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# ROMAN LODE, EXMOOR, DEVON TEPHROCHRONOLOGY

## SCIENTIFIC DATING REPORT

Ian Matthews


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# ROMAN LODE, EXMOOR, DEVON

# TEPHROCHRONOLOGY

Ian Matthews

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## SUMMARY

A peat sequence from Roman Lode, Exmoor, Devon was investigated for the presence of microscopic volcanic glass shards (microtephra). Sampling of the 54cm sequence was undertaken at 1cm resolution and four discrete microtephra layers were identified. These layers were geochemically determined as being of Icelandic origin. The two youngest tephra layers were correlated with eruptions of Hekla in AD 1947 and AD 1510. A third tephra layer yielded few geochemical results and those that were obtained displayed three distinct geochemical signals. Tentative correlations are drawn between this tephra layer and the BMR-90 tephra (*c.* AD 920) though the data suggest that some of the shards have also been derived from the Torfajökull volcanic system. The oldest tephra layer was correlated with the OMH-185 tephra layer (755–680 cal BC, 2705–2630 cal BP; Plunkett *et al* 2004). Roman Lode is the only site in south-west England from which tephra layers have been identified and geochemically characterised. The data provide a preliminary Late Holocene tephrostratigraphy for the region. The potential for expanding tephrostratigraphical research in south-west England is briefly considered.

## CONTRIBUTORS

Ian Matthews

## ACKNOWLEDGEMENTS

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## ARCHIVE LOCATION

Exmoor National Park Historic Environment Record
Exmoor National Park Authority
Exmoor House
Dulverton TA22 9HL

## DATE OF INVESTIGATION

2004–8

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# CONTENTS

# INTRODUCTION

The use of volcanic ash layers (tephra layers) as isochronous marker horizons has become widespread in Late Quaternary palaeoenvironmental research across Europe and the North Atlantic region (Dugmore *et al* 1995; Turney *et al* 1997; Hall and Pilcher 2002; van den Bogaard and Schminke 2002; Mortensen *et al* 2005; Wastegård, 2005; Lowe *et al* 2007). Tephra layers are deposits of volcanic ash that are laid down during volcanic eruptions. They form instantaneous marker layers and provide a basis for correlating palaeoenvironmental and archaeological records with a greater precision than is generally achievable using radiocarbon dating (Lowe 2001).

For many years the study of tephra layers (tephrochronology) was restricted to visible deposits that accumulated close to the source of the eruption (proximal deposition). However, pioneering research in Scandinavia, Scotland, and Ireland led to the identification of microscopic tephra shards (microtephra) in Holocene peats in areas distal to volcanic sources (Persson 1971; Dugmore 1989; Pilcher and Hall 1992). Currently in excess of 40 non-visible Holocene tephra layers have been identified in sites in Britain and Ireland, with the majority of the British layers being restricted to sites in Scotland.

In England, three microtephra layers have been detected and geochemically characterised from sites in Cumbria and Lancashire (Pilcher and Hall 1996), while extremely sparse microtephra layers have been recognised in Dartmoor and Wales (Buckley and Walker 2002; Hall and Pilcher 2002), although the lack of geochemical analyses from these sites reduce their potential as isochrones. The identification of tephra layers in the Lower Thames Valley (Matthews unpubl data) indicates that some tephra layers may be more widespread across southern England than previously thought. The aim of this research was to determine the potential for peat deposits in south-west England to contain tephra layers. Here we report the discovery of four discrete tephra layers detected in a peat sequence that is closely associated with an archaeological site from Exmoor, Devon.

# SITE LOCATION AND STRATIGRAPHIC CONTEXT

Roman Lode, Devon (NGR SS 753 382; 51°07'46"N 03°47'0.5"W) is located in Exmoor, 2km south-west of Simonsbath (Fig 1). The site was investigated as part of the English-Heritage funded Exmoor Iron project (Juleff and Bray 2007). A blanket peat deposit *c.* 100 m from the site was sampled in August 2004, using 0.5m monolith tins, to obtain a palaeoenvironmental sequence (Fyfe forthcoming). The monoliths were also processed for their microtephra content.

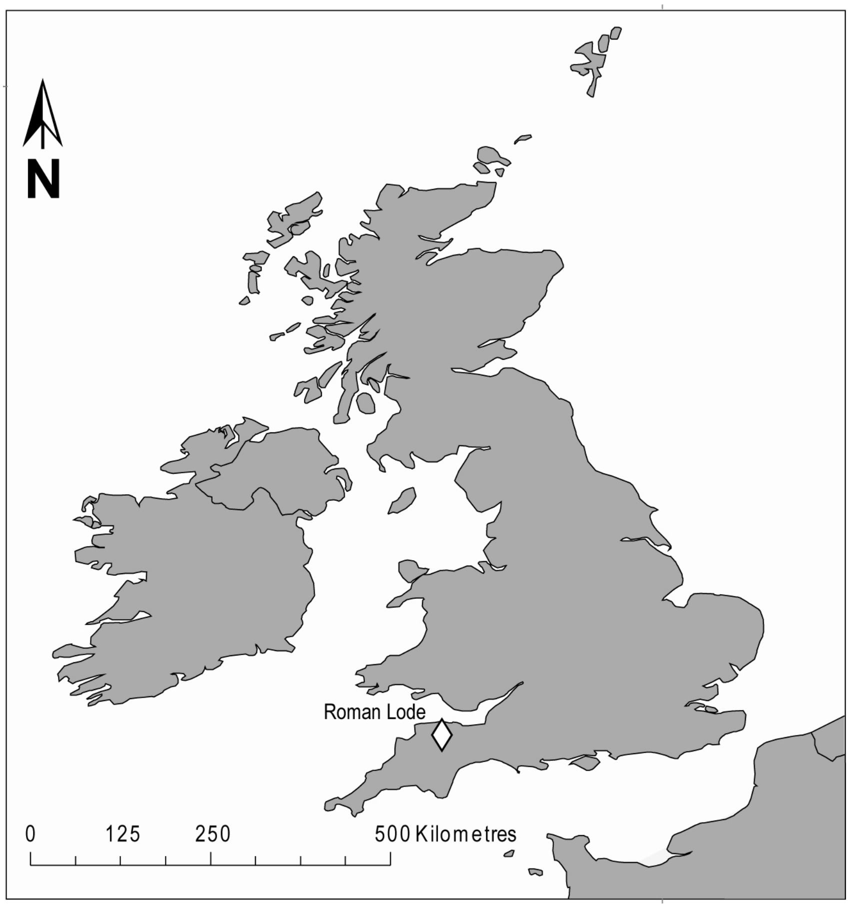



*Figure 1: location map of Roman Lode, Exmoor, Devon*

## METHODOLOGY

Contiguous sub-samples were extracted from the sequence between 11 and 55cm and processed for microtephra examination. The material between 0–11cm comprised modern unhumified plant material, which was not sampled. Contiguous samples of 1cm thickness were systematically cut from the sequence to minimise the risk of missing very thin microtephra layers. Samples were incinerated in a furnace at 550°C for four hours to remove organic matter. The resulting ash residue was then processed according to a modified version of the procedure outlined in Blockley *et al* (2005). All procedures followed Blockley *et al* (2005) with one principal exception: due to the unknown nature of tephra layers in south-west England, a larger sieve range (125 and 15 micron (µm) sieve meshes) was preferred to guard against loss of tephra shards during the extraction procedure. To prevent airborne contamination of the samples in the laboratory, all sieving was conducted in a laminar flow cabinet (providing clean filtered air), and the samples were stored in sealed centrifuge tubes. Slides of the extracted material were mounted in Euparal and examined optically using an Olympus CX-41 microscope fitted with crosspolarising filters. Tephra shards were initially classified by their optical properties (eg colour and morphology); three shard type groups were identified:

