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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:
The parallel roads of Glen Roy, Scotland. See article by Cope and Cooper

EDITORIAL

Issue 103 of *Quaternary Newsletter* brings to an end my term of office as editor. Editing *QN* has been enjoyable and stimulating, in part because members of the Quaternary Research Association have supplied a healthy and eclectic range of copy, and because the production of *QN* has received excellent help from a number of people and organisations. In particular, I would like to thank Val Siviter for typesetting *QN*, Gwasg Ffrancon for printing it, and Sue Rowland, Hazel Lintott and Martin Wingfield (University of Sussex) for providing cartographic and computing assistance. Stewart Campbell, the former editor, and members of the QRA Executive Committee have provided valuable guidance and support. I would also like to thank the many unacknowledged referees of articles submitted to *QN* during the last four years. They are:

David Anderson, Trevor Beebee, Doug Benn, Matthew Bennett, David Bowen, David Bridgland (twice), Jeff Blackford, Chris Caseldine, John Catt, Frank Chambers, Peter Coxon, Alistair Curry, Mark Dinnin, Andy Dugmore, Dave Evans, Calum Firth, Roland Gehrels, John Gerrard, Phil Gibbard, Neil Glasser (twice), Chris Green (twice), Phil Harding, Stefan Harrison, Adrian Humpage, Chris Hunt, Brian Huntley, Alison Jones, Leif Jonsson, David Keen, Martin Kirkbride, Tim Lawson, Simon Lewis, Olav Lian, John Lowe, Darrel Maddy, Danny McCarroll (twice), Jon Merritt, Tavi Murray, Adrian Parker, Doug Peacock, Brice Rea, Helen Roe, Danielle Schreve (twice), James Scourse, Richard Shakesby, David Sugden, Richard Tipping, John Walden (twice), Mike Walker (twice), Martyn Waller (twice), Richard Waller, Charles Warren, Mark White, Colin Whiteman (twice), John Wymer (twice).

The new editor of *QN* is Tim Mighall. Tim grew up in West Yorkshire and was educated at Colne Valley High School and Keele University. In 1987 he gained an upper second class honours degree in Geography and Geology. Tim stayed at Keele to begin doctoral research on palaeoecological aspects of early mining and metalworking in upland Wales. On completing his PhD, Tim was a temporary lecturer in physical geography at West London Institute of higher Education. In 1991 he was appointed as a lecturer in the Department of Geography at Coventry University. Subsequently, his research has continued to examine the relationship between humans and their environment during the Holocene and to reconstruct atmospheric pollution histories associated with ancient and historical mining and metalworking activities using methods such as pollen analysis, geochemistry and mineral magnetism. The majority of this research has been undertaken in the uplands of central Wales, Snowdonia and the Northern Pennines. During the last three years Tim has acted as publicity Officer for the Association of Environmental Archaeology and co-organised the QRA field meeting in south west Ireland.

Julian Murton

ARTICLE

MINERAL MAGNETIC EVIDENCE FOR THE LATEGLACIAL CATASTROPHIC LAKE DRAINAGE OF GLEN ROY/GLEN SPEAN IN AND AROUND LOCH NESS, SCOTLAND

Mark Cope and Mick Cooper

Introduction

Difficulty in recognising jökulhlaup deposits in proglacial areas has led to problems in differentiating them from non-flood outwash deposits (Maizels, 1997). Detailed studies of the sedimentological and morphological characteristics of these deposits, and the classification of distinctive lithofacies, have been carried out in order to address this. However, difficulties in interpretation still remain.

This paper proposes an alternative method of differentiating jökulhlaup deposits from other proglacial deposits. This method involves identifying the provenance of the deposits based on their mineral magnetic properties. Analysis of fraction-specific low frequency mineral magnetic susceptibility (hereafter referred to as magnetic susceptibility) offers a rapid, simple and inexpensive method for comparing the properties of sedimentary deposits. The magnetic susceptibility depends on the amount of ferromagnetic substance (i.e. iron) present in a sample and so can be used to create an environmental fingerprint for matching materials (Dearing, 1999). Whilst grain size is an influence on this, the local bedrock from which sediments are derived is also a major control of magnetic susceptibility (Björck *et al.*, 1982). Hence, if sediments are transported by a jökulhlaup from one area of distinctive local bedrock to another possessing a different bedrock, the transported sediments will exhibit different magnetic susceptibility values to the sediments that were derived locally. It is hypothesised therefore that magnetic susceptibility offers a tool for differentiating between jökulhlaup deposits and other deposits.

Area of study

The study area is the Great Glen in the northwest Scottish Highlands, which experienced catastrophic jökulhlaup flooding during the Loch Lomond Stadial. The flooding originated from a huge glacial lake situated in Glen Roy and Glen Spean, estimated by Sissons (1979a) to have been 35 km long and to have had a volume of 5 km^3. The lake developed behind the Spean and the Treig glaciers, which advanced from the Great Glen and Ben Nevis Range respectively, and acted as a dam. During retreat of the glaciers the water level of the ice-dammed lake dropped in stages from 350 m to 325 m and then to 260 m, evidenced by ancient lake shorelines at these altitudes (Sissons, 1978, 1979b). When the lowest lake level of 260 m was reached, the ice dam failed and flooding ensued (Sissons, 1979a; Russell *et al.*, 2003).

Sissons (1979a) argued that during this initial period of jökulhlaup activity drainage occurred subglacially under the Spean Glacier, flowing through the Spean Gorge before passing under the Great Glen glacier to emerge near Fort Augustus. Here the jökulhlaup deposited sand and gravel on the Auchteraw Terrace, first interpreted by Sissons (1979a) and later by Russell and Marren (1998). The jökulhlaup then discharged into Loch Ness, where it is evidenced by terraces indicating a rise in the loch level (Sissons, 1979a; Firth, 1986). Final drainage occurred along the River Ness and terminated into the Moray Firth at Inverness (Figure 1), where a large sand and gravel deposit up to 39 m thick was deposited, interpreted by Sissons (1981a) as originating from the jökulhlaup.

It is likely that drainage of the Glen Roy/Glen Spean ice-dammed lake after the 260 m level was reached produced the largest flood event evidenced in Great Britain. The flow of the jökulhlaup was estimated by Sissons (1979a), utilising an equation developed by Clague and Mathews (1973), to be of the order of 22,500 $m^3 s^{-1}$. Sissons (1979a) also suggested that the jökulhlaup raised the water level in Loch Ness by around 8.5 m, based on interpretation and measurement of terraces around the edge of the loch. However, a much more detailed study of these terraces by Firth (1986), taking into account the isostatic depression during the Loch Lomond Stadial, revealed that the increase in the loch level was probably closer to *ca.* 4 m. Loch Ness, therefore, can be considered a main depocentre for the Glen Roy/Glen Spean jökulhlaup and thus should provide the best sedimentary record of the event. Indeed, a study of the stratigraphy in northern Loch Ness by Pennington *et al.* (1972) revealed a conspicuous layer of brown sand embedded in grey clay 1.66 m from the surface. This may have been deposited by the same jökulhlaup. Apart from the studies by Sissons (1979a), Firth (1986), and Russell and Marren (1998), who investigated deposits marginal to Loch Ness, jökulhlaup deposits within the loch have not been previously investigated.

Since the bedrock in the southwestern area of the Great Glen (including Glen Roy) generally comprises mica schists, and that in the northeastern Great Glen (including the Loch Ness basin) comprises Old Red Sandstone, it may be postulated that sediments transported by the jökulhlaup from Glen Roy to Loch Ness will be different from those that accumulated from local sources in the Loch Ness basin. Thus, if it can be shown that the magnetic susceptibility values of a sediment flux anomaly in Loch Ness differ from those of other sediments in and around Loch Ness, while showing a strong resemblance to the values

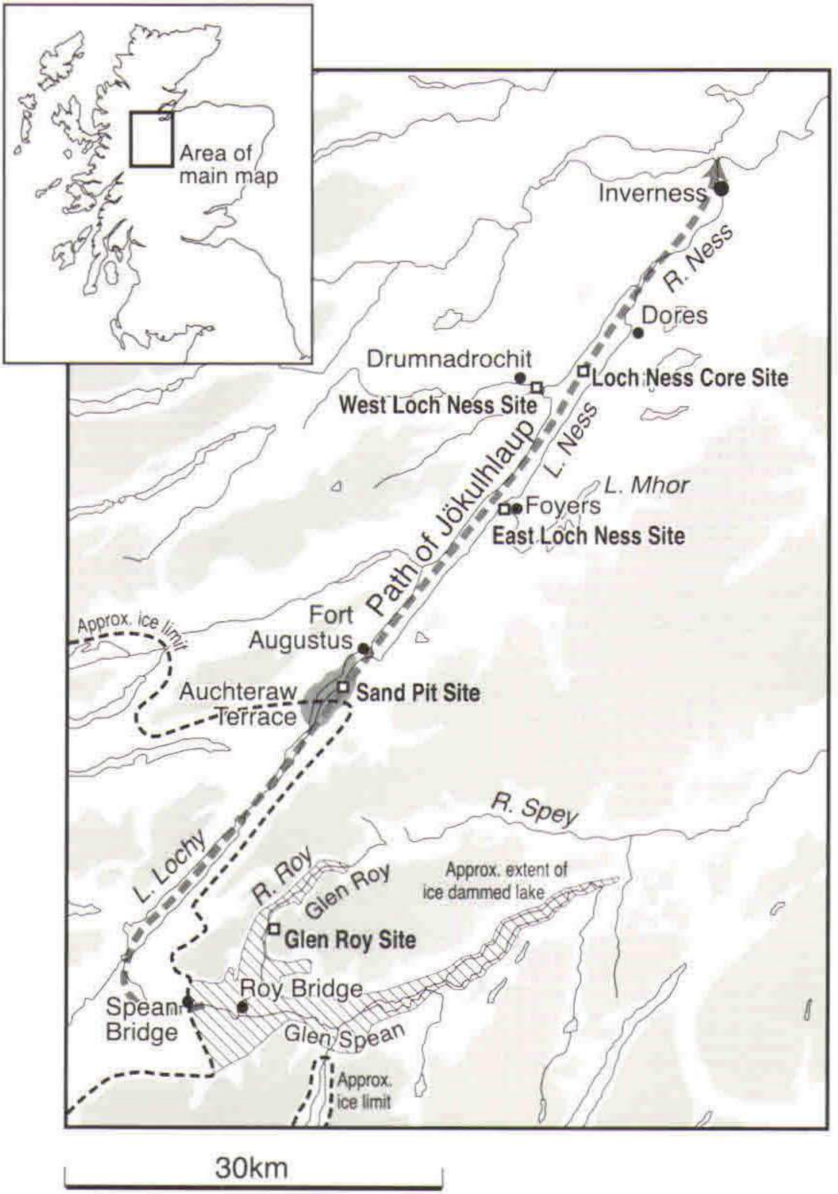


Figure 1. The area of the central Scottish Highlands affected by the Glen Roy/ Glen Spean jökulhlaup. The approximate extent of the ice-dammed lake is indicated by the diagonal hatching. The interpreted path of the jökulhlaup is indicated by the dashed arrow.

found in the Glen Roy area, then it can be inferred that the sediment flux anomaly originated in the latter. This argument would be strengthened if the magnetic susceptibility values for the sediment flux anomaly in the Loch Ness stratigraphy and the Glen Roy deposits are similar to that of an interpreted jökulhlaup deposit located on the Auchteraw Terrace near Fort Augustus (after Sissons, 1979a; Russell and Marren, 1998).

Sampling

A 6 m-long core was extracted from the northern basin of Loch Ness (Figure 1). The core consisted of 4.5 m of laminated gyttja, grading into 3.5 cm of laminated grey silty clay, below which was a sand layer about 1 cm thick and un-laminated grey silty clay to the base of the core (Cooper and O'Sullivan, 1998; Cooper, *personal communication*) (Figure 2). Three AMS ^{14}C dates place the age of the base of the gyttja at *ca*. 9500 yr BP (Cooper and O'Sullivan, 1998) and indicate that the sand layer may have been deposited within the correct time coincident with the Glen Roy/Glen Spean jökulhlaup.

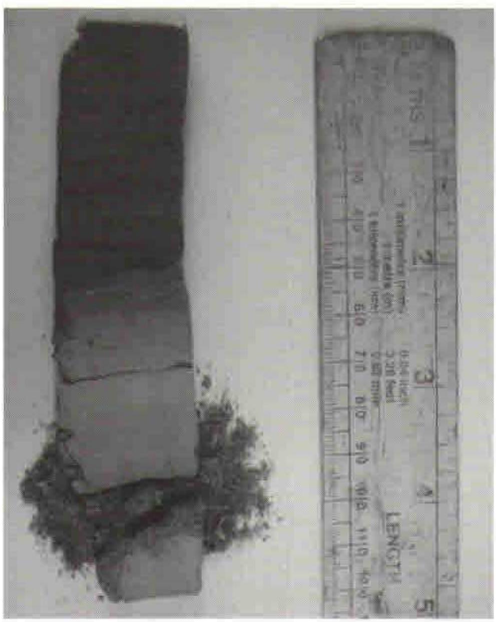


Figure 2. The section of the Loch Ness core used for mineral magnetic analysis. Note the sand layer embedded in the grey silty clay.

A further sample of terrestrial sediment was extracted into a plastic monolith tin from mid Glen Roy (NN 296 861) (Figures 1 and 3). This sample comprised laminated sediments previously interpreted by Peacock and Cornish (1989) as deposits laid down in the former ice-dammed lake. The sediments could be classified as Group I and II laminates, as defined by Miller (1987) by colour, texture and position in the stratigraphy (Peacock and Cornish, 1989). Group I laminates were described as brown to fawn-coloured fine sands and silts that are present at the top of the stratigraphy in Glen Roy. The Group II laminates were grey/blue silts and clays located at the bottom of the stratigraphy. Following definitions of varve morphology suggested by Ashley (1975), Peacock and Cornish (1989) interpreted the Group I laminates as later proximal glaciolacustrine deposits, and the Group II laminates were interpreted as glaciolacustrine deposits laid down in the early stages of rising lake level.

