in the proportion of quartz and quartzite in bed 2 suggests increased input of far-travelled lithologies via the Bytham River. Beds 1 and 2 are correlated with the Norwich and Wroxham Crags (Rose *et al.*, 2001) respectively. Overlying these gravels are fine-grained organic sediments, deposited in a river channel, under temperate climate conditions (bed 3). These are overlain by fluvial gravels of the Bytham Formation (bed 4) and outwash sands (bed 5), which are equated with the Corton sands.

Bed 3 has yielded a variety of palaeoenvironmental indicators including plant remains, molluscs and ostracods, insects and vertebrates. Among the large mammals present are hippopotamus, an extinct equid and hyaena (coprolites). The insects indicate a fully temperate climate. These sediments are correlated with the Cromer Forest-bed Formation.

The grant from the Quaternary Research Fund contributed towards palaeomagnetic analysis of the fine-grained sediments of bed 3.

Results

The results indicate that, with the exception of the basal, coarse-grained sands and gravels (bed 1 or 2), the sediments are dominated magnetically by the presence of greigite, a magnetic iron sulphide that probably formed soon after deposition of the sediments. Minor amounts of haematite also occur

through the section. The sediments are predominantly of normal polarity. However, the interpretation of the palaeomagnetic data from Norton Subcourse is complicated because, as with other sites in the region, the sediments lack significant magnetic detrital inputs and are overprinted by post-depositional magnetic remanences.

Significance

The palaeomagnetic data suggests that bed 3 was deposited during a period of normal magnetic polarity. In the light of these data and the biostratigraphical information provided by vertebrate and molluscan assemblages, it is probable that bed 3 represents an interglacial event early in the Brunhes Chron. Correlation with other temperate episodes in the Cromer Forest Bed Formation (Preece and Parfitt, 2000) is uncertain, though there are palaeontological similarities with Pakefield.

Acknowledgments

Professor Barbara Maher and Dr Vassil Karloukovski (University of Lancaster) undertook the palaeomagnetic analyses. Simon Parfitt, Richard Preece, Russell Coope, Rob Scaife and John Whitaker have contributed significantly to the palaeoenvironmental and biostratigraphical aspects of the site.

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New Research Workers Award Scheme

DENDROCHRONOLOGICAL ANALYSIS OF SUB-FOSSIL PINE IN N. SCOTLAND TO EXAMINE THE TIMING AND EXTENT OF A C. 4000 CAL. YR BP CLIMATIC EVENT

Introduction

The study of short-term abrupt events may support our understanding of the North Atlantic mechanism of climate change (Selten *et al.*, 1999) and dramatically increase our knowledge of the impacts of climatic change.

Dendroclimatological research in northern Scotland is still limited. Although, the region is beyond the current ecological limit of pine (c. latitude 58 °N), horizons of sub-fossil pine occur within one of the largest mostly intact areas of blanket bog in the world (Figure 1), potentially providing evidence of past climatic change. Humification analysis indicates that the occurrence of sub-fossil stumps corresponds with a drying of mire surface conditions followed by a return to wet conditions" (Binney, 1997). The presence of sub-fossil pine beyond its current ecological range is therefore expected to reveal a c. 400 year-long shift to dry conditions, albeit local to each site, from relatively wet conditions.

An early attempt to dendrochronologically date sub-fossil pine at Rannoch Moor (Bridge *et al.*, 1990) was unsuccessful, probably due largely to two characteristics of the site - the lack of an apparent synchronous horizon of pine and a general short length of tree-ring series. A number of unpublished c. > 200 yr long sub-fossil pine chronologies have since been established in Scotland, independently by the author and by John Daniell (University of Gloucestershire).

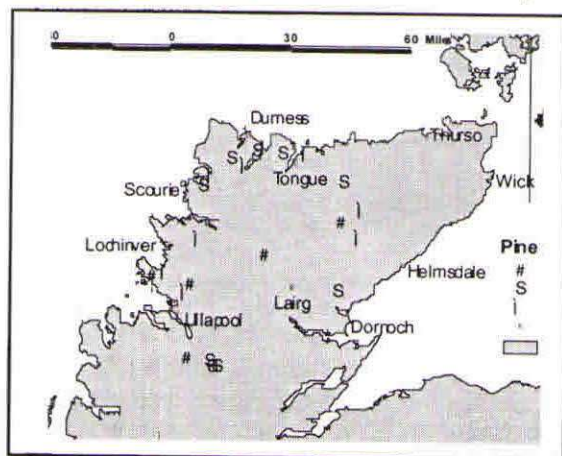


Figure 1. Holocene pine network of chronologies in Northern Scotland

From the mire sites currently known it is unlikely that long (> 1000 yr) chronologies can be established from sub-fossil pine in northern Scotland. Nevertheless, Daniell (1997) successfully established calendar dates for some chronologies by long-distance cross-matching with Irish chronologies.