i. 'Colourless' shards that tended to be vesicular and contained mineral inclusions
ii. 'Intermediate' shards that ranged from yellowish-brown to olive-brown in colour with fluted and vesicular morphologies
iii. 'Brownish' shards that were deep brown in colour and had a characteristic 'blocky' morphology.

Any shards encountered were counted and quantified as the number of shards per gram dry weight of sediment.

Samples selected for geochemical analysis were prepared using the procedures outlined above. Extracted glass shards were then mounted on a resin stub, sectioned using P1200 Silicon Carbide grinding paper and polished using progressively finer grades of diamond suspensions (9, 3, and 0.3μm). The polished stub was then carbon coated prior to analysis.

Geochemical analysis was undertaken at the Begbroke Earth Sciences facility in the University of Oxford using a Jeol JXA8800R microprobe system fitted with 4 wavelength dispersive spectrometers (WDS). The operating conditions for this system were a defocused 10μm beam with a voltage of 10na and accelerating voltage of 15kV, checked by Faraday cup. The system was calibrated using pure metals and silicate minerals as primary standards. To measure system instability or drift in calibration, secondary glass standards consisting of internally assayed obsidians and anthropogenic glasses (NIST 612) were measured before and after sample measurements. Sodium was measured first, in order to mitigate against its mobilisation, an operating difficulty when analysing glass samples using EPMA (Dugmore *et al* 1995).

Shard numbers permitting, a minimum of 30 targets were acquired for each tephra sample submitted. Unfortunately, tephra shards were sparse in some samples, not all targets analysed were tephra, and some analyses produced low analytical totals and are considered statistically unreliable. Hence the generated data for individual tephra layers frequently comprise fewer than 30 analyses. In European tephrochronology, it is common practice to reject analyses that return analytical totals below 95%, as these are perceived to be unreliable (Hunt and Hill 1993). There are many reasons for low analytical totals and the exclusion of data returning totals below 95% has recently been reappraised (Pollard *et al* 2006). For the Roman Lode project, a 95% cutoff was observed, although several analyses from the oldest layer consistently returned totals between 91–96%. For this layer, element percentages for analytical totals lower than 95%, but above 93%, were not significantly different from those returning totals >95%, and hence a lower cut-off value of 93% was considered acceptable in these cases. These data are presented in Table 1 because they provide valuable information, but they were not used in the correlation of this layer to reference material.

## RESULTS

Figure 2 displays the tephrostratigraphic record from Roman Lode. Four discrete layers of tephra deposition were identified in the sequence, based on counts of numbers of observed shards per gram dry weight of each samples. These were:

1. 12–13cm: A layer containing intermediate shard-types, with a peak of 30 shards $g^{-1}$ at 12cm.
2. 16–21cm: A layer containing intermediate shard types similar to those found in Layer 1, but mixed with low numbers of colourless shards. A peak of 26 shards $g^{-1}$ was identified at 17cm.
3. 32–40cm: A layer containing three closely spaced peaks of both colourless and intermediate shard types. The largest peak identified was 106 shards $g^{-1}$ at 34cm, although smaller secondary peaks were identified at 32 and 40cm.
4. 52–3cm: A layer containing predominantly large colourless shard-types (long axis >60µm), with abundant mineral inclusions. A peak of 343 shards $g^{-1}$ was identified at 52cm.

Examples of each shard type are presented in Figure 3.

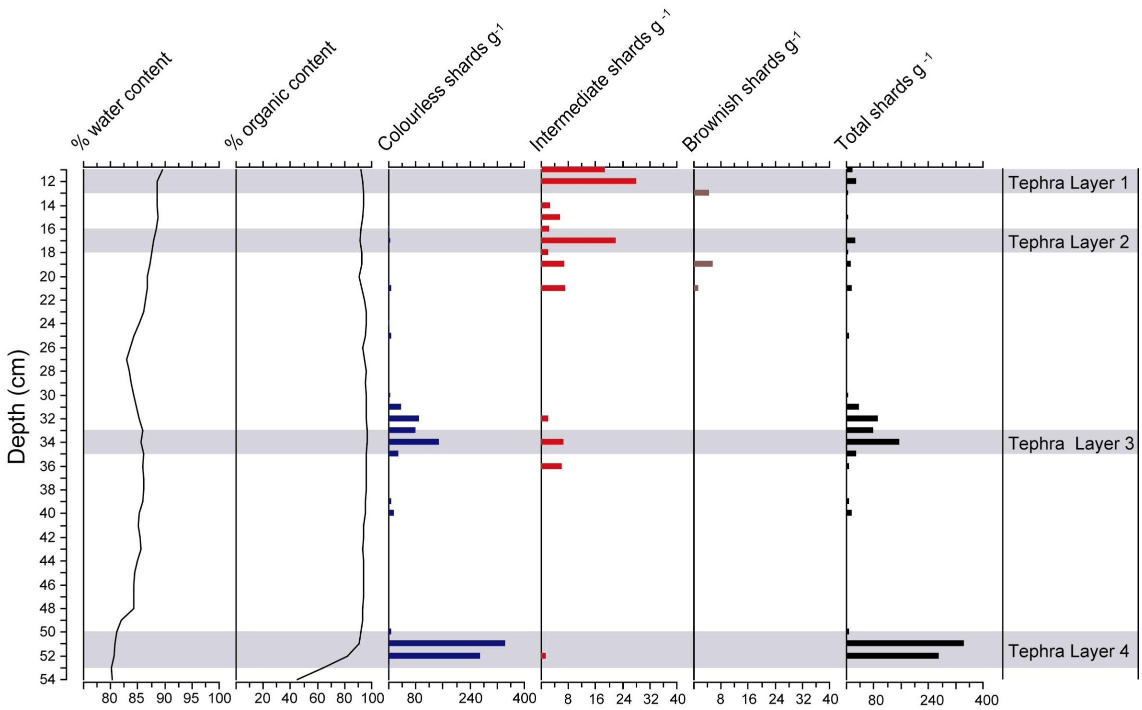



*Figure 2: water content, organic content, and tephra shard counts for Roman Lode, Devon. Shard numbers are presented as number of shards per gram of dry sediment*