Cores extracted with a Dutch Auger were also collected from two sites around Loch Ness (Figure 1). The first was extracted from the delta where the River Enrick flows into western Loch Ness (NH 523 292). The stratigraphy consisted of an impenetrable layer overlain by 19 cm of un-cohesive, coarse sand (A), 15 cm of sandy clay (B) and 8 cm of organic silt (C). Owing to slumping of the un-cohesive sand from the bottom of the Dutch Auger, the base of the core was poorly sampled. The second core was extracted from a small isolated basin on the delta of the River Foyers in eastern Loch Ness (NH 415 212). The stratigraphy was similar to that of the River Enrick site, comprising an impenetrable base layer, overlain by 10 cm of medium sand (A), 21 cm of coarse sand (B) and 21 cm of silty peat (C). Each layer in both of the cores was sampled.

Figure 3. An exposed section of the laminated sediments from mid Glen Roy. The Group I laminates overlie the group II laminates in the lower part of the sequence. The trowel used for scale is 30 cm long.

An interpreted jökulhlaup deposit comprising laminated sand and gravel (after Russell and Marren, 1998) (Figure 4) was sampled from a sand pit on the Auchteraw Terrace near Fort Augustus (NH 363 081) (Figure 1). Three samples were collected in plastic monolith tins from the finer sediments in the topmost 1 m of the deposits on the most westerly exposure. The first sample was extracted highest in the deposit and mainly comprised coarse sand and fine gravel fractions (A). The other two samples were located lower in the deposit and mainly comprised medium and coarse sand fractions (B1 and B2).

Figure 4. The section sampled from the sand pit neat Fort Augustus. The top 1 m is an interpreted jökulhlaup deposit. The figure used for scale is 1.83 m tall.

Textural and mineral magnetic analysis procedures

Each of the samples from Glen Roy, the margins of Loch Ness and the Auchteraw Terrace was washed through 2000 µm, 600 µm, 212 µm and 63 µm sieves with distilled water. Dispersing agents such as calgon ($Na_4P_2O_7$) were not used in order to avoid oxidising the samples. The contents of the 600 µm, 212 µm and 63 µm sieves and the remaining water were retained and oven dried at <40°C in order to avoid changing the magnetic properties of the sediments (Walden, 1999).

When preparation was complete, the samples were packed into individual pre-weighed 10 ml plastic sample pots and low frequency susceptibility measurement following the procedure of Dearing (1999) was carried out using a Bartington MS2 dual frequency sensor. All measurements were repeated five times to ensure statistical integrity of resulting data. Bulk susceptibility measurements of the individual layers in the Loch Ness core were carried out in order to test if differences in magnetic susceptibility existed between layers. Fractionation and further susceptibility measurements of different fractions were deemed unnecessary because the gyttja, laminated silty clay and un-laminated silty clay layers in the Loch Ness core were within the <63 µm fraction. Fractionation of the sand layer in the Loch Ness core and susceptibility measurement of the different fractions was attempted, as it was apparent that the sediments in this layer were less well sorted.

Results

The large range of results obtained from measuring the bulk magnetic susceptibility of the different layers in the Loch Ness core indicates a range of origins for these layers (Figure 5). This is strange considering that the gyttja, laminated silty clay and unlaminated silty clay were hypothesised to have originated from the same local origin in the Loch Ness Basin. Indeed even the silty clay layers, which appear to be one stratigraphic unit 'interrupted' by the sand layer, yielded distinctly separate results.

Sieving of the sand layer in the Loch Ness stratigraphy revealed that it comprised mainly medium sand (599-212 μm) (67.5%), with a small amount of fine sand (211-63 μm) (20.6%) and much less silt and clay (<63 μm) (3.8%) and coarse sand (1999-600 μm) (8.1%). Too little silt, clay and coarse sand were obtained for fraction specific mineral magnetic analysis to be carried out. Sieving of the other samples provided abundant material for fraction-specific mineral magnetic analysis to be carried out on the >63 μm size fractions.

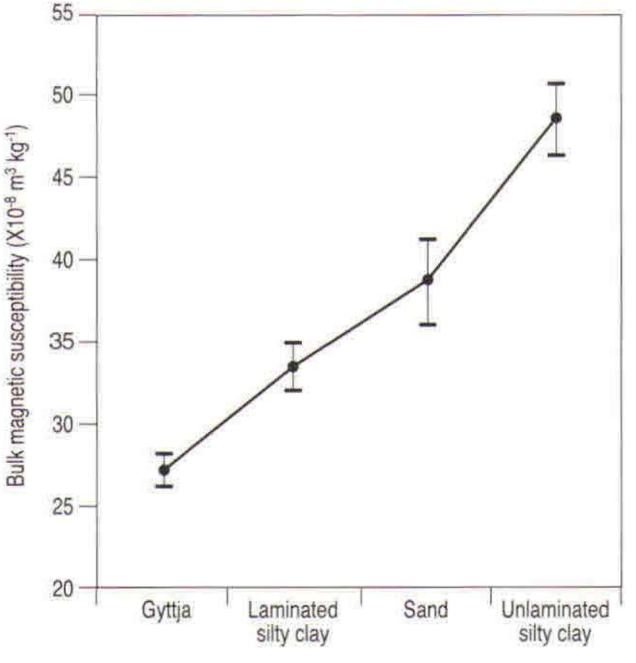
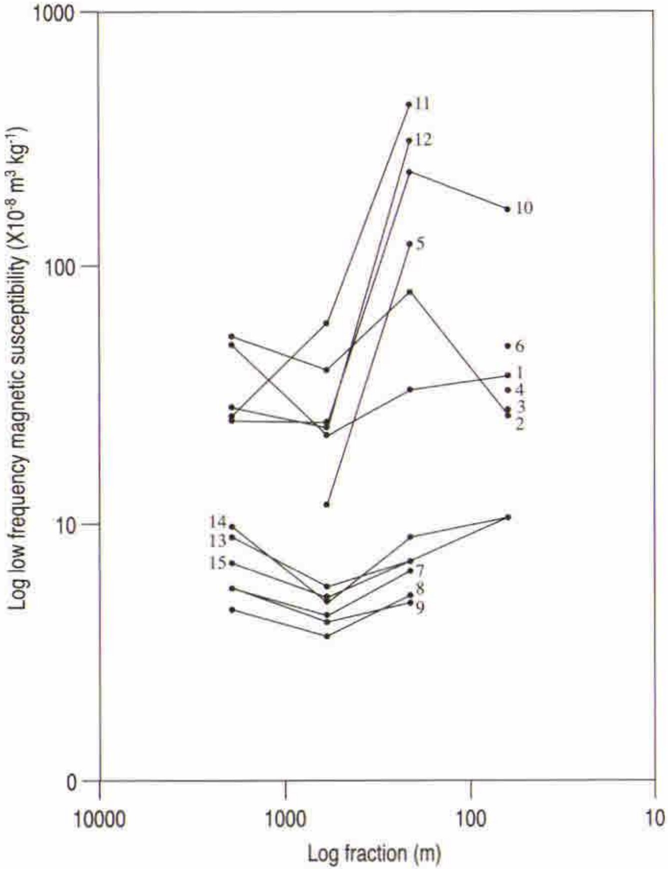


Figure 5. Bulk low field magnetic susceptibility plot for the different layers in the Loch Ness core. The vertical error bars indicate standard deviation.



1 Glen Roy gp I laminates
2 Glen Roy gp II laminates
3 Loch Ness core gyttja
4 Loch Ness core upper grey clay
5 Loch Ness core sand
6 Loch Ness core lower grey clay
7 Loch Ness east A
8 Loch Ness east B
9 Loch Ness east C
10 Auchteraw Terrace A
11 Auchteraw Terrace B1
12 Auchteraw Terrace B2
13 Loch Ness west A
14 Loch Ness west B
15 Loch Ness west C

Figure 6. Fraction specific low field magnetic susceptibility plots for all the samples collected. Standard deviation values for the data can be found in the Appendix.

However, for all the samples collected from eastern Loch Ness, those in the lower part of the sequence from western Loch Ness and those in the lower part of sequence on the Auchteraw Terrace, not enough clay and silt was obtained for fraction-specific mineral magnetic analysis to be carried out. Such a poor range of <63 μm samples makes interpretation of the results problematic.

Fraction specific magnetic susceptibility measurements on the samples indicate that the samples can be divided into two distinct groups, one with distinctly higher magnetic susceptibility results than the other (Figure 6). This highlights a major difference in the magnetic properties of sediments that originated in Glen Roy and those that originated from the area surrounding the Loch Ness basin. The Group I and II laminates from Glen Roy yielded high magnetic susceptibility values, whereas the samples obtained from the western and eastern shores of Loch Ness yielded distinctly lower magnetic susceptibility results. However, the layers in the Loch Ness core and the sediments from the Auchteraw Terrace deposits (which are also located within the Loch Ness basin) yielded high magnetic susceptibility values which are more comparable with those of the Glen Roy samples than with those from the Loch Ness deltaic deposits.

Discussion

The similarities in the magnetic susceptibility results obtained from analysis of sediments from the areas of the same local bedrock in Glen Roy and in the Loch Ness basin, and the differences in magnetic susceptibility results between these two areas highlight the effect of local bedrock on magnetic susceptibility values. As mentioned, the bedrock of southwestern area of the Great Glen (including Glen Roy) generally comprises mica schists and that of the northeastern Great Glen (including the Loch Ness basin) comprises Old Red Sandstone. The results reflect this, because the samples from Glen Roy have high magnetic susceptibility values, whereas the samples from the east and west Loch Ness have relatively low magnetic susceptibility values. Moreover, the high magnetic susceptibility values of the sand layer in the Loch Ness stratigraphy and the interpreted jökulhlaup deposit on the Auchteraw Terrace indicate that these deposits originated in Glen Roy.

This demonstrates that the magnetic properties of these sediments were preserved when they were eroded from Glen Roy and transported by the Glen Roy/Glen Spean jökulhlaup to Loch Ness. It also explains why there is a wider spread of results for the deposits associated with the jökulhlaup, for as the sediments it transported were reworked, they would have become mixed with other sediments and diluted. Hence the magnetic susceptibility values of these sediments would also be diluted. Since the laminated sediments from Glen Roy and the samples from eastern and western Loch Ness are less likely to have been reworked, their magnetic susceptibility values are more uniform. The possibility that the sediments were reworked prior to erosion by the jökulhlaup is considered insignificant because any reworked sediment is unlikely to have been transported from outside of Glen Roy.

The provenance of the deposits does not explain the results obtained from analysis of the gyttja, the laminated silty clay and the un-laminated silty clay layers from the Loch Ness core, which also produced comparable results to the Glen Roy deposits. In theory these sediments should have yielded results similar to the Loch Ness deltaic deposits. Perhaps this anomaly may be explained by these sediments being transported to Loch Ness by the River Oich, which is the largest river flowing into it. The Oich and many of its tributaries flow through the mica schist bedrock of the southwestern Great Glen.

Conclusions

This investigation demonstrates that the sediments in Loch Ness do indeed contain stratigraphic evidence for the Glen Roy/Glen Spean jökulhlaup in the form of a textural and mineral magnetic sediment flux anomaly. It also confirms and develops initial research by Björck *et al.* (1982), concluding that magnetic susceptibility can be used to investigate Lateglacial deposits. It has been shown that fraction-specific low frequency mineral magnetic susceptibility may be used to identify jökulhlaup deposits transported from one area of distinct local bedrock to another. This technique may be applied to deposits in other areas in order to elucidate known or unknown past catastrophic events. However, uncertainty exists over the results obtained from the other layers in the Loch Ness stratigraphy and so further investigation is needed before this technique can be refined. The magnetic susceptibility of different deposits along the Great Glen should also be investigated and compared with those measurements obtained from analysis of the other layers in the Loch Ness core in order to clarify this. Furthermore, a greater amount of material needs to be collected in order to produce a larger data set, particularly for the <63 μm fraction.

Appendix

Standard deviation values from the fraction specific low field mineral magnetic susceptibility results for the samples from Glen Roy and in and around Loch Ness:

Sample	*Standard deviation*			
Fraction (µm)	*2000*	*600*	*212*	*63*
Glen Roy group I laminates	1.7	0.3	0.3	0.2
Glen Roy group II laminates	0.7	0.2	0.3	0.6
Loch Ness gyttja				1.0
Loch Ness laminated silty clay				1.4
Loch Ness sand		1.1	14.0	
Loch Ness unlaminated silty clay				2.1
Loch Ness east layer A	0.6	0.5	0.3	
Loch Ness east layer B	0.7	0.7	0.3	
Loch Ness east layer C	1.5	0.5	0.3	
Loch Ness west layer A	0.2	0.2	0.8	0.4
Loch Ness west layer B	0.4	0.4	0.4	0.4
Loch Ness west layer C	0.3	0.6	0.5	
Auchteraw Terrace layer A	25.2	0.2	0.3	0.9
Auchteraw Terrace layer B1	0.4	0.6	1.1	
Auchteraw Terrace layer B2	0.8	0.5	0.6	

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REPORTS

QRA ANNUAL DISCUSSION MEETING: 'ANNUALLY-BANDED RECORDS IN THE QUATERNARY'

University of Wales (Bangor), 7th–9th January 2004

Day 1

In the first session of the meeting, chaired by **William Austin** (St Andrews), **Juergen Thurow** (UCL) asked "what drives the North Atlantic Climate?" He presented one of two complimentary studies of marine varves from a variety of sites over the last glacial period and the Holocene. Thurow addressed the role of the tropics (and the super-ENSO) in driving the prominent North Atlantic Dansgaard-Oeschger Cycles. Based on the absence of a D-O signal in the Guaymas Basin, western USA, he concluded that there is, at present, no evidence for a tropical influence. This assertion was received sceptically as it is based on a single site, and it was questioned whether tropical records would reveal a high-amplitude signal even if they were driving global climate. **Alexandra Nederbragt** (UCL) demonstrated the strong presence of the Antarctic Circumpolar wave (forced by the presence of ENSO) from spectral analysis of varve-thickness and colour variations from the Palmer Deep between 4000 and 9500 yr BP. This contrasts with preliminary results from the Cariaco Basin, where power spectra suggest that, after the Bolling/Allerod, variability on ENSO-scales shows a decreasing influence relative to that on NAO frequencies.