Anderson *et al.*'s review (1998) updates the wide body of evidence for a c. 4000 cal. yr. BP climatic event in northern Scotland. Based on dendrochronological analysis, the author's part-time PhD research aims to identify whether this transition occurred abruptly, or possibly over a decade or century timescale. The New Research Workers Award assisted the funding of fieldwork in 2002. This short report outlines the rationale for this research and presents some preliminary findings.

Aims and Methods

- To establish site chronologies of sub-fossil pine with sufficient replication to maximize their cross-dating potential through standard dendrochronological techniques.
- To examine the feasibility of extending the network of Holocene pine chronologies to create a calendar dated stratigraphic marker horizon for the c. 4000 cal. yr BP climatic event across northern Scotland.
- To investigate the c. 4000 cal. yr BP climatic event over the region in terms of timing, extent and rates of change through its effect on pine.
- To quantify possible changing influence of temperature, precipitation and particularly wind on sub-fossil pine during the c. 4000 cal. yr BP climatic event.

Gear and Huntley and Huntley (1991) present a range of 4,390 – 3,980 uncal. yr BP for radiocarbon-dated pine stumps across northern Scotland. This identifies a broadly synchronous target for sampling. Peat cuttings, roadside cuttings, as well as streams and rivers (where erosion has occurred into a peat bank) often exposes sub-fossil pine. Changes of water level in lochs used as reservoirs also erodes peat and reveals exposures. Preliminary fieldwork in 2001 mapped exposures of sub-fossil pine, which were then assessed for their potential for standard dendrochronological analysis (English Heritage, 1998). Groups of more than 10 pine stumps, containing at least 150 rings, traces of bark and *in-situ* samples were the main considerations, but accessibility was an additional factor.

Wind is a critical climatic element which exerts serious detrimental effects on commercial forestry in the uplands of Scotland (Miller, 1985), yet this factor is rarely considered in palaeoclimatic or dendroclimatic studies. Binney (1997) suggests wind as a factor controlling the surface conditions of mires. Skewed ring growth has been observed in sub-fossil pine and this has been interpreted

as due to wind action (Figures 2 and 3). A study on living conifers identified that ring widths tended to be wider to the lee of the prevailing wind (Bannan and Bindra, 1970). Where pine stumps were sampled *in-situ* details on stump height, root and stem orientations were recorded. To help the assessment of topographic effects the location in the form of NGR co-ordinates were also recorded.

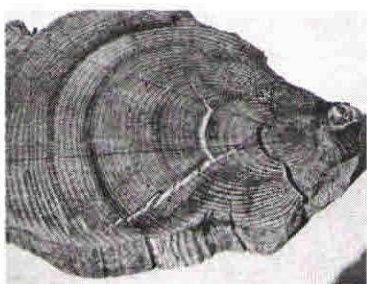


Figure 2. Skewed growth in pine

Results and Discussion

Fieldwork in the summer 2002 resulted in the recovery of 127 pine stumps from eight main sites. One fifth of the samples have undergone dendrochronological analysis. Intra-site cross-matching has established 6 working site mean sequences with mean lengths of 240 rings. Cross-matching between sites is indicated, but it is hoped that the statistical evidence for these matches increases as the chronologies become better replicated. There is tentative evidence for the grouping of pine germination at some sites which would indicate rapid colonisation. Bark was recorded on 38% of the samples, which should enable accurate analysis of the terminal decline of these trees to be examined.

The preliminary results are encouraging in that the new samples should cross-match with existing reference chronologies to produce calendar dated sub-fossil pine chronologies. The dendrochronological analysis of a regional network of sites provides a greater potential to identify factors attributable to climatic change than could be examined through the analysis of a single site. Subsequent analysis may dramatically increase our understanding of an archaeologically important period of change, which in turn could be applied to current changes in climate.

Acknowledgements

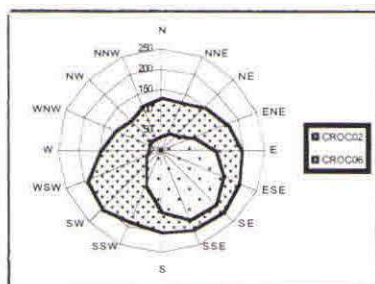


Figure 3. Rose diagram of skewed growth in two of the sampled pines

I would especially like to thank the landowners for their permission to sample and my parents and uncle who assisted with the fieldwork. I am grateful to the QRA for the grant, which partly funded fieldwork for this research and to my supervisors: Prof. Suzanne Leroy and Dr Phil Collins.