Four discrete tephra layers have been detected, the first defined by intermediate shards, the second and third by both colourless and intermediate shards, and the forth by colourless shards only. Note the x-axis scale change between colourless, intermediate, brownish, and total shard counts

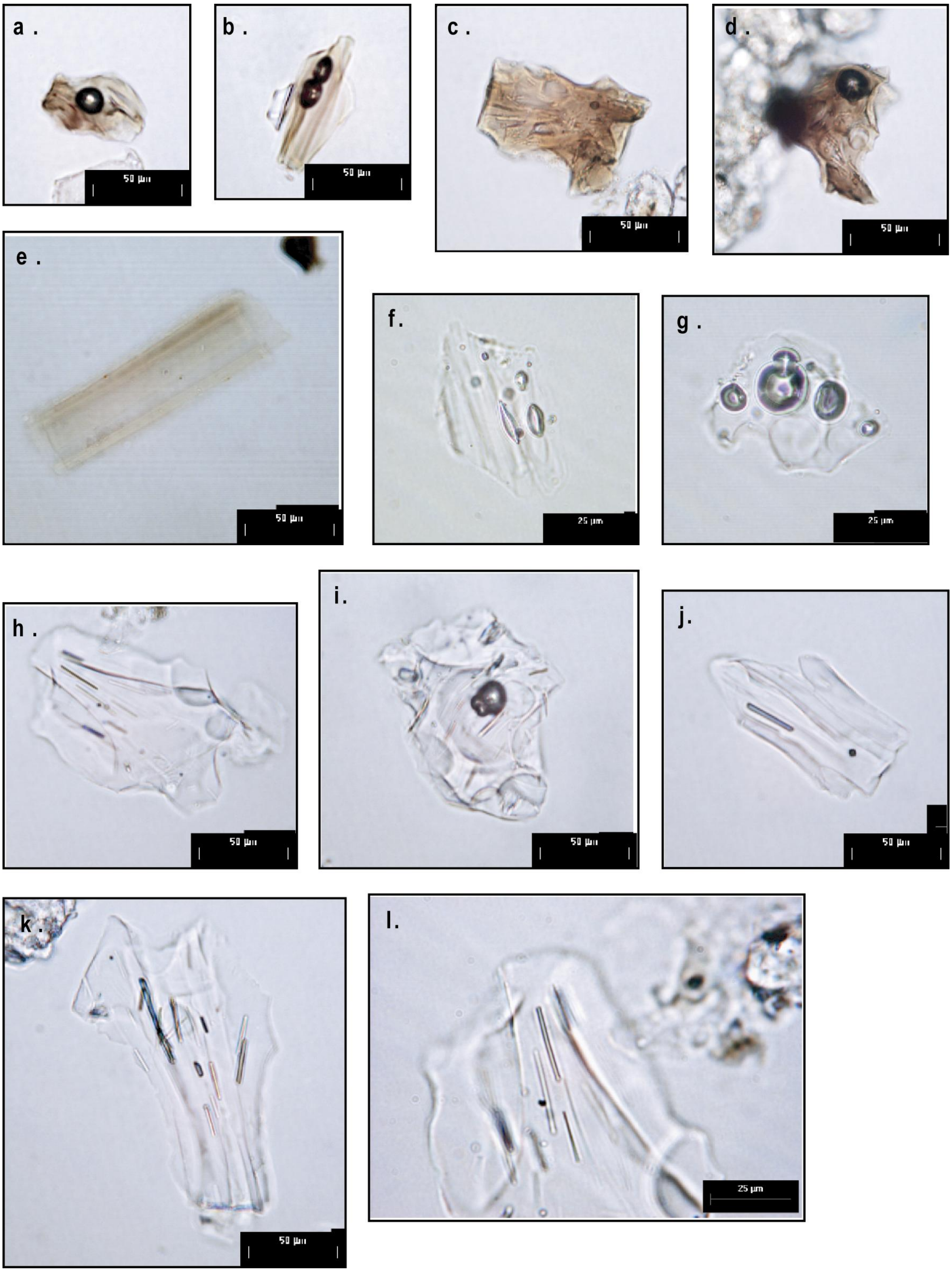



*Figure 3: Examples of the tephra shards identified at Roman Lode, Devon*

a+b = ash layer 1 (12cm), c+d = ash layer 2 (17cm), e = Intermediate shards from ash layer 3 (34cm), f+g = Colourless shards from ash layer 3 (34cm), h+k = ash layer 4 (52cm). l = Microlite inclusions from ash layer 4. Note the change of scale in f, g, and l

*Table 1. Microprobe determined major element chemistry of tephras from Roman Lode, Devon. Results are presented as oxides by stoichiometry and are not normalized. Totals below 95% are given in italics.*

