Quaternary Science Reviews 83 (2014) 11–27

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

Was there a '4.2 ka event' in Great Britain and Ireland? Evidence from the peatland record

T.P. Roland [a,b,*], C.J. Caseldine [b], D.J. Charman [b], C.S.M. Turney [c], M.J. Amesbury [b]

[a] Palaeoenvironmental Laboratory (PLUS), Geography and Environment, University of Southampton, UK
[b] Geography, College of Life and Environmental Sciences, University of Exeter, UK
[c] School of Biological, Earth and Environmental Sciences, University of New South Wales, Australia

A R T I C L E I N F O

Article history:
Received 7 August 2013
Received in revised form
23 October 2013
Accepted 24 October 2013
Available online 18 November 2013

Keywords:
4.2 ka event
2.8 ka event
Multi-proxy
Peatlands
Great Britain and Ireland
Testate amoebae
Hekla 4
Abrupt and extreme climate change

A B S T R A C T

Palaeoenvironmental and archaeological data from several regions around the world show evidence of a multi-centennial climatic event occurring approximately 4200 cal yr BP (4.2 ka). Whilst the climatic change and/or impact of the 4.2 ka event is clear in certain regions, such as western Asia, evidence for the event has yet to be fully evaluated in northwest Europe. This study presents high-resolution, multi-proxy palaeoclimate records from sites in Northern Ireland, ideally located for an objective examination of the nature of the event in Great Britain and Ireland within the broader context of mid-Holocene climate change c. 6.5–2.5 ka. The peatlands of northwest Europe possess considerable potential for the examination of climatic change in the North Atlantic region, demonstrated by the range of palaeohydrological proxy data generated during this study (peat humification, plant macrofossil and testate amoebae analyses) supported by a high-resolution chronology (including comprehensive AMS ^{14}C and tephrochronology). The inter-site testate amoebae reconstructions appear coherent and were combined to produce a regional climatic record, in marked contrast to the plant macrofossil and peat humification records that appear climatically complacent. The testate amoebae reconstruction, however, provides no compelling evidence for a 4.2 ka event signal and is consistent with previously reported studies from across northwest Europe, suggesting the origin and impact of this event is spatially complex.

1. Introduction

In the context of current and projected future climate change, past abrupt climate events during the Holocene (the last 11.65 ka; Walker et al., 2009) and their impact(s) on human populations are important foci for palaeoclimatic research (Alley et al., 2003; Broecker, 2006). Unlike early-Holocene events associated with deglaciation at the end of the last glacial period, mid- to late-Holocene events occurred under environmental boundary conditions similar to those of the present day and are therefore likely to provide better analogues for future change.

The '4.2 ka event' has been identified globally as a period of abrupt climate change (Cullen et al., 2000; Bond et al., 2001; Thompson et al., 2002; Marchant and Hooghiemstra, 2004; Booth et al., 2005; Drysdale et al., 2006; Liu and Feng, 2012), initially associated with urban abandonment and societal collapse in Mesopotamia driven by a severe multi-centennial drought (Weiss et al., 1993). Subsequent work has since linked this event to societal disruption in other key centres of early civilisation (Weiss and Bradley, 2001; Stanley et al., 2003; Staubwasser and Weiss, 2006; Liu and Feng, 2012). In a comprehensive review of palaeoclimatic evidence for the 4.2 ka event, Roland (2012) found a broad global pattern at this time characterised by pronounced dry conditions at lower latitudes, with more ambiguous but often cooler and/or wetter conditions at higher latitudes of the northern hemisphere and also in South America. Similar climatic anti-phasing has been observed in other palaeoclimate studies associated with the 4.2 ka event (e.g. Marchant and Hooghiemstra, 2004; Booth et al., 2005) as well as in examinations of modern low-latitude drought episodes (e.g. Hoerling and Kumar, 2003). The origin of the 4.2 ka event has been linked to ocean-atmospheric circulation changes in the North Atlantic (Bond et al., 2001; Booth et al., 2005; Roland, 2012) but its climatic impact remains poorly understood in comparison to similar events in the Holocene. Despite this, Walker et al. (2012a) have recently identified the 4.2 ka event as a suitable marker to subdivide the Holocene period into 'middle' and 'late' chronozones.

* Corresponding author. Palaeoenvironmental Laboratory (PLUS), Geography and Environment, University of Southampton, University Road, Southampton, Hampshire SO17 1BJ, UK.
E-mail address: t.p.roland@soton.ac.uk (T.P. Roland).

0277-3791/$ – see front matter
http://dx.doi.org/10.1016/j.quascirev.2013.10.024

Proxy records developed from ombrotrophic raised bog systems are likely to possess a strong climate signal, owing to their reliance on a combination of precipitation and temperature (Charman, 2007; Charman et al., 2009; Booth, 2010; Amesbury et al., 2012a). Their potential in Great Britain and Ireland for recording North Atlantic climatic change is well documented (Charman et al., 2006; Swindles et al., 2013). Progress in the discipline now allows for cross-proxy and cross-site validation of a range of quantitative and semi-quantitative proxy reconstructions (e.g. Blackford and Chambers, 1993; Barber et al., 1994; Charman et al., 2007) to identify and verify the presence of a regional climate signal (e.g. Charman et al., 1999; Chiverrell, 2001; Langdon et al., 2003; Blundell and Barber, 2005; Hughes et al., 2006). Such comparisons are aided by relatively high accumulation rates and the potential for developing highly-precise and accurate chronologies (e.g. ^{14}C and tephrochronology) associated with raised bogs.