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REVIEW

DAS PLEISTOZÄN VON UNTERMASFELD BEI MEININGEN (THÜRINGEN), VOLS. 2 AND 3, EDITED BY RALF-DIETRICH KAHLKE.

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Zentralmuseum and the Senckenbergischen Naturforschenden
Gesellschaft.

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72 euros for volume 2, 81 euros for volume 3.

These two volumes of collected papers (together with Part I, published in 1997) document the finds made at the remarkable locality of Untermassfeld, near the town of Meiningen in eastern Germany. Over twenty field seasons, directed by R-D Kahlke, have produced a stunning array of fossil vertebrate remains in stratigraphic context, making this unquestionably one of the most important Quaternary localities in Europe. The site is formed from deposits of the Early Pleistocene Werra river, in two main units: the Lower Fluvatile Sands, interpreted as a series of flood deposits, and the Upper Fluvatile sands, the infill of a channel cut into the lower deposit. Fossil bones and other fauna occur throughout, up to a current total of over 12,000 determinable mammal remains comprising over 40 taxa. These include several new species, including a large but gracile bison *Bison menneri*, and a species of large deer, *Eucladoceros giulii*. The accounts of these and other taxa are not merely descriptive but are given in the context of a review and revision of their respective groups. Hippopotamus remains are particularly abundant and have allowed a major osteological study of this lineage. Other spectacular finds include the giant hyaena *Pachycrocuta*, represented not only by massive crushing jaws but also gnaw marks on prey bones and nests of coprolites. There are no fewer than six species of big cat, including sabre-tooths and forms akin to modern leopard and cheetah. Biostratigraphically important small mammals include *Mimomys savini*, *M. pusillus* and *Pliomys episcopalus*. As well as detailed taxonomic descriptions of various groups, illustrated by 131 plates of excellent black-and-white photos, Volume 3 also includes an in-depth analysis of site taphonomy, with all remains (including many partially-articulated skeletons) plotted in three dimensions. It is a valuable exemplar of the role of fluvatile processes in accumulating fossil remains, with cadavers from upstream arriving at the site in various stages of decomposition. The totality of the fauna and flora unquestionably indicate a temperate episode at least as warm as today, with

relatively mild winters. In terms of faunal evolution and biostratigraphy, the mammal fauna is particularly important in documenting a transitional phase between the Early Pleistocene 'Villafranchian' faunas and those of the early Middle Pleistocene ('Galerian'). On this basis, a change of palaeomagnetic polarity just below the fluviatile sands is interpreted as the bottom of the Jaramillo event and the fauna, at around 1.0 Ma, has been named the 'Epivillafranchian' by Kahlke. A fourth volume, incorporating finds since 2001 and revision of some previous accounts, is in preparation.

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ABSTRACTS

HOLOCENE COASTAL CHANGE IN LEWIS AND HARRIS, SCOTTISH OUTER HEBRIDES

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The western coastline of the Outer Hebridean island chain has received much attention regarding the development of the large expanses of sandy grassland known as the Machair. Historically, the work that has been carried out has concentrated on the coastal exposures of intercalated sands, palaeosols and peats, from the islands found in the lower reaches of the Hebridean chain, namely North and South Uist, Benbecula and Barra. The now, well documented history of the landwards movement of shelly sand that characterises much of the western coastline, and forms the basis for the machair plains, has to date failed to look at the relative movement of the sea during the Holocene in any detail. The most recent studies have involved the development of a chronology of sand drift/movement, but once again the data has been constrained to locations from the lower part of the island chain.

This study aims to address the lack of field data concerning the coastal development of the western fringes of the upper part of the Hebridean island chain by examining locations on the Isles of Lewis and Harris. As opposed to looking at coastal exposures, low lying coastal marshes/basins that lie behind beach and dune systems and well developed areas of saltmarsh have been examined. In south western Lewis three locations on the Bhàltos Peninsula, Clibhe (Cliff), Cnip (Kneep) and Riof (Reef) were chosen for study along with three locations in south western Harris, Sieleboist, Horgabost and Northton.

Morphological mapping and stratigraphical analysis of the basins was carried out, followed by diatom and grain size analysis of the buried sediments and the modern beach areas. The key periods associated with fluctuations in the level of the sea and the landward movement of the coastal sand bodies were dated using radiocarbon techniques.