| $SiO_2$ | $TiO_2$ | $Al_2O_3$ | $FeO^{(total)}$ | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | Total |
|---|---|---|---|---|---|---|---|---|---|
| 12–13cm, Hekla, AD 1947 | | | | | | | | | |
| 62.663 | 0.949 | 15.389 | 7.393 | 0.212 | 1.244 | 4.512 | 3.992 | 1.763 | 98.117 |
| 62.582 | 0.93 | 15.373 | 7.448 | 0.123 | 1.223 | 4.534 | 4.085 | 1.830 | 98.128 |
| 62.133 | 0.907 | 15.351 | 7.759 | 0.196 | 1.272 | 4.512 | 4.112 | 1.783 | 98.025 |
| 61.755 | 0.869 | 15.48 | 7.708 | 0.239 | 1.174 | 4.400 | 4.105 | 1.838 | 97.568 |
| 60.896 | 0.921 | 15.591 | 7.690 | 0.261 | 1.177 | 4.412 | 4.058 | 1.772 | 96.778 |
| 60.369 | 1.159 | 15.502 | 8.377 | 0.225 | 1.595 | 5.157 | 4.017 | 1.626 | 98.027 |
| 60.362 | 1.162 | 15.355 | 8.898 | 0.186 | 1.741 | 5.011 | 4.068 | 1.549 | 98.332 |
| 60.325 | 1.202 | 15.63 | 8.640 | 0.268 | 1.647 | 5.081 | 4.156 | 1.623 | 98.572 |
| 17–18cm, Hekla, AD 1510 | | | | | | | | | |
| 62.095 | 1.066 | 15.525 | 7.787 | 0.191 | 1.461 | 4.699 | 4.182 | 1.822 | 98.828 |
| 61.698 | 1.064 | 15.353 | 8.245 | 0.217 | 1.520 | 4.954 | 4.193 | 1.753 | 98.997 |
| 61.199 | 1.132 | 15.596 | 8.443 | 0.144 | 1.669 | 4.945 | 4.210 | 1.669 | 99.007 |
| 61.152 | 1.040 | 15.416 | 7.930 | 0.300 | 1.441 | 4.918 | 4.086 | 1.704 | 97.987 |
| 61.096 | 1.120 | 15.334 | 8.060 | 0.259 | 1.488 | 4.840 | 4.093 | 1.747 | 98.037 |
| 60.909 | 1.110 | 15.132 | 8.266 | 0.230 | 1.537 | 4.979 | 4.015 | 1.658 | 97.836 |
| 60.629 | 1.190 | 15.453 | 8.468 | 0.225 | 1.660 | 5.086 | 4.081 | 1.691 | 98.483 |
| 60.580 | 1.105 | 15.288 | 7.979 | 0.265 | 1.557 | 4.931 | 4.070 | 1.688 | 97.463 |
| 60.541 | 1.166 | 15.305 | 8.405 | 0.252 | 1.623 | 5.044 | 3.916 | 1.696 | 97.948 |
| 60.537 | 1.137 | 15.127 | 8.510 | 0.190 | 1.591 | 4.929 | 3.852 | 1.674 | 97.547 |
| 60.497 | 1.177 | 15.388 | 8.250 | 0.226 | 1.630 | 5.035 | 4.089 | 1.643 | 97.935 |
| 60.437 | 1.175 | 15.302 | 8.352 | 0.244 | 1.587 | 5.055 | 3.96 | 1.698 | 97.810 |
| 60.129 | 1.145 | 15.309 | 8.545 | 0.186 | 1.571 | 5.082 | 3.958 | 1.652 | 97.577 |
| 59.878 | 1.177 | 15.321 | 8.401 | 0.202 | 1.628 | 5.072 | 4.043 | 1.658 | 97.380 |
| 58.480 | 1.119 | 15.267 | 8.414 | 0.221 | 1.577 | 5.190 | 4.007 | 1.621 | 95.896 |
| 34–35cm, Unknown, group 1 (BMR-90? *c.* AD 920) | | | | | | | | | |
| 68.300 | 0.754 | 14.067 | 4.455 | 0.142 | 0.529 | 2.017 | 3.951 | 3.214 | 97.429 |
| 67.789 | 0.771 | 13.887 | 4.732 | 0.161 | 0.587 | 2.135 | 4.047 | 3.265 | 97.374 |
| 34–35cm, Unknown, group 2 | | | | | | | | | |
| 72.247 | 0.476 | 13.472 | 2.807 | 0.085 | 0.357 | 1.723 | 3.620 | 3.310 | 98.097 |
| 34–35cm, Unknown (Torfajökull?), group 3 | | | | | | | | | |
| 67.957 | 0.438 | 15.513 | 2.393 | 0.070 | 0.596 | 1.648 | 4.478 | 4.669 | 97.762 |
| 52–53cm, OMH-185, 2705–2630 cal BP (755–680 cal BC) | | | | | | | | | |
| 74.710 | 0.141 | 12.034 | 1.276 | 0.014 | 0.015 | 0.613 | 3.911 | 4.049 | 96.763 |
| 73.467 | 0.203 | 12.349 | 1.479 | 0.013 | 0.068 | 0.706 | 3.871 | 3.880 | 96.036 |
| 73.463 | 0.132 | 12.074 | 1.349 | 0.043 | 0.054 | 0.594 | 3.635 | 3.859 | 95.203 |
| 73.233 | 0.141 | 12.154 | 1.272 | 0.050 | 0.032 | 0.624 | 3.709 | 3.911 | 95.126 |
| 73.046 | 0.155 | 12.193 | 1.614 | 0.063 | 0.076 | 0.728 | 3.573 | 3.796 | 95.244 |
| 73.043 | 0.171 | 12.289 | 1.616 | 0.018 | 0.083 | 0.770 | 3.987 | 3.722 | 95.699 |
| 73.036 | 0.234 | 12.320 | 1.613 | 0.013 | 0.096 | 0.784 | 3.687 | 3.841 | 95.624 |
| *73.012* | *0.136* | *11.973* | *1.271* | *0.037* | *0.029* | *0.603* | *3.502* | *3.871* | *94.434* |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *72.899* | *0.113* | *11.725* | *1.076* | *0.059* | *0.039* | *0.545* | *3.528* | *3.891* | *93.875* |
| 72.795 | 0.184 | 12.259 | 1.628 | 0.023 | 0.057 | 0.788 | 3.676 | 3.843 | 95.253 |
| 72.747 | 0.117 | 12.228 | 1.584 | 0.063 | 0.060 | 0.785 | 3.661 | 3.784 | 95.029 |
| *72.743* | *0.151* | *12.151* | *1.393* | *0.008* | *0.070* | *0.738* | *3.647* | *3.947* | *94.848* |
| *72.695* | *0.161* | *12.105* | *1.339* | *0.000* | *0.031* | *0.611* | *3.618* | *3.870* | *94.430* |
| *72.672* | *0.127* | *11.946* | *1.349* | *0.002* | *0.044* | *0.616* | *3.493* | *3.787* | *94.036* |
| *72.648* | *0.149* | *11.992* | *1.282* | *0.030* | *0.053* | *0.686* | *3.528* | *3.998* | *94.366* |
| *72.556* | *0.105* | *11.957* | *1.101* | *0.059* | *0.033* | *0.559* | *3.561* | *3.956* | *93.887* |
| *72.547* | *0.147* | *12.554* | *1.123* | *0.053* | *0.028* | *0.726* | *4.007* | *3.645* | *94.830* |
| *72.530* | *0.148* | *12.016* | *1.598* | *0.000* | *0.085* | *0.749* | *3.483* | *3.838* | *94.447* |
| *72.420* | *0.142* | *12.020* | *1.251* | *0.006* | *0.027* | *0.585* | *3.534* | *3.840* | *93.825* |
| 72.377 | 0.196 | 12.511 | 1.891 | 0.133 | 0.093 | 0.847 | 3.629 | 3.799 | 95.476 |
| *72.335* | *0.091* | *11.707* | *1.164* | *0.070* | *0.018* | *0.580* | *3.409* | *3.968* | *93.342* |
| *72.168* | *0.149* | *12.246* | *1.700* | *0.022* | *0.062* | *0.753* | *3.689* | *3.756* | *94.545* |
| *72.084* | *0.126* | *11.950* | *1.155* | *0.120* | *0.037* | *0.623* | *3.517* | *3.909* | *93.521* |
| *71.931* | *0.168* | *12.069* | *1.432* | *0.007* | *0.061* | *0.744* | *3.445* | *3.858* | *93.715* |
| *71.692* | *0.193* | *12.246* | *1.631* | *0.050* | *0.075* | *0.772* | *3.634* | *3.828* | *94.121* |

## TEPHRA LAYERS

### Layer 1, 12–13cm – Hekla, AD 1947

Eight geochemical determinations were obtained from this tephra layer, which can be classified on a UIGS Total Alkali vs Silica (TAS) diagram as a sub-alkali Andesite (Fig 4), with geochemical affinities to products from the Hekla volcano in Iceland. The layer may be correlated with the eruptions of Hekla in AD 1947 or AD 1510 (Fig 5a), which have identical major-element chemistries. The proximity of this layer to the sediment surface, its position relative to layer 2, which returned a similar chemical signal, and an associated radiocarbon date (Table 2) together suggest the most likely correlative to be the AD 1947 eruption. This tephra has been identified in proximal deposits in Iceland and in microtephra form in Southern Ireland and Finland (Larsen *et al* 1999; Hall and Pilcher 2002; Cole and Mitchell 2003).