Such questions regarding the presence and amplitude of palaeoclimatic signals in the tropics calls for an extension of tropical records. The first Keynote speaker, **Alan Kemp** (Southampton) discussed one way of realising this through studying long marine piston cores. Scanning electron microscopy has revealed variability of phytoplankton species and terrigenous input down to the intra-annual scale, and cores such as ODP 848–854, from the eastern equatorial Pacific, potentially record varves in the deep-marine realm. Kemp also outlined, however, the problems associated with inferring the causes of the laminae, their preservation, disturbance and modification, and whether the laminae are annual. Discussion of these issues formed one of the central debates of the meeting.

An ideal record should be annually-banded and have a precise age model. It should also contain a proxy that can be accurately matched to the specific area of study. The nature of such stratigraphic matching was beautifully illustrated by **Konrad Hughen** (Woods Hole, USA) in the John Wiley Lecture. He argued that the use of methane in Greenland ice cores as a proxy for tropical climate has led to the possibly erroneous conclusion that global climate change is not triggered in the tropics. This conclusion is based on deglacial shifts in methane concentrations (i.e. tropical climate shifts) lagging behind those in $\delta^{15}N$ (a proxy for high-latitude climate) by 2030 years (Severinghaus and Brook 1999). It is not that methane does not record changes in tropical climate *per se*, but that it charts changes in wetland extent, i.e. the response of vegetation to climate, and thus is likely to inherently lag climate change. This has been confirmed by results from the Cariaco Basin, tropical South America, a record which can be correlated to GRIP with an uncertainty of <20–50 years. Highly sensitive greyscale records chart the tropical climate change (e.g. terrestrial run-off and influx of terrigenous material; coastal upwelling and ocean productivity) over the entire deglacial period and vary synchronously with $\delta^{13}C$ records, thought primarily to reflect changes in deep ocean ventilation driven by high-latitude atmospheric and oceanographic change. However, vascular plant biomarkers within the annual laminations indicate that tropical vegetation change consistently lagged the deglacial climate shifts by 20–50 years.

Eleanor Maddison and **Catherine Stickley** (Cardiff) illustrated the potential of diatom-rich, seasonally-laminated records from the continental margin of Antarctica to address the dynamics of the glacial retreat of the Antarctic Ice Sheet and, in the case of Palmer Deep sediments, as a record of the disintegration of the Larsen B ice shelf.

After lunch, **Danny McCarroll** (Swansea) took over the role of Chairman and the first two presentations introduced two analytical techniques. **Anders Rindby** (Cox Analytical) outlined the relatively new technique of XRF core-scanning using digital ITRAX technology, which minimises the X-ray scattering volume, achieves resolution down to *ca.*20 mm and provides the potential for high contrast-low noise results. Konrad Hughen had already emphasised the importance of developing proxies which can be analysed from the same sediment sample in addressing issues surrounding the inter-regional phasing of climate change, and non-destructive techniques such as XRF core scanning facilitate this approach. **Damon Green** (New Wave Research) summarised the main instruments used for laser ablation and developments within the new UP266 MACRO, developed for bulk analysis applications such as ICP-Ms and ICP-OES. The applications and constraints of this technique were discussed further by **David Mattey** (RHUL) on the second day of the meeting.

The debate on global climate synchrony and teleconnections is complicated further when the Pacific is introduced into the equation. **Sandy Tudhope**

(Edinburgh) clearly illustrated the role of the Pacific Ocean in ENSO, a phenomenon with a non-stationary frequency and varying amplitude. Annually-banded, tropical corals from Papua New Guinea provide exceptionally high-resolution (±1–2 months over several centuries) records of sea level, water temperature and salinity, river run-off, upwelling/ocean mixing and pollution, and therefore have the potential to address questions surrounding such climate oscillations. Tectonic uplift of 2–3 m ka^{-1} has raised corals of up to 125 ka, revealing that in the past, ENSO was intermediate in magnitude compared to much weaker and stronger signals in the early-mid and late Holocene, respectively. The question of what causes this change in amplitude, whether it is due to a non-linear response to the precessional cycle, is still subject to debate.

At the 2003 meeting, **Takeshi Nakagawa** (Newcastle) presented records from Lake Suigetsu, Japan, indicating a substantial (200 yr) lag of the transition into the 'Younger Dryas' in Japan (Pacific) relative to Greenland (Atlantic). This year he proposed an interesting but highly speculative theory to explain this asynchrony: differential hysteresis between regions can explain leads and lags in response to a common forcing. Testing this theory would involve not only identifying the systems and mechanisms involved but also constructing detailed numerical models for comparison and correlation with annually-resolved palaeorecords: a true challenge to the Quaternary community.

Matthew Jones (Plymouth) illustrated the use of terrestrial lake records in unravelling the varying climatic controls on a single proxy. Comparison of instrumental data with the $\delta^{18}O$ record in lakes in central Turkish reveals the complex balance between the temperature and precipitation signals within this proxy: some lakes show primary control by P/Et rather than temperature.

Eske Willerslev (Oxford) addressed a remarkably different possibility offered by annually-laminated records. Ancient DNA from floral, faunal and bacterial species had been discovered, preserved in New Zealand cave sediments and Siberian permafrost extending back 400,000 years, even in the absence of obvious macrofossils. These genetic records may hold the potential not only to reconstruct past ecosystems but to address questions of species' evolution over these time scales.

After the talks, there was a chance to study posters representing a wide range of disciplines, nationalities and collaborations.

Day 2

The morning session was chaired by **Mike Walker** (Lampeter). In a stimulating and thought-provoking talk, **Mike Baillie** (Queen's, Belfast) reiterated the point that even with accurate dating, interpretation can still be ambiguous. In dendrochronological records, geological events such as volcanic eruptions have long been recognised by the presence of frost-rings or reduced ring density. However, the response is often subject to a time-lag which varies over space and time. Baillie challenged the audience to think against their instinctive scientific reasoning and not to force simple cause-effect relationships. He illustrated how an extreme cold event seen in tree ring records at 540 AD is undocumented in historical records as regards to a cause. The only clue comes from Celtic mythology, which mentions a 'Sky God' rising in the western skies, a phenomenon now thought to indicate a comet passing close to the Earth and a possible cause for the 540 AD event. Baillie revealed the qualitative nature of human perception in the recording of historical events and the uncertainty introduced into scientific study. **Danny McCarroll** (Swansea) noted the need to replicate measurements and dates on tree rings to test the reproducibility and resolution of the techniques used. This should at least produce well-constrained, statistically quantifiable confidence limits on palaeoclimatic estimates, always associated with some degree of natural variability. A multi-proxy approach to climatic reconstruction significantly improves their statistical correlation with climate. Dendrochronological proxies all reveal complimentary climatic information, enabling tree rings to be used as a physical as well as numerical archive.

Keith Briffa (UEA) went on to explore some of the problems and solutions involved in using this archive to its full potential. He discussed how single climate variables may be isolated by studying trees located near to their geographical and climatological limits. Combining the work of a large team of dendrochronologists, he constructed a picture of recent temperature variability across the northern Hemisphere. His talk highlighted the enormous database that exists across much of the northern Hemisphere and the potential it holds, and Chris Turney (Queen's University, Belfast) discussed extending this potential down-under! In an entertaining and visually engaging presentation, Turney outlined a project aiming to use New Zealand kauri (*Agathis australis*) to extend the dendrochronological calibration of the radiocarbon timescale back to the limits of radiocarbon dating, through Oxygen Isotope Stage 3, a time of exceptional climate variability and significant hominid migrations.

Sigfus Johnsen (Copenhagen) summarised the research on Greenland ice cores. He outlined a new chronology for the GRIP core (ss09sea), using sea water corrected isotope values for the accumulation model. He focused on the new North-GRIP (NGRIP) ice core, taken from the ice divide to minimise problems associated with ice flow. NGRIP has been analysed using scanning radiography in order to compile a visual stratigraphy from 10 to 105 ka BP. This reveals considerable band-width down to >83 ka BP and identifies Interstadial 25, never before seen as clearly in ice-core records. Work in progress includes combining the NGRIP signal with that of GRIP and DYE 3, and carrying out between-core comparisons of specific events such as the pre-Boreal Oscillation.

In comparison to palaeoarchives such as tree-rings and varved records, the potential of speleothems and marine molluscs to provide annual information has only recently been recognised. **Julian Andrews** (UEA) introduced the palaeoarchive potential of carbonates by discussing work on annually banded tufas. The seasonal signal they contain is revealed in micrite-sparite alternations, stable isotopes ($\delta^{18}O$ and $\delta^{13}C$, showing strong covariance) and trace element variations (e.g. Mg, Sr, Ba), recording information about temperature, P/Et conditions and changes in CO_2 degassing and calcite precipitation.

Ian Fairchild (Birmingham) described the nature and significance of annual variations within speleothems. Many factors affect the chemistry of the laminae, including variations in air circulation in caves, dripwater chemistry, flow conditions and changes in the mechanism and rate of growth of the speleothem. Annularity has been demonstrated using, among other things, trace element variations. However, concentration changes are seen both between and along aragonite crystals and indeed in some sites the concentration of elements such as Mg, which should reflect hydrological changes, is relatively constant. Such factors provide real challenges to interpreting palaeoclimatic signals.

In developing new techniques it is essential not only to investigate exactly what palaeoclimatic information they may reveal but also to identify the uncertainties within the records. One such uncertainty is whether the laminae are annual. **Andy Baker** (Birmingham) discussed ways to determine annularity from visible and luminescent laminae in speleothems and to maximise the information extracted from such records.

Douglas Jones (Florida) discussed sclerochronology, in particular the use of *Arctica islandica*, 'the tree of the sea', a marine bivalve that can live for over 200 years. It inhabits mid to high latitudes and produces yearly growth bands, thus offering the scope to extend high-resolution, long-term climatic reconstructions out from the restricted areas in which warm water corals grow. **Rob Whitbaard** (NIOZ) explained that although the NAO has the potential to influence the ecosystem in which *Arctica islandica* lives, it seems that shell growth is primarily related to the competition for food rather than directly to climate. However, **Stephen Houk** (Goethe) presented results indicating that shell growth is able to record variations in the NAO. He produced a 245-year record of winter NAO variability, verified by spectral analysis, revealing amplitude bands in agreement with terrestrial and instrumental records. **James Scourse** (Bangor) presented an exciting application of molluscan chronology. Until now, calculations of the ^{14}C marine reservoir effect have been based on single point calibrations using tephra 'isochrons.' The construction of the first geological, cross-matched sclerochronological record for NW Europe (AD1128–1392) offers the potential for ^{14}C dating on more material of known age. This will enable ^{14}C to be used not only as a dating tool but also as a palaeoenvironmental proxy directly related to changes in reservoir age. However, sclerochronology is not without problems. **Chris Richardson** (Bangor) demonstrated that surface striae and growth bands within bivalves, previously assumed to be produced through diurnal changes in illumination, may in fact reflect the tidal regime. Accurate species identification and site selection are therefore essential for constructing accurate sclerochronologies.

On the final day of the meeting, Chris Richardson ran a valuable workshop dedicated to *Arctica islandica*. Participants debated issues about collection methods, curation, ethics and unravelling the nature and possible causes of so-called band 'doublets.'

Although the meeting title appears to directly address the nature of specific records and their high-resolution correlation, **Douglas Jones** pointed out in the Sir Kirby Laing keynote address that "correlation without causality is an exercise in futility." Hence study on the spatial scale is just as important as the temporal scale. Both were exemplified well during the meeting and special thanks and recognition should be extended to the conference convenors, James Scourse, Leon Clarke, Chris Richardson and Fabienne Marret for organising such a comprehensive and fascinating programme.

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THE PHILOSOPHY OF GEOSCIENCES SYMPOSIUM

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The first symposium on the Philosophy of Geosciences attracted more than 80 participants in various disciplines of geoscience, physics, biology and philosophy. Considering its impact and success in the Netherlands, I would like to share our experiences of the symposium with Quaternary colleagues elsewhere.

In the introduction, the organizer of the symposium, **Maarten Kleinhans** (Utrecht University), stressed that disciplines such as biology and economics have a well-established tradition of philosophy, unlike the geosciences, where there is little peer-reviewed literature on the theme. According to Kleinhans, the reason for this is that geosciences are often considered to be descriptive sciences, their methodology merely 'stamp-collecting'. Although it is often possible in geosciences to reduce problems to fundamental physics and chemistry, this is scarcely put into practice, because of 'underdetermination' (see below): before we can physically model processes we must know their boundary conditions, which can rarely be inferred from the geological record.

The geosciences occupy a special position amongst the sciences because of the 'underdetermination' of geo-data. Typical examples include the erosion of evidence, equifinality, difficulties of direct observation (e.g. at the base of glaciers) and the impossibility to determine precise initial conditions of a complex chaotic geo-system in order to predicts its future behavior. Kleinhans pointed out that it seems hard in some fields of earth science to reduce geo-systems to terms of fundamental physical and chemical laws (reductionism) and that one has to be content with a descriptive level of so called 'explanation sketches' (*sensu* Van der Steen and Kamminga, 1991). He defined reduction as 'showing that a complex phenomenon is or can be explained as nothing but an aggregate of more fundamental, simpler phenomena'. Kleinhans posed the central thematic question of the symposium as follows: "How to obtain non-ambivalent and sufficient data for a complete historical narrative and a associated causal explanation of the course of the event, if they have to be inferred from present situations to past ones, or from a limited set of observations to a hypothesis or theory?"

Gerbrand Komen discussed reductionism in meteorology and climatology, illustrating the increased successes, in last 50 years, of a reductionalist approach to weather forecasting. He also emphasized that non-linear processes and the averaging through parameterization of complex smaller scale climatic processes resulted in uncertainties and limitations of predictions. Unexpected climatic factors produce a 'woodworm effect', just as a woodworm in a billiard table may cause a ball to disappear suddenly, due to collapse of part of the table, before the ball is expected to collide with another ball. Physical structures with higher levels of organization may come into existence with their own patterns like El Nino events. Komen concluded that there is no indication that the earth system is not governed by the basic equations of physics, but there is limited understanding and predictability in the climatic system. Therefore in studying climate systems a pragmatic reductionistic approach is followed and much effort is put into quantifying uncertainty on the basis of the laws of physics.