The most important phases of coastal development identified from this study are highlighted in terms of sand drift (associated with increases in storminess and changes in the relative level of the sea) and relative sea level change. Noted periods of sand movement occur after c. 7370 ¹⁴C years BP, c. 2360 ¹⁴C years BP, c. 1790 ¹⁴C years BP, between c. 820 and c. 740 ¹⁴C years BP, and

between c. 460 and c. 120 ^{14}C years BP. Evidence for former sea levels is not as widespread across the chosen study areas as the evidence associated with periods of storminess. The Holocene relative sea level record is mainly contained in the sediments from the two most southern locations in Harris, Horgabost and Northton, with the latter providing the earliest date for marine incursion to be c. 7370 ^{14}C years BP. Following this period of marine incursion a number of sea level fluctuations are recorded, including a Holocene transgression that occurred between c. 4500 ^{14}C years BP and 2130 ^{14}C years BP, that have allowed a graph of relative sea level movements in the Outer Hebrides to be constructed.

A POLAR PARADISE: THE GLACIATION OF SOUTH VICTORIA LAND, ANTARCTICA

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This thesis reports aspects of terrestrial glaciation from South Victoria Land, Antarctica. The key findings concern an improved comparison into the subglacial nature of cold versus warm-based ice masses and questions the existence of sublimation till at Taylor Glacier terminus. Micromorphology is the primary technique, but two new field methods were introduced: the *Stihl TS400* angle grinder, which proved effective in ambient temperatures of -30°C when sampling semi-lithified tillites, and the creation of a 'field-laboratory' to facilitate induration of diamicts in the polar field. Other laboratory techniques used were particle size analysis, clay mineralogical analysis and differential thermal analysis.

Four types of erosion, three types of deposition and three scales of glaciectonism resulting from cold-based glacial advance in the Allan Hills during the Last Glacial Maximum were described. One of the deposits is proposed to be a cold-based tectomict and was investigated by micromorphology. Many features recognisable in temperate subglacial tills were noted in the tectomict, but the difference lay in the style of deformation: the cold-based tectomict is dominated by a planar style, whereas temperate tills are characterised by rotational deformation. The preservation potential for cold-based glacial features was discussed, and found to be high in polar climates but very low beyond on account of the more rapid weathering in sub-polar or temperate climates.

In contrast, glacitectonised bedrock attributed to a north-easterly flowing, warm-based Neogene East Antarctic Ice Sheet(s) is also observed in the Allan Hills. The glacitectonic structures are distinguished from those of the 'original' bedrock geology and any cold-based features, because they are formed by subglacial simple shear and/or frequently infilled with laminated sediment, e.g. downward tapering clastic dykes and tillite wedges. Fracturing is the first stage in bedrock glacitectonism, and sandstone cycles overlying brecciated beds are not *in situ*, but have been horizontally displaced by overriding ice masses. It is further thought that bedrock glacitectonism significantly contributes to local till production; but without direct glacial ice contact. Thin section analysis of the clastic dyke sediments, provide evidence for rotational deformation and syn- or post-depositional brittle deformation; but no tillite. The observed combination of extensive, diverse micro-Water Escape Structures (micro-WESs) with large, isolated turbates, grain lineations and a laminar, imbricate fabric are tentatively regarded as diagnostic for clastic dyke sediments. In contrast, the tillite wedge thin sections express evidence for subglacial shearing. The complex three-dimensional micro-WESs are the result of a pressure gradient generated by forceful dewatering in an unfrozen aquifer. This suggests that supposedly 'impermeable' tills have the potential to drain large fluxes of subglacial meltwater downward and laterally.

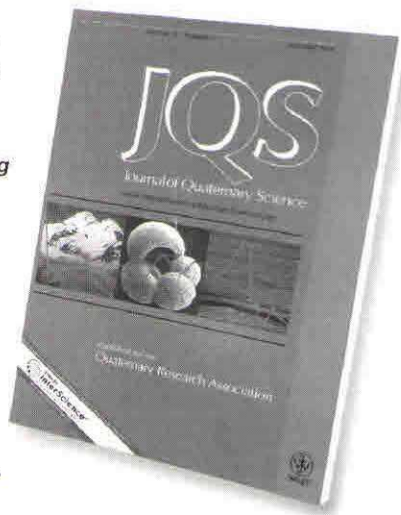
Sublimation till, the rarest till on Earth, is reportedly found at the snout of Taylor Glacier. However, field observations and thin section analysis reveal a dynamic sedimentological history, but no sublimation till. In contrast, four other sediment types were identified in thin section: (i) aeolian fines, (ii) meltout till, (iii) meltout till that has experienced syn- and/or post-depositional flow and (iv) deformed proglacial lacustrine deposits. Furthermore, $\sim 100 \mu\text{m}$ thick clay coatings observed around grains in thin section are proposed as evidence for meltout till.

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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.

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