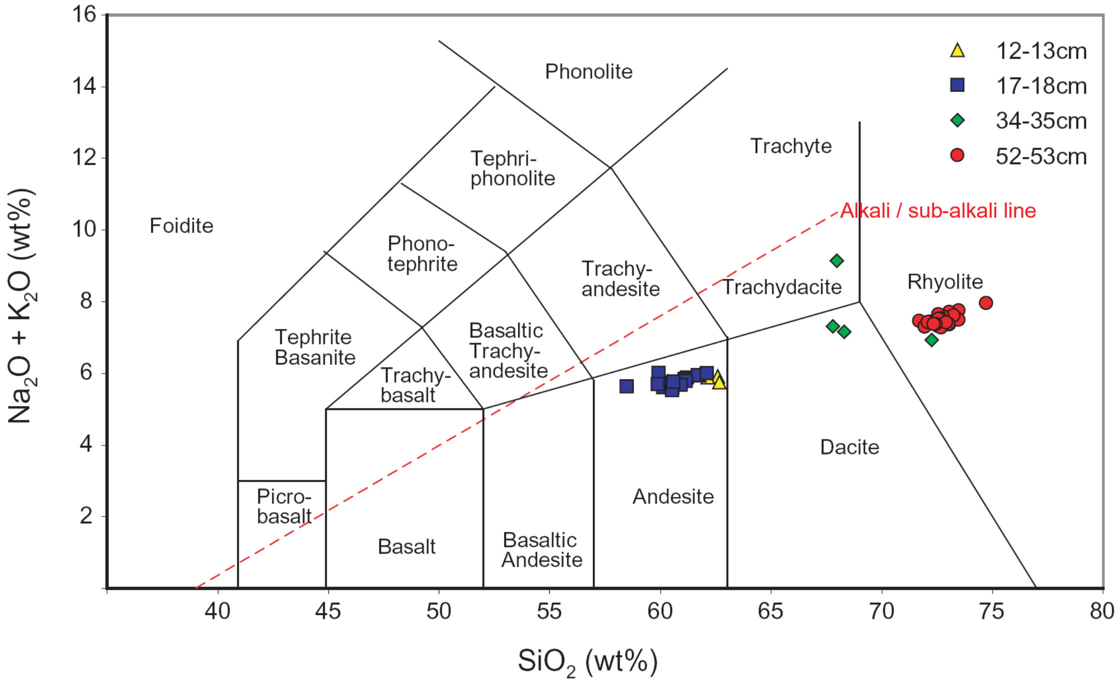



*Figure 4: Total Alkali vs Silica classification graph for the tephra layers identified at Roman Lode*

Tephra classification values are based on the divisions set by Le Maitre *et al* (1989). The data are presented as untransformed values and have not been normalised to 100%

### Layer 2, 17–18cm – Hekla, AD 1510

Fifteen geochemical determinations were obtained from on this tephra layer. It can be classified as a sub-alkali Andesite derived from the Hekla volcano in Iceland (Fig 4). The chemistry obtained for layer 2 is identical to layer 1, which could reflect reworking of one layer into two separate peaks, or two closely spaced eruptions from the same volcano (Fig 5a). There is no evidence for disturbance in the peat that might lead to vertical movement of tephra, and hence the layer is provisionally considered to represent a separate eruption event. The most likely correlation is the AD 1510 eruption of Hekla which has been recorded as a visible layer in Iceland and in microtephra form in Scotland and Ireland (Dugmore *et al* 1995; Pilcher *et al* 1996; Larsen *et al* 1999; Cole and Mitchell 2003). Another possibility is that the tephra layer correlates with the AD 1845 eruption of Hekla, but this layer is not known to be widely distributed across Europe or Britain and a correlation with the AD 1510 eruption is preferred here.

### Layer 3, 34–5cm – unknown tephra

Typically the colourless shards encountered in layer 3 were small (long axis <40μm), highly vesicular, and sparse in number, and acquiring reliable geochemical data proved problematic. In contrast the intermediate shards although also sparse were larger in size which made obtaining geochemical assessment easier. Four successful analyses were obtained, which suggest a mix of three geochemical populations. Two shards can be classified as a sub-alkali dacites, with the other shards classified as a sub-alkali rhyolite and a sub-alkali trachy-dacite (Fig 4). Group 1 is tentatively correlated with the BMR-90 tephra layer dated to *c.* AD 920 (Hall and Pilcher 2002) (Fig 5b). Although the BMR-90 tephra has been confirmed at one site so far in a sequence from Barnsmore in the north of Ireland (Hall and Pilcher 2002), it has recently been recognised in a sequence from the central Irish Midlands (Matthews unpubl data) suggesting a wider distribution than previously thought. However, the low number of geochemical measures available for comparison means that a definitive correlation is not yet possible.

Groups 2 and 3 are represented by single analyses and cannot be confidently correlated with any known eruptions of Late Holocene age. Both are thought to be derived from Iceland, and group three has a chemical signature similar to tephra deposits from the Torfajökull volcano. In the absence of more detailed information, however, no further comparisons can be made.

### Layer 4, 52–3cm – OMH-185, 755–680 cal BC (2705–2630 cal BP)

Twenty-five analyses were performed on this layer. Analytical totals were typically low, with 15 of the 25 analyses returning totals of between 93–95%. The layer is classified as a sub-alkali rhyolite and is correlated with the OMH-185 (Barnsmore) tephra (Figs 4, 5c). The OMH-185 tephra has been identified in Ireland where it has been dated by wiggle-match radiocarbon dating to 755–680 cal BC (2705–2630 cal BP) (Plunkett *et al* 2004). This layer has also been identified in Germany where it is termed the 'DOM-6 microlite-tephra'; this is because of the large numbers of mineral inclusions that are typically observed in the shards (van den Bogaard and Schminke 2002). It is also recorded in Scotland where it is known as the BGMT-3 tephra (Langdon and Barber 2001), while a geochemically similar layer dating to 600 BC, derived from Vatnajökull, has been identified in Iceland (Larsen and Eiríksson 2008). In Ireland two distinct populations have been identified for the OMH-185; population 2 has elevated FeO and CaO values when compared to population 1 (Fig 5c). Population 1 has been identified at Roman Lode.

## DISCUSSION

Three unequivocal tephra isochrones have been established for Roman Lode; Hekla AD 1947, Hekla AD 1510, and the OMH-185 tephra 755–680 cal BC (2705–2630 cal BP). These provide a preliminary tephrostratigraphy for the last 2700 years for south-west England and collectively make a significant addition to the English tephrostratigraphic record. The number of isochrones available for correlation may increase if further geochemical analysis can be obtained from layer three.