Victor Baker (University of Arizona) gave an inspiring paper questioning the validity of reductionist approaches in geology. He quoted Fairchilds (1904), who stated that geologists have been too generous in allowing other people to make their philosophy for them. According to Baker, this is still the case. After summarising the history of the philosophy of science relevant to geologists, he discussed 'abduction', a term invented by the American Peirce, a late 19^{th} century philosopher in logic with a background in pioneering geophysics (Baker, 1996). Whereas induction derives theories from facts, and deduction derives theories from logical connections, abduction involves postulating (guessing) theories to accommodate the evidence. Those theories that accommodate the evidence the best are considered valid. According to Baker, abduction plays an important role in finding important new discoveries in geology, such as plate tectonics, continental glaciations and meteor impacts.

Henk W. de Regt (Free University of Amsterdam) gave an excellent résumé on reductionism and holism in the exact sciences. Through its means of analyses and simplification, a reductionistic approach has proven to be successful in Newtonian mechanics, Maxwell electromagnetic field theory and quantum theory. De Regt pointed out that physicists are today hunting for the theory of everything, the ultimate reduction of all natural phenomena in a single law. He postulated that branches of geosciences should be reducible to basic physics and chemistry, illustrating this with examples of hydrology, whereby ground water processes can be reduced to Darcenian flow laws. He argued that through bridge principles processes manifest on larger scales can be connected with pure physical and chemical laws by scaling down. The geoscience community ought to focus on formalizing such bridge principles, an issue in geoscience modeling studies. In the discussion that followed, Komen suggested that geological processes are more complex compared to climatological processes and therefore are harder to reduce. Some questioned this point and suggested that due to the shorter time scales in climatology compared to geology underdetermination effects are smaller.

Arno Wouters (Nijmegen University) argued against pure reductionism in a paper entitled 'the autonomy of biology'. Kleinhans had pointed out in his introduction that philosophical problems with reductionism in biology in many ways correspond with those in geoscience. Wouters pointed out that biological principles cannot be directly linked to basic physics and that bridge principles cannot be identified. Biology represents a different type of science than physics or chemistry, and in this respect is an autonomous science. For example, Mendel's principles of inheriting properties through recessive and dominant alleles cannot be reduced to a molecular level. Due to processes acting on a higher 'organism' level it is impossible to judge, on the basis of DNA, whether or not transmission of Mendelian properties is dominant or not. Wouters also argued that evolution theory does not involve reductionist elements; evolutionary principles are the result of the interactions between complex organisms and their environments. This leads to autonomous organic structures, processes and patterns that are not directly controlled by pure physics. Coupling to pure physics seems senseless. Wouters presented two arguments why pure reductionism does not work in biology: (1) higher level processes control which processes are active on the lower (molecular) level and how they are organized; and (2) higher level laws are compatible with but not determined by lower level processes like the organisms' struggle for existence. In the discussion that followed, Wouters noted that the compliance of everything to the laws of physics does not mean that all biological processes or structures are defined by the laws of physics. The discussion considered whether similar complex processes operate in geosciences and whether some geosystems cannot be reduced like organisms in biology. Indeed the increasing realization of geoscientists that biological processes are often intertwined with geological processes seems to suggest that idea. Perhaps geoscientists ought to look more into the philosophy of biology for useful concepts and ideas.

The meeting ended with a plenary discussion which concluded that geosciences include branches with strong reductionist elements like climatology and other branches with more holistic elements, whereby patterns in processes act autonomously (ecology, paleontology) or cannot be correlated back, due to underdetermination, to basic physics (geology). Does this mean that geosciences represent soft sciences using ill-defined and arbitrary methodological principles? It cannot be denied that there is currently an element of this present when witnessing, for instance, how some wiggles are matched. However seminars such as this help to define for geoscience methodological standards and to recognize why some methodologies are successful and why others are fundamentally flawed – the latter degrading its scientific image. Geo-related disciplines like climatology, geology and ecology increasingly rely on each other and interact in order to unravel global processes. Geoscience, involving Earth system sciences, is in this respect a young science integrating all these geo-related disciplines. It seems timely to consider its methodological fundamentals in order to establish it as a mature science to be taken seriously with physics and chemistry. Kleinhans' successful efforts to organize a symposium on the philosophy of geosciences certainly contributed positively to the professional self-awareness of geoscience community in the Netherlands. I look forward to the second Dutch symposium on geoscience, in 2006, and hope that the Quaternary community will be widely represented.

A literature review, the abstracts of the meeting, more explanatory text and useful references are given on Kleinhans' philosophy of geoscience website: http://www.geog.uu.nl/fg/philosophy/

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DATING THE MORAINES IN THE LEONES AND EXPLORADORES VALLEYS, HIELO PATAGÓNICO NORTE, CHILE

Introduction

The glaciers of the Hielo Patagónico Norte in southern Chile are extremely sensitive to climatic change. Well-developed moraines occur throughout the valleys draining the icefield and reflect fluctuations of the outlet glaciers (Harrison, 2003). While there has been considerable work dating the most recent (Little Ice Age) glacial moraines in the area (e.g. Aniya, 1995; Winchester *et al.*, 2001; Glasser *et al.*, 2002), there has been little analysis of the nature or age of the earlier moraines. Although these moraines clearly relate to an earlier expansion in the volume of the icefield, which resulted in the extension of its outlet glaciers, there has been no previous attempt at mapping these nor in assessing their morphostratigraphic characteristics.

The QRA Research Grant allowed us to fund a research project that aimed to analyse the morphostratigraphy and ages of moraines in the Exploradores valley and Leones valleys which drain the northern and eastern flanks of the North Patagonian Icefield (Figure 1). This report concentrates on the moraines identified in the Exploradores valley and places these in a chronological scheme based on their morphostratigraphy. This provides a classification for a subsequent dating programme.

Study area

The Exploradores river system drains the northern flanks of the Hielo Patagónico Norte. The present watershed lies 1 km to the west of Lago Tranquilo. Mountains to the north, south and west nurtured valley and cirque glaciers during the Quaternary and these, at various times, coalesced to produce large valley glaciers. To the south of this valley, the Leones valley runs eastwards for 25 km from the present icefield.

Methods

The geomorphic and morphostratigraphic relationships of the Lago Tranquilo region of the Exploradores valley were established through detailed geomorphological mapping of an area of approximately 35 km^2. Field mapping was carried out using base maps reproduced from the 1:50000 Chilean Instituto

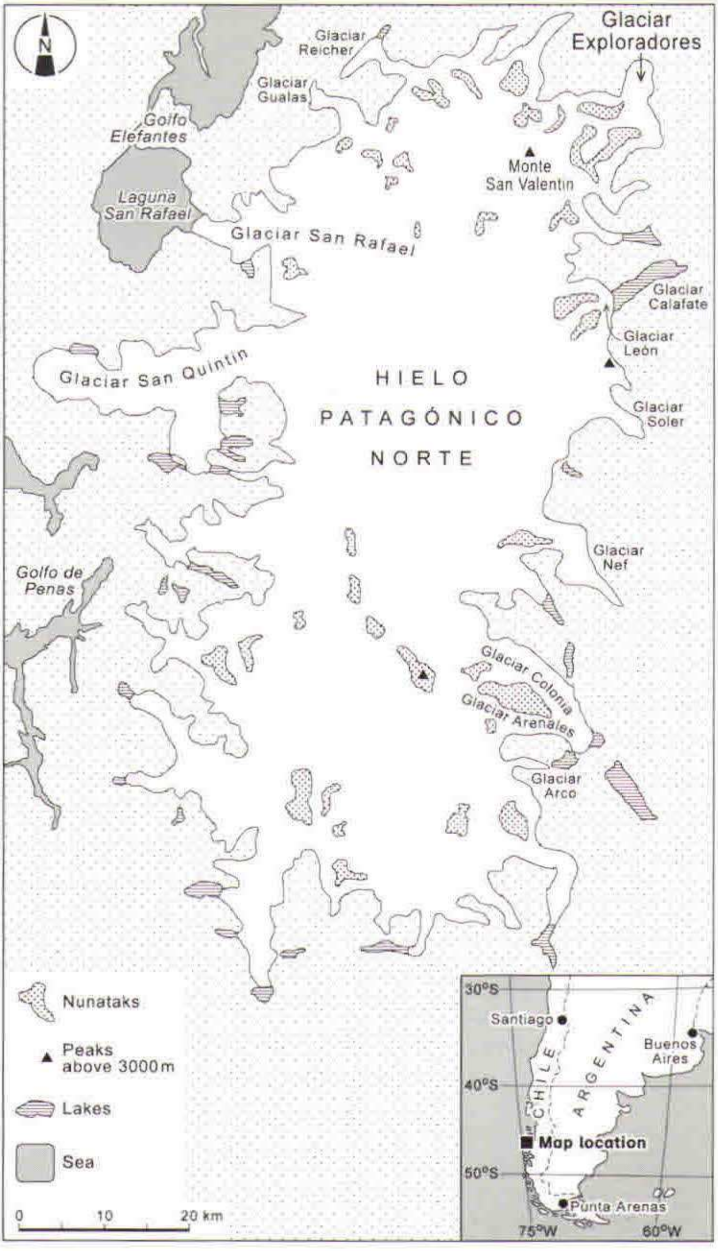

Figure 1. The Hielo Patagónico Norte showing the main outlet glaciers.

Geografico Militar map 4630-7240. In February 2000 we mapped the glacial landforms of the Leones valley in the vicinity of the present ice front, and in March 2003 extended this mapping eastewards from the large terminal moraine which dams Lago Leones. Samples from the moraines and associated deposits in both valleys are being dated using OSL and analysis of cosmogenic isotopes, and build on OSL dating of moraines carried out in 2000.

Glacigenic landforms and sediments in the Exploradores Valley

Glacial landforms in the Lago Tranquilo area can be grouped into four distinct landform assemblages on the basis of their morphological and topographic characteristics (Harrison *et al.*, in press). These are referred to as the Stage One, Two, Three and Four landform assemblages.

Stage One glacial landform/sediment assemblage

Stage One moraines are associated with recent glacier recession and are found at the snouts of contemporary valley and cirque glaciers. The largest of these moraines occurs as a terminal ridge in front of Glaciar Exploradores.

Moraines of similar morphology and relationship to contemporary glaciers are widely reported from other glaciers of the Hielo Patagónico Norte and dated by lichenometry and dendrochronology to the "Little Ice Age" (e.g. Winchester and Harrison, 1996; Winchester *et al.*, 2001).

Stage Two glacial landform/sediment assemblage

Stage Two moraines are restricted to <20 m high sharp-crested terminal moraines deposited at the mouths of tributary valleys at altitudes above *ca.* 850 m above sea level. It is clear that these moraines and sediments are older than the 'Little Ice Age' moraines developed in the region. However, their small size and position suggest that they reflect a short-lived climate deterioration, probably during the latter part of the Holocene.

Stage Three glacial landform/sediment assemblage

Stage Three glacial deposits and landforms form large (c. 100 m high) sharp-crested terminal and lateral moraines and are mainly found to the west and south of Lago Tranquillo. Several of the lateral moraines form multiple features. Boulders are common on their surfaces and up to 8 m or so in height; many are weathered with considerable spalling of surface layers. The altitude of these landforms falls from 600–900 m above sea level in the east of the area to 400 m above sea level further west.

The landforms and sediments associated with Stage Three moraines reflect a glacial advance which was restricted to tributary valleys and large cirques. Whilst the age of this event is not clear as yet, we can speculate that it represents a significant climatic deterioration during the Holocene or the Late-Glacial. In the Leones valley to the south, the large glacial moraine damming the eastern side of the Lago Leones has been dated to *ca.* 3000 years BP using OSL dating of lacustrine sediments 5 m below the crest of the moraine (Winchester *et al.*, unpublished data) and it would be surprising if such a glacial event was not represented in other valleys draining the icefield.

Stage Four glacial landform/sediment assemblage

Stage Four depositional landforms include moraines; drift hummocks; bedrock-cored ridges; large fans and kames, and their associated sediments. These are concentrated in an area 1–2 km to the west, south and east of Lago Tranquillo. Since these landforms and sediments cover a large area of the landscape they are described here collectively as a "morainic surface". The morainic ridges are very broad with low relative relief and with an absence of boulders on their surfaces. These deposits are restricted to below 500 m above sea level.

Collectively, these landforms and sediments comprise a main valley glaciation event. To the west and north of Lago Tranquillo, the valley glaciers have produced a landscape dominated by glacial erosion of bedrock. The few drift landforms developed in this eastern sector of the valley comprise Holocene alluvial and debris cones at the mouths of tributary valleys. The only well-developed moraine here occurs near the present snout of Glaciar Exploradores and this is interpreted here as being younger than Stage Four.

Discussion

The dating of these moraines is nearly complete. We have obtained an age of 3000 years BP for the terminal moraine damming Lago Leones and ages of 10,000–11,000 years for glacial deposits in the Exploradores valley. Further determinations will allow us to develop a glacial chronology for this climatically-important region.

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LUMINESCENCE DATING OF LOESS DEPOSITS IN WESTERN EUROPE

Background and rationale

This study seeks to establish the extent to which variation in loess-palaeosol geochemistry can be used as an index of climate change in northwest Europe during the Weichselian glacial stage. It is based on two sites with clear and readily-accessible loess exposures: Harmignies (Belgium) and Koblenz-Metternich (Germany). Previous work at these sites (e.g. Boenigk and Frechen, 2001) shows that the loess was deposited during the Weichselian, overlying soils formed during the Eemian interglacial (Oxygen Isotope Stage 5e). In common with many other loess deposits, the apparent homogeneity in vertical profile at both sites conceals variations in sedimentology and other characteristics, which reflect alternating episodes of loess deposition (linked to stadials) and soil formation (linked to interstadials).

Geochemical analysis has shown that on the Chinese Loess Plateau, interglacial palaeosols are depleted in mobile elements compared to the parent loess material (e.g. Diao and Wen, 1999). This study seeks to determine whether a similar depletion process occurred at Harmignies and Koblenz-Metternich during the relatively brief periods that characterise interstadials. The major, minor and rare-earth element compositions of closely-spaced sample sequences will be used to examine element mobility. The study will also compare the geochemical data with the results of sedimentological and mineral magnetism analysis.