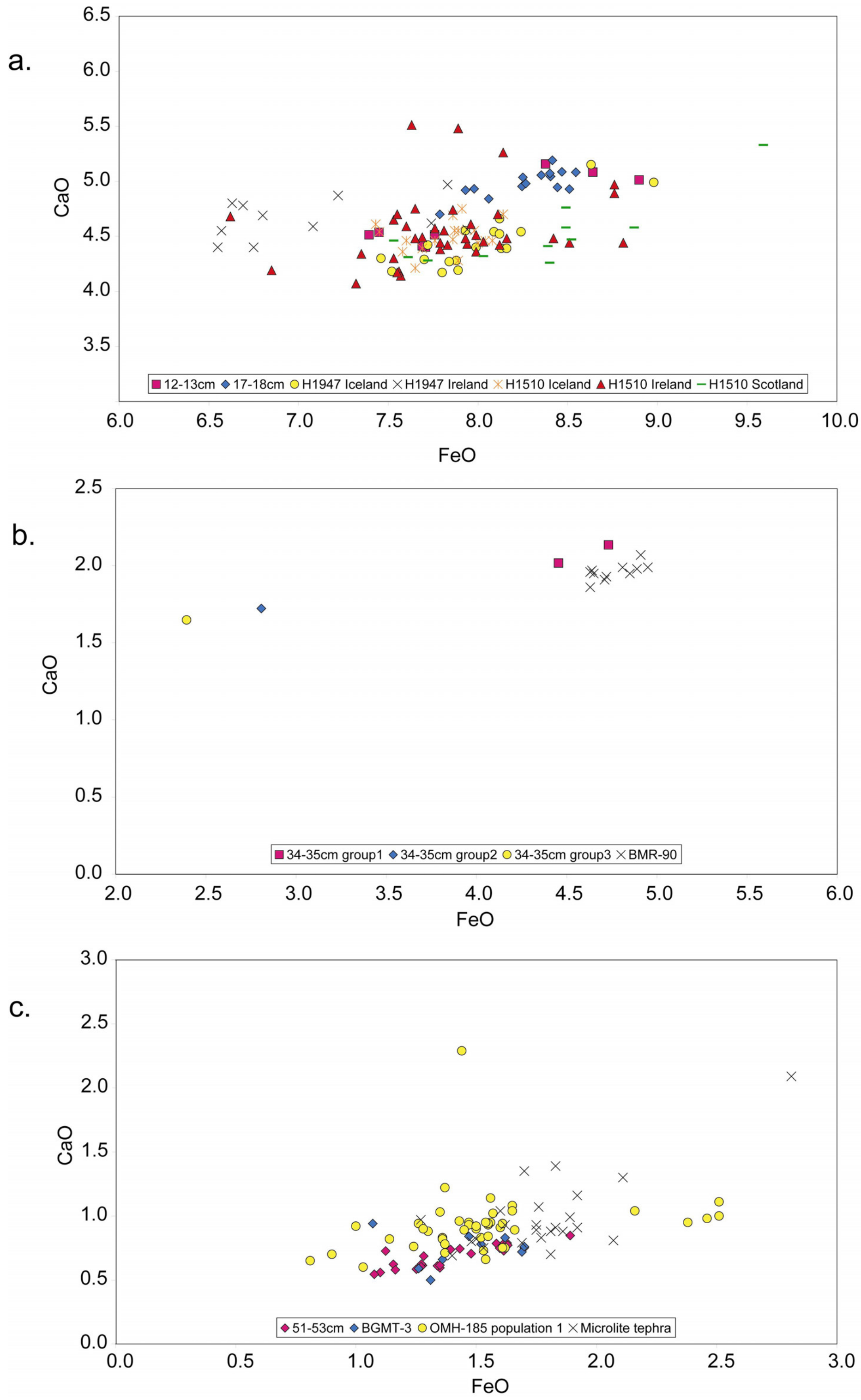



*Figure 5: geochemical correlation plots for ash layers 1–4*

a = ash layers 1 and 2 compared to published data from the eruptions of Hekla in AD 1947 and AD 1510 (Dugmore *et al* 1995; Larsen *et al* 1999; Hall and Pilcher 2002).
b = Comparison of ash layer 3 to published data for the BMR-90 tephra (Hall and Pilcher 2002).
c = ash layer 4 compared to the OMH-185, BGMT-3, and microlite tephra layers (Langdon and Barber 2001; Hall and Pilcher 2002; van den Bogaard and Schminke 2002; Plunkett *et al* 2004). ).
The data are presented as untransformed values and have not been normalised to 100%

The presence of tephra layers in Roman Lode suggests that tephra deposition is considerably more widespread than previously thought. If these or other tephra layers can be detected in more sites across south-west England, then the potential for developing a regional tephrostratigraphic framework can be fully explored. A tephrostratigraphic framework for south-west England would provide two crucial advantages in future palaeoenvironmental studies: firstly a means of testing radiocarbon derived age-depth models, and secondly a technique for correlating palaeoenvironmental sequences across south-west England and Europe, circumventing the problems inherent in radiocarbon dating. The OMH-185 layer at Roman Lode provides a good example of both of these points.

## Testing age-depth models

Two levels in the peat sequence were sampled by English Heritage for radiocarbon age determinations as part of a wider palaeoenvironmental research project; these were between 10–11cm and 52–3cm. The humic and humin fractions of each sample were dated at the Oxford Radiocarbon Accelerator Unit by Accelerator Mass Spectrometry (AMS) and returned age estimates of cal AD 1956–7, and 2310–2060 cal BP respectively (Table 2).

*Table 2: Radiocarbon results from Roman Lode, Exmoor*

| Sample | Sample type | Laboratory code | $\delta^{13}C$ (‰) | $^{14}C$ result (BP or pMC) | Calibrated Date (95% confidence) |
|---|---|---|---|---|---|
| RLBP 2006:1 10–11cm | peat, humin fraction (macrofossils) | OxA-15750 | -26.8 | 106.5 ±0.3 pMC | |
| | peat, humic acid | OxA-15825 | -27.7 | 106.6 ±0.3 pMC | |
| Weighted mean | T'=0.1; v=1; T'(5%)=3.8 (Ward and Wilson 1978) | | | -509.6 ±16 BP | AD 1956–7 |
| RLBP 2006:1 10–11cm | peat, humin fraction (bulk) | OxA-15826 | -27.6 | 101.9 ±0.3 pMC | AD 1955–6 |
| RLBP 2006:2 52–3cm | peat, humin fraction | OxA-15827 | -28.2 | 2184 ±29 BP | |
| | peat, humic acid | OxA-15865 | -26.7 | 2127 ±26 BP | |
| Weighted mean | T'=2.1; v=1; T'(5%)=3.8 (Ward and Wilson 1978) | | | 2153 ±19 BP | 2310–2060 cal BP |

Samples were taken by D E Robinson. Samples were prepared following Hedges *et al* (1989), and measured as described by Bronk Ramsey *et al* (2004). All dates have been calibrated using either the IntCal04 curve (Reimer *et al* 2004) in the case of samples designated RLBP 2006:2 or the Kueppers *et al* (2004) curve for RLBP 2006:1. Calibration was undertaken using OxCal (v3.10) (Bronk Ramsey 1995; 1998; 2001). Where the humic and humin fractions returned radiocarbon determinations that were statistically consistent, they were combined prior to calibration using the method of Ward and Wilson (1978)