The New Research Workers Award was used to pay ferry and petrol costs for an 8-day trip during which luminescence samples and supporting field data were collected from both sites, plus magnetic susceptibility data and supplementary samples. It is important to establish a rigorous chronology based on luminescence dating since this will allow the intended geochemical index to be compared against other indices of climate change in the northern hemisphere, including data from ice and ocean cores. In this way, it may be possible to match the study data against the known sequence of stadials and interstadials.

Previous chronological investigations used thermoluminescence (TL) and infra-red stimulated luminescence (IRSL) multiple-aliquot additive and regenerative-dose protocols to examine fine silt polymineral fractions. This study seeks to enhance that chronological control through the use of other luminescence techniques. Discordance in TL and IRSL ages, as at Koblenz-

Metternich (Boenigk and Frechen, 2001), may be attributable to partial bleaching and leads to the supposition that these IRSL ages represent only maximum ages. However, those IRSL ages may be underestimates since the feldspar signal dominates the IRSL response and feldspars are subject to anomalous fading (Wintle, 1973). This process has never been detected within quartz. This study has, therefore, isolated quartz grains in the 5–15mm (fine silt) fraction from 20 master samples by fluorosilicic acid pre-treatment and is determining the luminescence ages of this fraction. Further luminescence age estimates will use the fine silt polymineral sample from the same 20 samples but will incorporate a procedure proposed by Huntley and Lamothe (2001) that attempts to correct for anomalous fading.

In addition, the use of multiple-aliquot protocols to evaluate the total dose exposure can generate inaccurate and imprecise ages due to inherent complications arising from inter-aliquot normalisation and sensitivity change. A single-aliquot regenerative dose protocol identified by Murray and Wintle (2000) circumvents these complications, providing accurate and precise estimates of total dose exposure, and will be used to produce further age estimates.

Results and significance

Preliminary results for Koblenz-Metternich show that the earliest sample, taken from the 'loess marker horizon' (Boenigk and Frechen, 2001) at a depth of 18.7 m, provides an age estimate of approximately 66 ka. This corresponds closely to the Rousseau *et al.* (1998) age estimate of 64.9 ± 6.9 ka for a layer of aeolian fine-grained dust in eastern France. This is also found in central and eastern Europe, and Rousseau *et al.* suggest that the climate change which drove Europe from grassland and woodland to barren Pleniglacial landscapes at the OIS 5a/4 boundary may also have caused continental-scale dust storms.

Samples taken above that horizon show a progressive decrease in age and the highest sample currently dated gives an age estimate within OIS2. Some samples show age anomalies but this will be the subject of further investigation. These dates compare favourably with those previously reported for this site.

Acknowledgements

The author is grateful for the financial assistance provided by the QRA New Research Workers Award Scheme. Thanks are also extended to Phil Toms as supervisor and for his support in luminescence work, to Mr Alain Canivet at Crayeres, Cimenterie et Fours a Chaux d'Harmignies and to Mr Manfred Flöch at Koblenz-Metternich.

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GROUND-PENETRATING RADAR ANALYSIS OF ICELANDIC SEDIMENT

Background and rationale

This project forms part of a larger investigation of sedimentary environments in front of nine Icelandic glaciers of both surge- and non-surge-type. The work involves integrating ground-penetrating radar data with macro- and micro-sedimentological analyses. Ground-penetrating radar (GPR) has recently become a valuable geophysical tool for determining subsurface stratigraphy in glacial sedimentary environments (Bristow and Jol, 2003). Before the use of GPR, a mainly sedimentological approach was taken, involving qualitative logging and quantitative descriptions of units and boundaries of the subsurface stratigraphy. GPR is a non-destructive quantitative tool that allows the acquisition of high-resolution data that can be used to reveal 2D profiles of subsurface stratigraphy that is inaccessible for logging, as well as 3-dimensional views of sediment stratigraphy. Because GPR techniques in glacial sediments are still in their infancy, there is a need to combine GPR data with conventional logging.

This specific project is an investigation of sediment stratigraphy in the forefield of Fláajökull, an outlet glacier of the Vatnajökull Ice Cap in southeast Iceland. The site is a 100 m cross-section oriented parallel to glacier flow through a terminal moraine ~40 m from the present-day ice front that has been exposed by meltwater channel incision. The techniques employed involve a macro-sedimentological component, including identification of lithofacies, clast fabric, clast shape, and particle-size distribution; a micro-sedimentological component, involving preparation of thin sections and analysis of microfabrics and microstructures; and a geophysical component (GPR) which this award funded. These GPR profiles were then compared to the logged stratigraphy of the area beneath the radar profiles.

Results

A PulseEKKO 100 GPR system was used with 50 and 100 MHz antennas. The parameters for collecting and processing the data are displayed in Table 1.

Frequency (MHz)	Step size (m)	Antenna Separation (m)	Pulse Voltage (V)	Number of of Stacks
50	0.5	2	400	16
100	0.25	1	400	16
Frequency (MHz)	**Survey Mode**	**Gains**	**Filters**	**Correction**
50	Reflection	AGC	Down-the-trace	Dewow
100	Reflection	AGC	Down-the-trace	Dewow

Table 1. Parameters of GPR collection and processing, including Automatic Gain Control (AGC) to a maximum value of 150 X the recorded signal value, a three point moving down-the-trace average, and dewowing.

Only 20 m of the 100 m GPR profile were accessible for logging as the river was actively undercutting the remaining 80 m. The three logged exposures are presented in Figure 1 and described in terms of their lateral correlation. Using the macro-sedimentological data, three lithofacies were identified. The lowermost unit is a massive clast-supported boulder-gravel with clays draping and filling the porespace between the clasts. Above this is a lens of interbedded sands and gravels extending between 5 and 25 m along the profile. Overlying this is a brown fissile diamict facies. These facies are provisionally interpreted as hyperconcentrated stream flow deposits, plane bed stream deposits, and till respectively.

The GPR profiles of the first 30 m containing the logged exposures are shown for the 50 MHz and 100 MHz antennas in Figures 2A-B and for the full 100 m using the 50MHz antenna in Figure 2C. A common midpoint (CMP) survey was used to calculate a penetration velocity of 0.07 m/ns for this material and place a depth scale on the profiles. Topography from a levelling survey was also applied. The 50 MHz profile (Figure 2A) shows lower resolution but deeper penetration to a maximum depth of ~4 m, whereas the 100 MHz profile (Figure 2B) displays higher resolution but shallower penetration to a maximum depth of ~2.2 m. Each of the profiles show a distinct reflector, or set of reflectors, at ~2 m depth. This is most likely due to the dialectric difference between the lower clay-rich boulder-gravel and the overlying sediment. The boundary between the interbedded sands/gravel facies and the overlying diamict facies may have been detected, but is too close to the lower boundary (~20 cm) to produce a separate signal. Figure 2C shows the lateral extent of the 50 MHz profile to 100 m. Unfortunately, the signal from the lower clay-rich boulder-

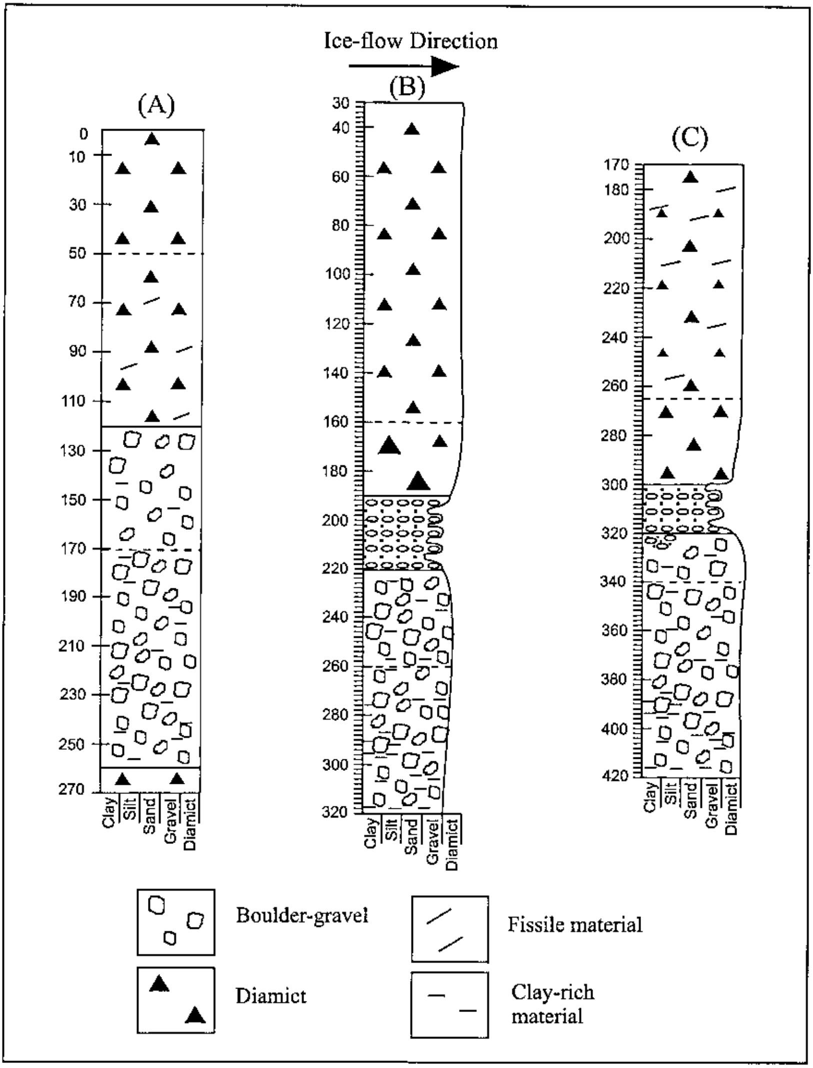

Figure 1. Sediment logs at (A) 0m, (B) 10m, and (C) 20m along GPR profile. The depths are true depths from the surface of the landform and correlate to the depths on the GPR profiles of Figure 2.

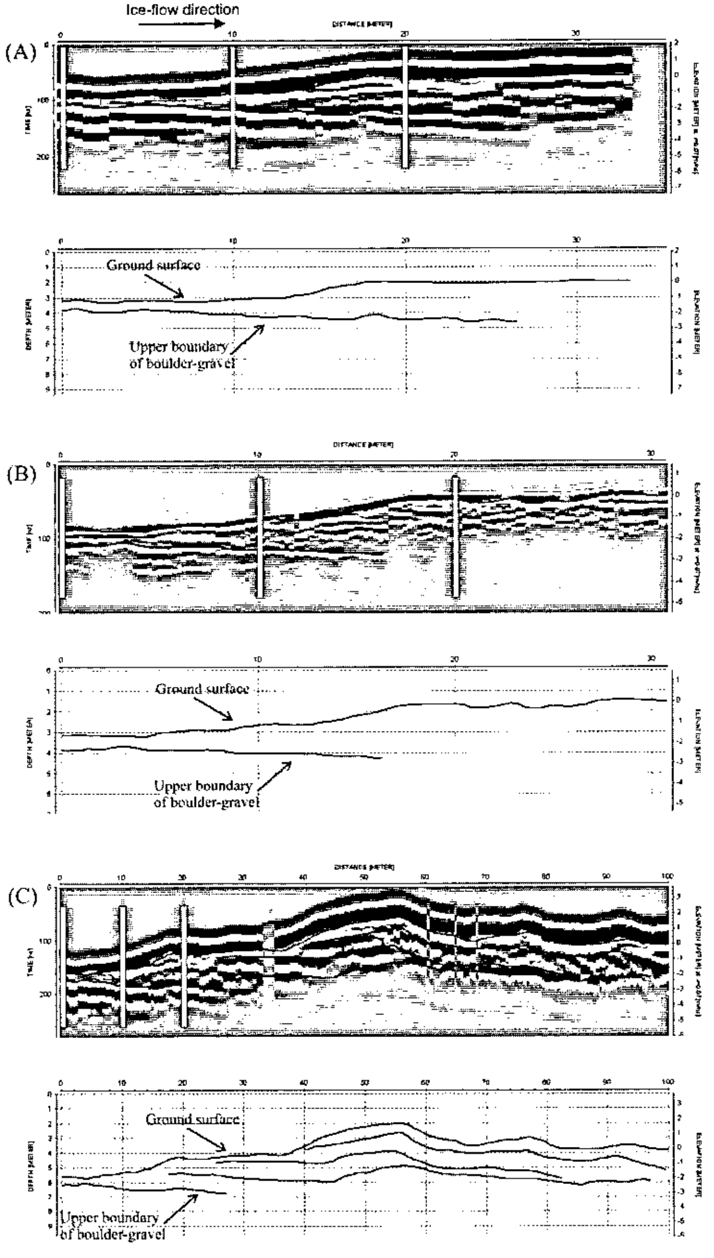

Figure 2. (A) 50 MHz GPR section. (B) 100 MHz GPR section. (C) 50 MHz GPR section for 100m line. The sedimentary logs from Figure 1 are numbered above the GPR profiles.

gravel is lost as the thickness of the section increases, although other reflectors are observed extending along the section.

One difficulty in working in glacial environments is the presence of clay. As the radar travels through clay-rich material, the signal is scattered and the signal strength diminished. As sediments in glacial environments are often clay-rich, this loss in signal strength potentially poses a problem. Another difficulty is that the sediments tend to be water-saturated in glacial environments. Even with the application of filters and gains, this may also produce significant attenuation of signal strength.

Conclusion

The proglacial sediment in front of Fláajökull is dominated by diamict, sands and gravels, and boulder-gravel, which have significantly different dialectric properties to be detected by the radar. Although clay and water affect the signal strength, this study has shown that GPR, when coupled with sediment logging, is a useful tool for identifying subsurface sediment stratigraphy.

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REVIEWS

QUATERNARY OF NORTHERN ENGLAND

By D. Huddart and N.F. Glasser (2002)

Geological Conservation Review, Joint Nature Conservation Committee, 745 pp.

ISBN 1861074905; Price £70.00

This is volume number 25 in the Geological Conservation Review (GCR) series formerly published by Chapman and Hall and now part of the Kluwer partnership with the Joint Nature Conservation Committee. It therefore follows in the footsteps of other regional Quaternary reviews of Scotland, Wales, South-west England and The Thames. The remit of these volumes is to highlight geological and geomorphological sites of national and international importance by presenting their current state of scientific knowledge and their worthiness for conservation. It is written to "provide a public record" and as such seeks to walk a difficult line between writing a detailed and balance scientific summary of sites for the Quaternary Science community and also making this information accessible to a non-specialist audience.