The older radiocarbon age determination is from the same stratigraphic level that contains the OMH-185 tephra; wiggle-match radiocarbon dated in Ireland to 2705–2630 cal BP and separately dated to the same period in Germany and Iceland (van den Bogaard *et al* 2002; Plunkett *et al* 2004; Larsen and Eiríksson 2008). The age assignment of this tephra layer indicates that the peat from 52–3cm is at least 310 years older than the radiocarbon determination suggests (Fig 6). Artificially young radiocarbon ages can be produced in slow-growing blanket peats (like those found at Roman Lode) through rootlet penetration, or through the mobilisation, downward movement, and subsequent absorption of humic acids (Head *et al* 2007). This second factor is not thought to be a dominant influence at Roman Lode, as the dated humic and humin fractions produced age determinations that are statistically inseparable. Without the OMH-185 tephra layer it would be difficult to test for or identify this offset, and the age-depth model for Roman Lode would be inaccurate, possibly leading to spurious interpretations of palaeoenvironmental data.

### Correlating palaeoenvironmental sequences

The OMH-185 layer has been identified across several raised bog sequences in Ireland, where it marks a regional shift to colder and wetter conditions (Plunkett 2006), whilst at Roman Lode the OMH-185 layer occurs just above the gleyed mineral soil and dates the beginning of peat formation. The tephra layer enables the correlation of the two sequences and links peat initiation in south-west England to a regional climatic event. Radiocarbon dating of this event would not have provided sufficient precision to confidently make this correlation.

In order to maximise the potential of tephrochronology to contribute to palaeoenvironmental research in south-west England it will be necessary to establish the number of tephra layers and their distribution in the region. Currently, the known layers are restricted to Roman Lode and the last 2700 years. It should therefore be a priority to establish a regional tephrostratotype by extending the tephra research spatially and temporally, and as such new sites that have this potential must be identified.

## CONCLUSIONS

The key findings of this research have been:

- An outline Late Holocene tephrochronology for south-west England has been developed.
- Three unequivocal tephra isochrones have been geochemically characterised at Roman Lode, Devon. These tephra layers have been correlated with the eruptions of the Hekla volcano in AD 1947 and AD 1510 and another tephra layer derived from Iceland, known as the OMH-185 (2705–2630 cal BP). More geochemical analyses are required from tephra layer 3 if it is to be a useful isochrone.
- An offset of *c.* 300 years between ages determined by radiocarbon dating and tephrochronology has been identified.

- The advantages of the tephrochronology in palaeoenvironmental research in the provision of greater chronological precision and accuracy, and the potential for future tephrochronological research have been highlighted.
- To further develop the regional tephrostratigraphy, more sites must be identified that have the potential to spatially and temporally extend the tephrostratigraphic framework.

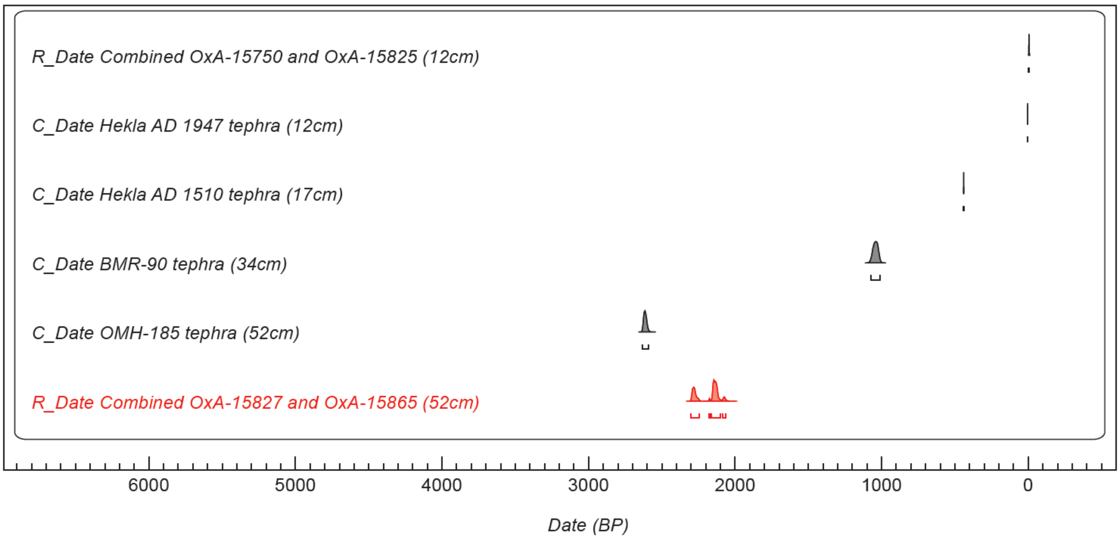



*Figure 6: Dating evidence from Roman Lode, Exmoor, Devon (cal BP)*

Age ranges for all the radiocarbon and tephra-dated levels from Roman Lode. The ages used for the BMR-90 and the OMH-185 tephra are from Hall and Pilcher (2002) and Plunkett *et al* (2004). The radiocarbon ages were calibrated in OxCal v4 using the IntCal04 calibration curve (Bronk Ramsey 1995; 2001; 2008; Reimer *et al* 2004). Radiocarbon data from 12cm depth broadly agrees with the tephra data from this interval where shards from the Hekla AD 1947 eruption have been detected. The combined radiocarbon dates at 52cm (in red) do not agree with the tephrochronological data. The offset between the tephra age estimate and the radiocarbon data is at least 310 years.

## REFERENCES


Bengtsson, L, and Enell, M, 1986 Chemical analysis, in *Handbook of Holocene Palaeoecology and Palaeohydrology* (ed B E Berglund), Sussex (Wiley), 423–54

Blockley, S P E, Pyne-O'Donnell, S D F, Lowe, J J, Pollard, A M, Matthews, I P, Molyneux, E G, and Turney, C S M, 2005 A new and less destructive laboratory procedure for the physical separation of distal glass tephra shards from sediments, *Quaternary Science Reviews*, 24, 1952–60

Blockley, S P E, Ramsey, C B, Lane, C S, Lotter, A F, 2008 Improved age modelling approaches as exemplified by the revised chronology for the Central European varved lake Soppensee, *Quaternary Science Reviews*, 27 (1-2), 61–71

Bronk-Ramsey, C, 1995 Radiocarbon calibration and analysis of stratigraphy: the OxCal program, *Radiocarbon*, 37, 425–30

Bronk-Ramsey, C, 1998 Probability and dating, *Radiocarbon*, 40, 461–74

Bronk-Ramsey, C, 2001 Development of the radiocarbon calibration program OxCal, *Radiocarbon*, 43, 355–63

Bronk-Ramsey, C, 2008 Deposition models for chronological records, *Quaternary Science Reviews*, 27 (1-2), 42–60