As highlighted by this volume, the North of England has a rich and varied Quaternary record, albeit heavily biased towards the Late Quaternary. The consequence of this is that for the purchase price of £70 you get a substantive volume consisting of just under 750 pages. This is structured essentially into 6 sections over the course of 8 chapters. The first 3 chapters outline the rationale behind the GCR series, the criteria for site selection and the baseline knowledge of what is understood about the pre-Quaternary landscape of northern England. Included within this initial section, aimed at the non-specialist, is a chapter which concentrates on defining the Quaternary and its divisions, followed with brief explanations of a slightly eclectic collection of records ranging from the Chinese loess and north Atlantic records to global sea-level change and the oxygen-isotope record.

Chapters four, five, six and eight each deal with a timeslice, starting with the pre-Devensian, then Devensian glacial record, the Late-glacial record and finishing with the Holocene record. Each chapter has an introductory section which overviews events during these time periods, drawing on GCR listed sites and other sites both within and outside the region. This is followed by individual sites, in no discernable specific order, whose records are described. The latter is approached both from the perspective of showing how scientific ideas associated with sites have changed and evolved but also attempts to indicate where areas of controversy exist and where there are gaps in understanding. This is no mean feat to achieve in the space provided for each site and also in a neutral fashion. Each site report is then concluded with a summary aimed at a wider non-specialist audience and some justification of why the site is important and should be conserved as part of our national heritage. Clearly not all arguments and areas of controversy can be explained fully and maybe it is unfortunate that some old ideas are once again aired and perhaps given credence, whilst others are not mentioned, for example the debate over the southern margin of the Dimlington Stadial ice-sheet in the Vale of York or drainage of pro-glacial Lake Humber. This could just reflect my own bias. Likewise the large majority of the sites selected for inclusion are geological (e.g. lake/kettle hole/peat records) rather than geomorphological; Dimlington moraines are only obliquely represented by the Tadcaster basin. But then I expect, like me, most people have pet sites that they would have liked to seen included, and the rationale of the book is to try and balance representative features with conservation potential at a national level.

Overall, structuring of the book into timeslices has a downside when it comes to the description of complex sites spanning more than one time period. They are, for obvious reasons, only listed once in the volume; but perhaps, with an eye to maximising the utility of this reference volume, more cross-references in other chapters could have been made or a separate appendix given listing all sites with deposits falling in given time period. In a similar vein, whilst OS grid references are given for all sites, and it doesn't pretend to be a fieldguide, the figure showing sites contained in the volume is buried on page 6 (not ideal for quick referral or those not familiar with the geography of northern England) and site numbers used in this figure do not appear in the site text. One slight oddity is chapter 7, which bucks the chronological approach of the rest of the volume by being devoted solely to periglacial landforms and slope deposits. No justification for this elevation in status of periglacial evidence is made. Whilst its perhaps understandable given the uncertain nature of tor formation and their antiquity, this is not the case for many of the other periglacial sites listed. The book concludes with an extensive bibliography, a glossary (helpful for the non-specialist), a fossil index (alas, no common names are given) and a good index.

It would be all too easy to find gaps or fault with a compilation of scientific information of this magnitude, especially now a few years have elapsed since the literature review was carried out. However, to find fault in this way would belittle the huge endeavors which have clearly been made in putting this volume together. Just having so many classic regional Quaternary sites described in detail in one volume with a comprehensive bibliography is of great use. Published information has been complimented with additional photographs and new figures, whilst for many site the key original published figures have been reproduced. As such this volume provides a useful reference volume as a starting point for both researchers and students alike.

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CLASSIC LANDFORMS OF THE COAST OF THE EAST RIDING OF YORKSHIRE

by Ada W. Pringle (2003)

Series editors: Chris Green, Michael Naish and Sally Naish

Published by the Geographical Association (in conjunction with BGRG) , 64pp.

ISBN 1 84377 071 7; price £9.99

At a time when schools are reviewing their priorities in the light of recent court cases involving fieldwork negligence, it is good to see this new initiative from the G.A. confronting this trend and encouraging us actively to pursue responsible field studies. Paper-swamped, performance-driven and pastorally-distracted, beleaguered teachers will welcome this new field study aid. Lawson (2000) and Farrow (2003) have called for greater liaison between the QRA and schools, recognising the need to disseminate Quaternary Science more effectively to the teaching community. How well does this guide fit their criteria?

The Coast of the East Riding of Yorkshire is the first in a new generation of G.A. *Classic Landforms* building on the success of the earlier series. The most obvious visible differences are a slimmer size (better suited to field use), the inclusion of colour diagrams and photographs, and, with the support of the Ordnance Survey Education Team, integrated extracts from the 1:50,000 Landranger maps. The series editors set out their brief: to provide a concise, simple and informative guide to help students and visitors to a better understanding and appreciation of the landscape. The target readership therefore is both educational groups and the general public, with a view to distilling recent research in a user-friendly form.

The author (Ada Pringle née Phillips) draws on many years of her own teaching and research in this area (Phillips, 1963; Pringle, 1981, 1985) and has had the opportunity, in this book, to bring the QRA Field Guide on East Yorkshire and North Lincolnshire (Bateman *et al.*, 2001) to a wider audience.

The style of the guide is much improved on its monochrome predecessors, but the quality in some photographs is faded and poorly-focused. It might have been enhanced by more panoramic aerial views. Apart from one spelling error (p.16) the typography is accurate. Graphics and maps are clear and attractive, with good cross-referencing. The inclusion of 'access and safety' sections is helpful, as always, and almost mandatory these days. As in the previous series, a glossary provides a useful appendix, but the selection of vocabulary seems inconsistent. Some terms are defined (sometimes awkwardly) in the text (e.g.

B.P., imbricated, clast, rhythmite, permafrost): why are these not assigned more tidily to the end? Some unnecessary duplication occurs (e.g. abrasion, wave refraction). Some terms do not need explanation (e.g. O.D., algae, quarrying). Some technical terms are not defined at all, either in the text or glossary (e.g. Devensian, Holocene, stadial, interstadial, extensional fault, mud drape, calcrete, dilation, Chart Datum). For a wider readership, greater clarity would seem to be needed.

After a brief introduction, the Chalk stratigraphy proves rather heavy-going for the non-specialist, before we move on to the Quaternary stratigraphy. A clear geological section across the Wolds and Holderness Plain might have set the scene better. My main concern, however, is that (unlike earlier *Classic Landforms*) there is no chrono-stratigraphic table. This would seem to be an essential reference point for the whole field guide. Is it not important that both general public and student should have a clear understanding of the time frame in which Quaternary studies are now firmly fixed? There is no attempt to explain the oxygen-isotope chronology, and the Devensian stadial-interstadial pendulum is not at all obvious.

Following this lengthy review of rock properties, the author turns her attention to marine processes. I did not find the explanation of tidal stream flow (p.19) or wave energy (p.21) clear; will the unaided reader find their way? An 8-figure grid reference (p.23) is both unnecessary and difficult. From here on, the reader is taken on a systematic journey southwards, with interesting insights along the way. I was rather disappointed with the Sewerby section, which was too short in my opinion. The juxtaposition of aeolian, glacial, proglacial and periglacial sediments here tells a fascinating story. A more serious omission, however, is the failure to establish a clear glacio-eustatic context. The reader is given no framework for relative sea-level change with which to make sense of this significant site. Context is again lacking in the interesting Barmston section. How does the sandur and lake sequence relate to Sewerby, merely 10 km away? The pro-glacial rhythmites could have been photographed in detail, and their seasonal interpretation discussed. Is the lower till Basement Till, Skipsea Till or Withernsea Till? Only the more careful reader will spot the answer (in the caption to Photo 6).

The author moves southwards to the famous (or infamous) Mappleton cliffs – so beloved of textbook writers and syllabus compilers. Her own research on 'ord' evolution makes interesting reading and is a useful tool for explaining longshore movement and cliff stability. The final section – Spurn Head – is detailed but unbalanced in my view. A disproportionately long account of its history, occupying six pages, three maps and two tables, seemed to squeeze out other nagging questions. I would have preferred more coverage of recent research on Holocene sedimentation and sea-level change. The description of spit evolution was not set in its postglacial eustatic context. The guide book ends abruptly at this point, without any concluding remarks. The future prospects of Spurn Head are alluded to, but the reader might have benefited from the author's insights into the broader issues of conservation and coastal management in the face of global warming.

Have the series editors succeeded in meeting the needs of students and general public alike? Will *The Coast of the East Riding of Yorkshire* reach its target readership? At £9.99 it is reasonably priced, and will be a useful addition to the armoury of the time-pressed teacher, but his or her students will require further clarification and context at various points. The unaided layperson may not find it so accessible as the editors had hoped.

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CLASSIC LANDFORMS OF THE LOCH LOMOND AREA

by David J A Evans and Jim Rose (2003)

The Geography Association, ISBN 1 84377 072 5

Over the past ten years I have been a keen reader of the 'Classic Landforms' series and have used several of them as very useful accompaniments when I have visited various parts of the country. It was therefore with a great deal of anticipation that I read this latest book in the series so as to renew my interest in the Scottish Quaternary. My own knowledge of the Scottish Quaternary is limited, confined to a typically inspirational series of undergraduate lectures by D.Q. Bowen in the seventies and an excellent fieldtrip to the south-west Highlands with John Lowe and Andy Haggart in the eighties.

This guide commences with an introduction that consists of a concise description of the pre-Quaternary geology followed by an extensive account of Quaternary events. There is an excellent table relating the litho and morphostratigraphy with the palaeogeography and the chronostratigraphy. There is also a clear explanatory diagram on peat-bog stratigraphy both inside and outside Loch Lomond Stadial limits, and a superbly detailed geomorphological map of the southern Loch Lomond basin.

Nine sub-regional chapters discuss the varied geomorphorlogy and features of different site areas of the region. Three of these chapters (the Campsie Fells, Drumbeg and Gartness and the western Forth Valley) are especially detailed. The others are chosen for their distinctive landforms, for example, ice-moulded whalebacks at Rowardennan Pier, detached slab and chasm at The Whangie, and kame terraces and eskers east of Conic Hill, plus Croftamie, the type site of the Loch Lomond Stadial. All chapters have superb photographs and diagrams, and this in my opinion is the great strength of this guide. It offers a range of explanatory diagrams that will greatly benefit able sixth-formers (such as the types of former glacial limits and whalebacks), as well as Quaternary professionals (such as the outstanding reconstructions of the Drumbeg quarry and the moraine ridges of the western Forth Valley).

Overall this book is exceptional, with the chapters on Drumbeg and the western Forth Valley being of an especially high order. A further plus for sixth-form students and schools is the referencing by Evans to several papers in *Geography Review,* which any good school geography department should possess. Having been 'brought up' in the Quaternary of west Wales with a distinct scepticism of morphostratigraphy, I believe that this guide illustrates its importance in Scotland, especially when underscored by lithostratigraphy, as at Drumbeg. It has also emphasises the contention that to improve one's Quaternary perspective and avoid becoming uni-dimensional it is an absolute necessity to visit various parts of the British Isles. I fully intend to visit Loch Lomond in the near future.

Without being too churlish, however, possible improvements would be the addition of two extra explanatory diagrams in the introductory chapter: one showing isostatic depression and rebound, which will be of special benefit to sixth formers, and the second a series of palaeogeographic maps (similar to Figure 5) showing relative sea level from the end of the Dimlington Stadial to the present day. These would enhance understanding of the varying relative magnitude on sea level of isostatic and eustatic forces throughout the period. I well remember as an undergraduate reading several times over the works of Donner and Sissons in order to understand this.

It must also be said that the authors of this outstanding guide are badly let down by poor editing with respect to the addition of 1:50,000 OS map extracts. The Conic Hill extract is mostly centred over Loch Lomond itself, with three of the features and their associated grid references not being on this map. The Campsie Fells extract has no Northings, whilst the Drumbeg/Croftamie has no Eastings and is also in the wrong chapter. A really imaginative use of OS map extracts would have been the use of the 1:25,000 maps in the Menteith area to see if the 5 m contour interval shows the parallel, cross-valley, morainic ridges. The authors deserve much better.

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THE HOLOCENE EVOLUTION OF THE LONDON THAMES: ARCHAEOLOGICAL EXCAVATIONS (1991-1998) FOR THE LONDON UNDERGROUND LIMITED JUBILEE LINE EXTENSION PROJECT

By Jane Sidell, Keith Wilkinson, Robert Scaife and Nigel Cameron (2000)

MoLAS Monograph 5, 144pp.

ISBN 1 901992 10 1

The landscape of London will be familiar to many, if not most readers of the *Quaternary Newsletter*. For many of us, London is a place of concrete and tarmac, slightly improved by some attractive buildings (which provide some interest for geologists). It might be expected that everything of interest to Quaternary scientists has been destroyed by the deep foundations of tall buildings, or is inaccessible.

Not so! In fact, there is a long history of Quaternary research in London (see for example, Gibbard 1985, 1994, or Bridgland 1994). Much of the research to date has been concerned with the longer term (mainly pre-Holocene) development of the Thames, or with more traditional archaeology. Although there have been tantalising snapshots from a limited number of sites, the environmental development of this important area has been understudied.

This monograph is a major step towards understanding the postglacial history of the middle and lower Thames. It builds on previous work (e.g. Devoy 1979), with new data from a suite of palaeoenvironmental techniques. Importantly, the palaeogeographical context of the information is carefully considered.

There are nine chapters, plus an appendix and French and German summaries. The first three chapters provide the background to the project, why it was possible, consideration of previous work and an outline of the approach taken. Chapters 4–6 present accounts of the work completed in Westminster, west Southwark and Rotherhithe and Canning Town. There is a real abundance of paleoenvironmental data here, principally site stratigraphy, sedimentology, pollen and diatom analyses and, where possible, dating. This may prove heavy going for non-specialists, but it provides the background for Chapters 7–10, where the evidence is synthesised, not only to provide a chronology of change, but also to explore the potential interaction between the river environment and people over time.

The bias of this monograph is to provide the geoarchaeological context for broader archaeological investigations and I feel that it probably achieves this – the confirmation of Westminster as an island, and consideration of the role of tidal inundation and a migrating tidal head allow a better appreciation of the physical controls on human movement, occupation and land use. A number of outstanding research questions related to this are identified at the end of the discussion.

What does not come over as strongly, though it is considered, is the contribution this research might make to the understanding of river and floodplain response to environmental change at the scale of the catchment. There appear to be significant differences in the palaeoenvironmental record of river and floodplain conditions between sites within London, and further up in the catchment. Are these simply the result of distance from source and gradient, or are other factors such as confluence with tributaries, hydrogeological controls, or spatial and temporal variability in land use?

As a book, this is very well written and, on the whole, well illustrated, though the pollen and diatom diagrams are a bit unwieldy, being printed across several pages in portrait format – landscape would have been better. The book contains a wealth of detail for the specialist but much, even most, of it is accessible to students and informed members of the general public. I thoroughly recommend this book to anyone researching or teaching river and floodplain environments, whether in London or elsewhere.

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CAINOZOIC GEOLOGY AND LANDSCAPE EVOLUTION OF NORTH-EAST SCOTLAND. *MEMOIR OF THE BRITISH GEOLOGICAL SURVEY*, SHEETS 66E, 67, 76E, 77, 86E, 87W, 87E, 95, 96W, 96E AND 97 (SCOTLAND)

By J.W. Merritt, C.A. Auton, E.R. Connell, A.M. Hall and J.D. Peacock (2003)

Published by British Geological Survey, 178pp.

ISBN 0 85 272463 2; price £40.00

The publication of this volume marks something of a departure from the normal styles of the BGS Geological memoirs. As David Fahey (Director, BGS) makes clear in his preface to this volume, the principal focus is the Cainozoic sediments of the north-east lowlands of Scotland, their origin, age, character, distribution and utilisation. This area, stretching from west of Elgin eastwards and southwards to the rocky cliff coastlands south of Stonehaven, possesses one of the longest and most complete Quaternary records in Britain, including sediments that may date back to Oxygen Isotope Stage (OIS) 8 or earlier. While the underlying bedrock has not been totally neglected, it is discussed principally in terms of their roles as the foundation on which the sedimentary deposits have accumulated, and the source of many of their lithological characteristics.

The authorship of the volume is also somewhat of a departure from the norm. While officers of the British Geological Survey are the principal authors of many chapters, there is also considerable input from outside research workers. The result is a synthesis of information collected over many years, centred on surveys for eleven Drift or Solid-and-Drift 1:50,000 geological map sheets and a number of Mineral Resource Sheets as well as other published material. It is to the considerable credit of the authors that they have managed to create a volume which is far from a mere repeat of recently published information on the area.

Following the introduction, Chapter 2 is concerned with aspects of the applied geology of the area, including mineral resources, hydrogeology, planning and conservation, ground stability and landslide hazard, land use and coastline stability. Engineering characteristics of various lithostratigraphical groups are discussed, although the reader has yet to be introduced to these groups and their geographical distributions. The consequent necessity to flick back and forth in the volume to obtain information is rather annoying.

The next two chapters discuss landscape evolution, and Palaeogene and Neogene deposits. They set the scene for the core of the volume, the discussion of Quaternary events and their impacts on the landscapes of north-east Scotland. This is considered across four chapters, the first of which is an introduction to the Quaternary period, including an overview of climate fluctuations as revealed by deep ocean cores and Greenland ice-core records, together with summaries of the offshore and onshore stratigraphic records. This leads to a review of theories about the glacial sequence in north-east Scotland which features previously unpublished adjustments to recent models.

Chapters 6 and 7 detail Quaternary deposits and geomorphological features respectively. Information is presented as a synthesis for the entire area, save for the glaciofluvial and glaciolacustrine deposits, which are discussed in terms of individual map sheets for some reason.

The concluding chapter describes the Quaternary lithostratigraphic units identified in the area. Of particular interest is a table showing the correlation of these units between different areas of north-east Scotland. Essentially the information is an expanded version of that contained in Table 1 of Merritt *et al.* (2000), but the use of colour makes this far more accessible to the reader than the earlier publication.

Appendices, including detailed descriptions of 26 key sites in north-east Scotland, are contained in a CD which accompanies the memoir. Additionally, the CD contains all the images (photographs, maps, tables) and the text of the memoir itself. It been configured so that it is possible to search it using Adobe Acrobat Reader, but printing and copying facilities have been disabled. Nevertheless, this is a marvellous resource.

The memoir is presented most handsomely. Many of the maps are versions of illustrations published elsewhere, but the use of colour enables them to be read more easily and to seem more informative than before. It is a pity therefore that some diagrams are from papers relating to only part of the area. In consequence, levels of information about the area vary from place to place. This is particularly evident when comparing descriptions of areas mapped several years ago with those from more recently surveyed map sheets. For example, most sheets show deposits classified morpho-lithogenetically, but more recently surveyed sheets feature a lithostratigraphic classification of some deposits.

It would be astonishing for a volume of this quality and complexity to be without minor blemishes, but even these are few and far between. A couple of references are made to details of topographical features in the area covered by 1:50,000 Sheet 86W, a map sheet which actually falls outside the remit of this memoir! Elsewhere reference is made to the Corse Gelifluctate Bed. That name does not appear in the table of lithostratigraphic units, but from the description of the unit and its associations, it is evident that it is in fact the Camphill Gelifluctate Bed. The term 'Corse Gelifluctate Bed' is actually a term used in earlier versions of the table. Again, on page 106, the buried channel of the River

Dee that leads to Bay of Nigg is said to branch from the present course of the river below the Wellington Suspension Bridge in Aberdeen, whereas it actually branches off upstream of that bridge. That I had to search hard to find the above 'aberrations' is testimony to the general level of care that has gone into the conceptualization and realization of this memoir. The authors are to be congratulated on a significant addition to the literature on the Quaternary of Scotland.

Reference

Merritt, J.W., Connell, E.R. and Bridgland, D.R. (2000). *The Quaternary of the Banffshire coast and Buchan: Field Guide*. Quaternary Research Association, London.

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STONEHAVEN (SHEET 67) [1], ELLON (SHEET 87W) [2], PORTSOY (SHEET 96W) [3] AND BANFF (SHEET 96E) [4]: SOLID AND DRIFT EDITIONS (SCOTLAND)

Published by : British Geological Survey 1999 [1] 2002 [2,3,4]

ISBN 0 7518 3060 7 flat 0 7518 3061 5 folded and cased [1]

ISBN 0 7518 3175 1 flat 0 7518 3176 X folded and cased [2]

ISBN 0 7518 3255 3 flat 0 7518 3256 1 folded and cased [3]

ISBN 0 7518 3066 6 flat 0 7518 3067 4 folded and cased [4]

1:50,000 sheets £11 each; 25 % discount for academic institutions when ordered from: **Sales Desk, British Geological Survey, Keyworth, Nottingham NG12 5GG Tel : 0115 - 936 3241 Fax : 0115 - 936 3488** (prices exclude post and packing - in the UK a minimum of £2·50 and 10% of the original value of the goods up to maximum of £7·50).

These maps, along with the Aberdeen sheet (77), which is still in press, are the newest sheets covering northeast Scotland (Merritt *et al.* 2003). Folded versions of the 2002 editions have yet to appear. They show the extent of the Quaternary deposits found at the surface and indicate the nature of the bedrock below them, even if there are intervening deposits. Compared to earlier maps they tend to show increasing levels of geomorphological detail.

In this area the Stonehaven (67) map, to the south of Aberdeen, was the first completely resurveyed sheet to go back to showing all the superficial deposits as solid blocks of colour. There had been a fashion for only outlining extensive tills and peat on the Banchory (66E) and Turriff (86E) sheets, which is rather disconcerting. Like the adjacent Banchory sheet to the west, the coastal Stonehaven sheet delineates eskers and glacial meltwater channels, marks glacial striae and crag and tail features and shows the extent of landslips and areas of worked, made and landscaped ground. While two 1:250,000 insert maps show offshore Quaternary geology and bathymetry and sea bed sediments, the local tidal range relative to Ordnance Datum is not stated (*Quaternary Newsletter* No. 95, 47–48), nor for that matter in the memoir (Merritt *et al.*, 2003), which describes them.

The Ellon (87W) map covers an inland area just north of Aberdeen, even if it includes the upper reaches of the tidal river Ythan below Ellon. In addition to the more established symbols, the axial direction of large glacial flutes and gouges is shown, along with one-sided glacial meltwater channels, ending with a half arrow. Merritt *et al.* (2003, figure 4) has an improved version of the insert map detailing the main late Devensian glaciation across the region and groups of glacigenic deposits, on which the location of the Ellon sheet is misplaced. However, above this there is a delightful series of annotated schematic cross-sections, incorporating local boreholes to constrain the geometry of the infilling deposits across the valley going down the river Ythan.

The Portsoy (96W) map covers part of the Moray Firth coast to the east of Elgin. As this strip is only up to 11 km deep, the bedrock geology can be repeated below the main map showing the superficial deposits with simplified Solid geology. This uses the same simplified lettering as the 1:250,000 insert map including the offshore bedrock geology, alongside the offshore Quaternary geology, sea bed sediments, and the usual geophysical maps at the same scale. While spreads of till cover large parts of the sheet, there are also complex glaciofluvial deposits, raised beaches, river terrace and alluvial deposits along with peat and blown sand. One final 1:125,000 insert map outlines the broad glacial features of this coastal strip with superimposed tills and shows the position of major ice-marginal glacial meltwater channels. Again, these are marked by lines ending in half arrows, which can be inferred from Merritt *et al.* (2003) are on the side away from the retreating ice sheet.

The Banff (96E) map covers adjacent the coastal stripto the west of Fraserburgh (97). As the bedrock geology is rather simpler and more widely exposed at the surface, there is no separate solid geological map. Again, a truncated sheet could have been printed at the top of the paper to be compatible with the neighbouring sheet and the main map would not have been unnecessarily divided when folded. In addition to the inserts on the adjacent Portsoy map, there is an offshore 1:250,000 cross-section through the Quaternary deposits with a massive, but effective, 30 times vertical exaggeration. This sheet also contains subglacial meltwater channels, which are distinguished from other channels by spots along their length indicating their highest points and by arrows at either end.

On all these 1:50,000 maps, apart from tidal mudflats, the topographic base map is clearly visible in most places, unless it is covered by, for example, the intricate patterns formed by successive glacial channels.

Reference

Merritt, J.W., Auton, C.A., Connell, E.R., Hall, A.M. and Peacock, J.D. (2003). *Cainozoic geology and landscape evolution of north-east Scotland.* Memoir of the British Geology Survey, Sheets 66E, 67, 76E, 77, 86E, 87W, 87E, 95, 96W, 96E and 97 (Scotland).

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THE GEOLOGY OF NORTHERN IRELAND-OUR NATURAL FOUNDATION. SECOND EDITION.

W.I. Mitchell (Ed.)

Geological Survey of Northern Ireland, Belfast, 2004, 318pp.
ISBN 0-85272-454-3; RRP£10.00

This book has obviously been a labour of love for the GSNI. The heavyweight paper and the glorious colour illustrations do magnificent justice to the diverse and fascinating geology of Northern Ireland. The book contains 23 chapters of varying length, covering all of importance from the basement structure through the various geological periods represented in NI (Devonian, Carboniferous, Palaeogene, Quaternary...) to important topics such as terranes (Grampian, Variscan orogeny...) to individual geological topics (geophysics, hydrogeology, minerals and geohazards). A reviewer cannot do justice to the exemplary layout of the chapters, each with colour-coded page edges to make navigation through the geological column a pleasure, without listing the entire contents. I won't do that but will just suggest you buy the book and take a look yourselves.

The authors of the chapters (many by Mitchell himself) must be congratulated for their compilations. The maps, cross sections and stratigraphic sections are marvelously and accurately reproduced in colour and there are scores of such high quality illustrations. There are not just detailed geological maps but many full colour plates of important landscape elements, aerial photographs, superb coastal sections and scenery, and geological localities (sections, structures etc.). Where the book really scores is that it is a serious memoir to accompany geological maps. Hence the material includes plates (again many in colour) of key fossils (from Late Ordovician brachiopods through fascinating microfossils from the Clay-with-Flints), rock thin-sections and sedimentary structures. I would be slow to single out any one part of this book but the Carboniferous chapter (W.I. Mitchell) bears mention here, as does the chapter on the Southern Uplands-Down-Longford Terrane (T.B. Andersen) for their striking illustrations, plates, explanatory sections and maps.

Naturally one's attention is drawn to the Quaternary. It is of course the most relevant geological period and NI contains some notable Quaternary geology including glacial geomorphology, an interesting Quaternary stratigraphy, a Holocene record and most importantly the ground has been worked by renowned Quaternary scientists from Coleraine and Queens Universities amongst others. The Quaternary chapter (R.A.B. Bazley) outlines the importance of the Pleistocene, puts that Epoch in perspective and presents a colour Quaternary timescale (for NI) as well as illustrations of the main sites in NI, details of the lithostratigraphy of the last glaciation (as studied at Agnadarragh) and ends with some information on the Holocene, including a plate of the Malone Hoard (Neolithic polished axes). It seemed to me that the author has sensibly chosen not to detail controversy about Pleistocene events (memoirs not being the place to argue the toss) but has taken a distinct line whilst giving a comprehensive (25 article) reference list so an informed reader can find the literature themselves. It is perhaps a pity that more of the magnificent glacial scenery is not illustrated in this chapter–a satellite image of NI immediately impresses, as on the book's cover! It is also a shame that some of the coastal sections of Marshall McCabe's work were not illustrated along with the dates outlining Heinrich Events and more on the Holocene (perhaps including some of the fascinating tephrochronological and dendrochronological work) but this is being picky as the Quaternary only gets 15 pages (and some of this work is both mentioned and referenced), so don't get me wrong.