Bronk-Ramsey, C, Higham, T, and Leach, P, 2004 Towards high precision AMS: progress and limitations, *Radiocarbon*, 46(1), 17–24

Buckley, S, and Walker, M J C, 2002 A mid-Flandrian tephra horizon, Cambrian Mountains, West Wales, *Quaternary Newsletter*, 96, 5–11

Cole, E E, and Mitchell, F J G, 2003 Human impact on the Irish landscape during the late Holocene inferred from palynological studies at three peatland sites, *The Holocene*, 13, 507–15

Dugmore, A, 1989 Icelandic volcanic ash in Scotland, *Scottish Geographical Magazine*, 105, 168–72

Dugmore, A J, Larsen, G, and Newton, A J, 1995 Seven tephra isochrones in Scotland, *The Holocene*, 5, 257–66

Fyfe, R, forthcoming *Pollen analysis of blanket peat deposits at Roman Lode, Burcombe, Exmoor, N Devon*, Engl Heritage Res Dep Rep Ser

Head, K, Turney, C S M, Pilcher, J R, Palmer, J G, and Baillie, M G L, 2007 Problems with identifying the '8200-year cold event' in terrestrial records of the Atlantic seaboard: a case study from Dooagh, Achill Island, Ireland, *Journal of Quaternary Science*, 22(1), 65–75

Hedges, R E M, Bronk, C R, and Housley, R A, 1989 The Oxford Accelerator Mass Spectrometry facility: technical developments in routine dating, *Archaeometry*, 31, 99–113

Hunt, J B, and Hill, P G, 1993 Tephra geochemistry: a discussion of some persistent analytical problems, *The Holocene*, 3, 271–8

Juleff, G, and Bray, L, 2007 Minerals, metal, colours and landscape: Exmoor's Roman Lode in the Early Bronze Age, *Cambridge Journal of Archaeology*, 17, 285–96

Kueppers, L M, Southon, J, Baer, P, and Harte, J, 2004 Dead wood biomass and turnover time, measured by radiocarbon, along a subalpine elevation gradient, *Oecologia*, DOI: 101007/s00442-004-1689-x

Langdon, P G, and Barber, K E, 2001 New Holocene tephras and a proxy climate record from a blanket mire in northern Skye, Scotland, *Journal of Quaternary Science*, 16, 753–9

Larsen, G, Dugmore, A, and Newton, A, 1999 Geochemistry of historical-age silicic tephras in Iceland, *The Holocene*, 9, 463–71

Larsen, G, and Eiríksson, J, 2008 Late Quaternary terrestrial tephrochronology of Iceland - frequency of explosive eruptions, type and volume of tephra, *Journal of Quaternary Science,* 23, 109-20

Le Maitre, R W, Bateman, P, Dudek, A, Keller, J, Lameyre Le Bas, M J, Sabine, P A, Schmid, R, Sorensen, H, Streckeisen, A, Woolley, A R, and Zanettin, B, 1989 *A classification of igneous rocks and glossary of terms*, Oxford (Blackwell)

Lowe, J J, 2001 Abrupt climatic changes in Europe during the last glacial-interglacial transition: the potential for testing hypotheses on the synchroneity of climatic events using tephrochronology, *Global and Planetary Change*, 30, 73–84

Lowe, J J, Blockley, S P E, Trincardi, F, Asioli, A, Cattaneo, A, Matthews I P, Pollard, A M, and Wulf, S, 2007 Age modelling of late Quaternary marine sequences in the Adriatic: towards improved precision and accuracy using volcanic event stratigraphy, *Continental Shelf Research*, 27, 560–82

Mortensen, A K, Bigler, M, Grönvold, K, Steffensen, J P, and Johnsen, S J, 2005 Volcanic ash layers from the Last Glacial termination in the NGRIP ice core, *Journal of Quaternary Science*, 20, 209–19

Persson, C, 1971 Tephrochronological investigations of peat deposits in Scandinavia and on the Faroe Islands, *Sveriges Geologiska Undersökning*, 65, 3–34

Pilcher, J R, and Hall, V A, 1992 Towards a tephrochronology for the Holocene of the north of Ireland, *The Holocene*, 2, 255–9

Pilcher, J R, and Hall, V A, 1996 Tephrochronological studies in northern England, *The Holocene*, 6, 100–105

Hall, V A, and Pilcher, J R, 2002 Late-Quaternary Icelandic tephras in Ireland and Great Britain: detection, characterization and usefulness, *The Holocene*, 12, 223–30

Plunkett, G, Pilcher, J R, McCormac, F G, and Hall, V A, 2004 New dates for first millennium BC tephra isochrones in Ireland, *The Holocene*, 14, 780–6

Plunkett, G, 2006 Tephra-linked peat humification records from Irish ombrotrophic bogs question nature of solar forcing at 850 cal yr BC, *Journal of Quaternary Science*, 21, 9–16

Pollard, A M, Blockley, S P E, and Lane, C S, 2006 Some numerical considerations in the geochemical analysis of distal microtephra, *Applied Geochemistry*, 21, 1692–1714

Reimer, P J, Baillie, M G L, Bard, E, Bayliss, A, Beck, J W, Bertrand, C J H, Blackwell, P G, Buck, C E, Burr, G S, Cutler, K B, Damon, P E, Edwards, R L, Fairbanks, R G, Friedrich, M, Guilderson, T P, Hogg, A G, Hughen, K A, Kromer, B, McCormac, G, Manning, S, Bronk Ramsey, C, Reimer, R W, Remmele, S, Southon, J R, Stuiver, M, Talamo, S, Taylor, F W, van der Plicht, J, and Weyhenmeyer, C E, 2004 IntCal04 Terrestrial radiocarbon age calibration, 0–26 Cal Kyr BP, *Radiocarbon*, 46, 1029–58

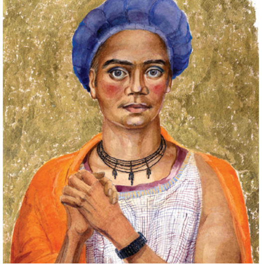
Turney, C S M, Harkness, D D, and Lowe, J J, 1997 The use of microtephra horizons to correlate Late-glacial lake sediment successions in Scotland, *Journal of Quaternary Science*, 12, 525–31

van den Bogaard, C, and Schmincke, H-U, 2002 Linking the North Atlantic to central Europe: a high-resolution Holocene tephrochronological record from northern Germany, *The Holocene*, 17, 3–20

van den Bogaard, C, Dörfler, W, Glos, R, Nadeau, M-J, Grootes, P M, and Erlenkeuser, H, 2002 Two tephra layers bracketing late Holocene palaeoecological changes in Northern Germany, *Quaternary Research*, 57, 314–24

Ward, G K, and Wilson, S R, 1978 Procedures for comparing and combining radiocarbon age determinations: a critique, *Archaeometry*, 20(1), 19–31

Wastegård, S, 2005 Late Quaternary tephrochronology of Sweden: a review, *Quaternary International*, 130, 49–62



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