Throughout its length the book is perfectly illustrated, it contains many recent references, it contains detail, well-chosen plates and at £10 is an absolute snip. Some important references were inevitably omitted (e.g. I thought Simms' (2000) work should have been referenced in Chapter 13, on the Cretaceous-Palaeogene boundary). It might also have been worth the book highlighting other geological literature in the introduction (or in a 'select' bibliography of 10 or so references), for example Holland's (2001) book, which offers a whole island perspective (although the latter does get referenced in the excellent chapter on the Carboniferous).

However, these few points remain very minor. (Reviewers have to find something to whinge about). I fully recommend this volume. In fact it should be a best seller. It will remain a star amongst memoirs for years to come and it does full justice to the diverse scenery and geology of Northern Ireland. I hope it is widely read by the readership it is directed at, not just geoscientists but for those with a love of landscape and its structure (as the book says *"...walkers, naturalists, cavers, climbers and other outdoor based pursuits..."*). I would love to see such a volume for the rest of Ireland.

References

Holland, C.H. (2001). *A Geology of Ireland. (Second Edition).* Scottish Academic Press, Edinburgh.

Simms, M.J. (2000). The sub-basaltic surface in northeast Ireland and its significance for interpreting the Tertiary history of the region. *Proceedings of the Geologists'* Association, 111, 321–36.

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ABSTRACTS

LUMINESCENCE INVESTIGATIONS AND DATING OF ANTHROPOGENIC PALAEOSOLS FROM SOUTH MAINLAND SHETLAND

Christopher Ian Burbidge (Doctor of Philosophy)

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This thesis aims to produce a chronostratigraphy of agricultural activity and sedimentary accumulation at two archaeological sites in the Shetland Islands, by directly dating the infield sediments associated with the sites. It describes optically stimulated luminescence (OSL) dating of a large number of samples, from often inhomogeneous sediments expected to have been subject to post-depositional mixing. The samples were collected at high spatial resolution, both vertically through sections and horizontally within layers, to assess the consistency of results at different scales.

A novel approach to *in situ* environmental dose rate determination was pursued, using aluminium oxide dosimeters to measure the combined beta, gamma and cosmic radiation fields at the points of sampling. This yielded rapid and accurate measurements of environmental dose rate for the large numbers of samples taken from inhomogeneous dose rate environments.

Detailed investigation of the luminescence behaviour of quartz separates from a limited number of samples was used to optimise measurement conditions within the single aliquot regeneration (SAR) protocol. These optimised conditions were used in a simplified measurement protocol based on a standardised growth curve, which enabled the measurement of equivalent dose (D_e) distributions for small aliquots from large numbers of samples. A novel approach to direct assessment of error on the D_e was applied.

The observed D_e distributions were analysed using a model selection approach. Most distributions were found to be consistent with simpler representations than expected. However, the results from some samples indicated the presence of multiple populations in the data. Ages calculated from these results were used to assess different components in some of the archaeological deposits. However, their occurrence was not strongly associated with evidence for bioturbation or tilling of the soils.

Using dates from 66 samples, chronostratigraphies were established for both the infield deposits at Old Scatness Broch and the Sumburgh Hotel Gardens site. The infield at Old Scatness contained soils, middens, and sands accumulated between the Bronze-Iron Age transition (~300 BC) and the 20th century. The Sumburgh Hotel Gardens site contained occupation deposits, sand and soils, mainly dating to the Early Bronze Age (~1500 BC). Quantitative estimates were made of the anthropogenic input to the soils at Old Scatness during the Iron Age.

THE SEDIMENTOLOGY OF LATE DEVENSIAN GLACIAL DEPOSITS IN ANGLESEY, NORTH-WEST WALES

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This thesis looks at the sedimentology of the Late Devensian glacigenic deposits of Anglesey, in particular the multiple till sequence of locally-derived basal till overlain by red till found along the northern coasts of Anglesey and mainland Wales. It has previously been proposed that this upper till represents a distinct readvance, following retreat of Irish Sea ice to a position just offshore. Subaerial exposure and weathering of the upper surface of the underlying till has therefore been suggested, and this study investigates the possible effects of weathering using geochemistry and mineral magnetic analysis.

Reconstructed weathering ratios and the mineral magnetic assemblage shows no apparent evidence for weathering of the surface of the lower till. A change in the lithological provenance of matrix material was found to be responsible for the change in colour of the till, supported by the findings of clast lithological analysis. Field observations and particle-size analysis suggested that both the postulated till facies were deposited under a subglacial environment as lodgement and deformation tills. Irish sea ice was found to be responsible for the deposition of all the glacial deposits on Anglesey, although debris eroded by Welsh ice was transported into the merged Irish Sea/Welsh ice stream, producing glacial deposits characterised by a mixed lithological assemblage along the north and east coasts of Anglesey. Variations in the relative contributions of the different lithological sources represent fluctuations in the relative dominance of Welsh and Irish Sea ice in the area, and oscillation within the zone of coalescence.

It is proposed that the whole sequence represents one single lithostratigraphic member, and constitutes a single till deposit laid down during the same glacial episode, with no need to invoke the retreat and readvance of Irish Sea ice. Vertical differentiation within the debris load at the ice-bed interface is suggested as the origin of the change in colour. Red (Permo-Trias) material derived offshore to the north was soon incorporated into locally derived sediment at the ice base, causing the distinctive colour to fade out as the ice flowed over Anglesey, eroding new material.

NOTICES

1. *JOURNAL OF MAPS*: A NEW MULTI-DISCIPLINARY, INTERNATIONAL JOURNAL

Website: http://www.journalofmaps.com

Launch: 4th May 2004

We are pleased to announce a "call for papers" for the newly created *Journal of Maps* (*JoM*). The establishment of *JoM* has come out of the realisation that academic map publication is in gradual decline. *JoM* will provide a channel for researchers to publish map based material not normally accepted by traditional journals that can then be referred to and viewed by others.

JoM has been established as a UK charity, aiming to publish original, bespoke, maps from ***any*** discipline. The editorial panel has been specifically put together to provide a broad range of knowledge, expertise and experience. As a journal, we suspect that initial emphasis will be upon traditional geo-subjects, however other subject areas will be strongly encouraged to submit original work.

JoM is an entirely electronic, online journal. All published material will be given away freely and therefore *JoM* has opted to follow a reverse publishing model. The author will pay a nominal fee to cover the review and distribution process. The journal's website (http://www.journalofmaps.com) will provide a fully searchable front-end to *JoM*'s published materials. We accept that not everyone will want to view maps electronically and therefore all materials will be of press publishable quality.

In order to use the online facilities of *JoM*, a user needs to register. Basic registration allows access to published materials; personal details need to be provided in order to submit a map for publication. The principal author will need to supply a press-quality map *and* a short article ready for review. The article should describe the data presented in the map and any pertinent techniques used during the collection/mapping process. We *will not* accept long articles incorporating data analysis and interpretation, as these would be better published in traditional subject-based journals. The principal author should also supply the details of two people who may act as external referees; these persons should not have recently published with the author(s) or work at the same institution. When submitted, an article will be reviewed by two members of the editorial panel, in addition to the two external referees.

Mike J Smith, School of Earth Sciences and Geography
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2. WORKSHOP ON THE APPLICATIONS OF COSMOGENIC ISOTOPE ANALYSIS IN GEOMORPHOLOGY AND QUATERNARY SCIENCE

23–25 October 2004, Institute of Geography, University of Edinburgh

Organisers: Professor Mike Summerfield and Dr. Mike Kaplan

This Workshop provides information on the application of cosmogenic isotope analysis across a broad range of research problems in geomorphology, Quaternary science and related fields in earth and environmental science. It is aimed at researchers (including postgraduates) who think that cosmogenic isotope analysis might be relevant to their research but who have little or no knowledge of the technique. We also welcome those who are already applying it in their research. There is no fee for attending the Workshop but the number of participants is limited. An outstanding group of international experts will present tutorials on applications.

Registration: Send by **1 August 2004** full name, institution and/or department, email address, phone no., and research interests (maximum 30 words) to:

Mike Summerfield at mas@geo.ed.ac.uk

Registration indicates a commitment to attend the Workshop.
For further information go to http://www.geos.ed.ac.uk/facilities/cosmolab/ or call +44 131 650 2519 or +44 131 650 2572.

3. Conference on Glacial Sedimentary Processes and Products

University of Wales, Aberystwyth

23–27 August 2005

The aim of this conference is to promote dialogue between researchers in the fields of contemporary glacial processes, glacial sedimentology and ice-sheet modellers in order to advance these fields in an integrated way. Contributions are invited from researchers working on all aspects of glacial sedimentary processes and products in glaciomarine, glaciolacustrine and terrestrial settings, from Archaean times to the present day. Contributions addressing the following themes are particularly encouraged:

1. Contemporary glacial processes

- Debris entrainment and transport by contemporary glaciers
- Depositional processes at contemporary glaciers
- Role of thermal regime in depositional processes
- Ice-marginal, glaciolacustrine and glaciofluvial processes and sediments
- Glacial processes and products in fjordal, continental shelf and deep ocean environments
- Subglacial and proglacial deformation of sediments
- Tectonic controls on glacial sedimentation
- The preservation potential of glacigenic successions
- The role of catastrophic events in glacial sedimentary environments
- Linking glacial sediments to glacier dynamics

2. The sedimentary record of past glacial systems

- Case studies from a process perspective
- Recognising styles of glaciation in the geological record
- Reconstructing former glacier thermal regimes from sedimentary products
- The role of tectonic setting in glacial sedimentology
- Using mineralogical, geochemical and biological criteria to define glacial sedimentary regimes
- Glacier-volcano interactions
- Applied aspects, e.g. application of glacial sedimentology to hydrocarbon and mineral exploration
- Sedimentary evidence for/against the "Snowball Earth" hypothesis

3. Modelling glacial depositional systems

- Quantitative aspects of sediment delivery to continental margins
- Seismic stratigraphy of glaciated continental margins
- Numerical modelling of former ice sheets and glaciers constrained by geological data
- Modelling interaction between ice streams and subglacial environments, in particular the influence of deformable sediment on ice flow
- Modelling subglacial erosion, sediment transport and long-term landscape evolution

Publication

Delegates are invited to contribute papers to an IAS Special Publication arising from the conference. Papers should be submitted to the Editors by 1 August

2005. Refereeing will follow the guidelines used for the IAS journal *Sedimentology*. Reviewing will take place over the following 6 months. Publication is anticipated by September 2006. Deadlines will be strictly adhered to.

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Field excursions

5/6 day pre-conference field excursion to glaciers of southern Iceland, led by Andy Russell (Newcastle)

2 day post-conference trip on glacial sediments and landforms in West Wales

1 day: Castles (Caernarfon, Harlech) and Darwin's glacial landscapes in Snowdonia, North Wales

1 day: Coastal scenery and St David's Cathedral, South Wales

4. EARTHWISE

Earthwise is the official magazine of the British Geological Survey. It is published twice a year and each issue focuses on the BGS's activities and expertise within a different theme such as minerals, sustainability, geohazards, health or planning. The most recent issue is on the theme of 'Modern geological mapping', and included several articles on Quaternary geology and geomorphology (e.g. Cutting the ice in East Anglia, The Vale of York, the Quaternary history of the Solway, and Somerset slides). *Earthwise* is primarily aimed at professional geologists in industry and government, but is widely read by lecturers, students, teachers, amateur geologists and other enthusiasts. *Earthwise* is free; to subscribe, visit the BGS website at **www.bgs.ac.uk/earthwise**, where you can also download digital copies of recent articles. If you are unable to access the Internet, write to the *Earthwise* editor at BGS, Keyworth, Nottingham NG12 5GG.

6. JOURNAL OF QUATERNARY SCIENCE

Forthcoming papers

Rapid Communication

Magny & Haas	A major widespread climate change around 5300 cal. yr BP at the time of the Alpine Iceman

Research Papers

Castañeda *et al.*	Temporal changes in Holocene $\delta^{18}O$ records from the northwest and central North Iceland Shelf
Oba & Murayama	Sea surface temperatures and salinity changes in the northwest Pacific since the last glacial maximum
Mohtadi *et al.*	Changing ocean productivity off northern Chile during the last 19,000 years: a multiparameter approach
Verleyen *et al.*	Late Quaternary deglaciation and climate history of the Larsemann Hills (East Antarctica)
Baroni & Hall	A new relative sea-level curve for Terra Nova Bay, Victoria Land, Antarctica
Evans *et al.*	Late Quaternary submarine bedforms and ice-sheet flow in Gerlache Strait and on the adjacent continental shelf, Antarctic Peninsula
de Franco *et al.*	The recent evolution of the intramontane Clusone basin (Southern Alps, Italy): integration of seismic and geological data
Gutsell *et al.*	Architecture and evolution of a fjord-head delta, Western Vancouver Island, British Columbia

Lohne *et al.*	Calendar year age estimates of Allerød – Younger Dryas sea-level oscillations at Os, western Norway
Berger *et al.*	Luminescence chronology of non-glacial sediments in Changeable Lake, Russian high Arctic: evidence for limited Eurasian ice-sheet extent during the LGM
Kemp *et al.*	Pedosedimentary development of part of a Late Quaternary loess-palaeosol sequence in Northwest Argentina
An *et al.*	Environmental changes and cultural responses between 8000-4000 cal. yr BP in the western Loess Plateau, NW China
Bennike *et al.*	Reinvestigation of the classical late-glacial Bølling Sø sequence, Denmark: chronology, macrofossils, Cladocera and chydorid ephyppia
Briant *et al.*	Fluvial system response to Late Devensian (Weichselian) aridity, Baston, Lincolnshire, England
Kovanen & Slaymaker	Glacial imprints of the Okanogan Lobe, southern margin of the Cordilleran Ice Sheet
Kelly *et al.*	Surface exposure dating of the Great Aletsch Glacier Egesen moraine system, western Swiss Alps, using the cosmogenic nuclide ^{10}Be
Giraudi	The Upper Pleistocene to Holocene sediments on the Mediterranean island of Lampedusa (Italy)

Further details on these and other papers published in JQS, future tables of contents and profiled alerts for e-mail can be found at: www.interscience.wiley.com/journal/jqs

QUATERNARY RESEARCH ASSOCIATION

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

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

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

All questions regarding membership are dealt with by the **Secretary**, the Association's publications are sold by the **Publications Secretary** and all subscription matters are dealt with by the **Treasurer**.

QRA home page on the world wide web at: http://www.qra.org.uk

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