Whilst other Holocene climatic deteriorations have been the subject of temporally-focussed, peat-based studies (e.g. Little Ice Age, Mauquoy et al., 2002; De Vleeschouwer et al., 2009; the c. 2.8–2.6 ka event, van Geel et al., 1996; Plunkett, 2006; Chambers et al., 2007; Swindles et al., 2007a; Plunkett and Swindles, 2008; the c. 5.2–5.1 ka event, Caseldine et al., 2005; the 8.2 ka event, Hughes et al., 2006; Daley et al., 2009), equivalent studies on the 4.2 ka event are remarkably limited in number. Where records from this period have been reported, data are frequently derived from single-proxy or single-site reconstructions with substantial differences in sampling and chronological resolution (e.g. Hughes et al., 2000; Barber et al., 2003; Barber, 2007; Mauquoy et al., 2008; Daley and Barber, 2012) (see Table 1, Fig. 10).

The peatlands of Great Britain and Ireland present an excellent opportunity to study the potential manifestation of the 4.2 ka event in the region, potentially documenting the timing and nature of its palaeohydrological effects and likely drivers. To help determine the existence, impact and potential driver(s) of the 4.2 ka in northwest Europe, we have investigated two highly-resolved peat sequences in northern Ireland, along the eastern seaboard of the North Atlantic. To place this event in the context of mid-Holocene climate change, we have undertaken high-resolution, multi-proxy palaeoclimate reconstructions supported by the development of robust chronologies to test whether a coherent 4.2 ka event can be identified within the broader period of c. 6.5–2.5 ka.

2. Regional setting

Ireland has a maritime climate dominated by prevailing westerly airflow and is sensitive to latitudinal variation of the Westerlies, the influence of the North Atlantic Oscillation (NAO) and thermohaline circulation (THC) and other ocean-atmospheric modes in the North Atlantic (McCabe and Clark, 1998; McDermott et al., 2001; Anderson et al., 2004; Turney et al., 2005; Swindles et al., 2010a). Ireland's climatic sensitivity, coupled with its large number of Holocene age peat sequences (Double, 1954; Smith and Goddard, 1991), well-developed regional tephrochronology (Pilcher et al., 1995a, 1996; Hall and Pilcher, 2002; Lowe et al., 2004) and archaeological record (Woodman, 1985) makes it an ideal location to study the 4.2 ka event. Importantly, the Hekla 4 tephra horizon (4345–4229 cal yr BP; Pilcher et al., 1996), serving as an important temporal marker for the time period, is particularly abundant in the peatlands of northern Ireland.

The lower valleys of the Rivers Main and Bann form an extensive lowland area overlying Tertiary basalts between the Antrim Hills and Sperrin Mountains in northern Ireland. Two ombrotrophic raised bogs, approximately 22 km apart, were investigated here: Sluggan Moss, in County Antrim, and Fallahogy Bog, in County Derry (Fig. 1). Both sites were once part of large peatland complexes but have been affected by peat cutting in recent centuries. Owing to the mid-Holocene focus of this study, however, it is assumed that this activity has not affected the palaeohydrological record from either site during earlier millennia. Sluggan Moss and Fallahogy Bog were also the focus of the first modern palaeoecological studies in the region (Smith, 1958; Smith and Goddard, 1991) and have been employed together many times since (e.g. Pilcher and Hall, 1992; Hall et al., 1993, 1994; Pilcher et al., 1995b, 1996; Hall, 2000, 2003; O'Connell and Molloy, 2001; Swindles et al., 2013). Plant macrofossil data produced by this study, together with evidence from previous studies, confirms that both bogs became ombrotrophic over 1000 years before the proposed 4.2 ka event.

Crucially, earlier work suggests that Ireland's peat archive possesses considerable potential for the examination of climatic variation in the North Atlantic region (Holmes, 1998; Plunkett, 1999, 2006; Barber et al., 2000; Turney et al., 2005; Swindles, 2006; Swindles et al., 2007a, b; 2010a; Amesbury, 2008; Blundell et al., 2008; Plunkett and Swindles, 2008; Langdon et al., 2012). Despite this, few published data extend beyond c. 4.5 ka (e.g. Swindles et al.,

Table 1
Existing evidence used to support the presence of a 4.2 ka event in Great Britain and Ireland (Detrended Correspondence Analysis – DCA; Non-metric Multidimensional Scaling – NMDS; Dupont Hydroclimatic Index – DHI; Transfer Function – TF; Percentage Light Transmission - %T; all AMS ^{14}C dates were from 1 cm stratigraphic depth).

Study	Site(s)	Proxy (stats)	Proposed nature of change	Proposed age of change; chronological control (2.5–6.5 ka)
Hughes et al. (2000)	Walton Moss, northern England	Plant macrofossils (DCA)	Major wet event	4.41–3.99 ka; 2 radiometric ^{14}C dates of bulked material from 8 cm stratigraphic depth, no tephrochronology.
Barber et al. (2003)	Abbeyknockmoy Bog, central Ireland	Plant macrofossils (DCA)	Major change to wetter/cooler conditions	4.4 ka; 6 radiometric ^{14}C dates of bulked material from 2 cm stratigraphic depth, no tephrochronology.
	Bolton Fell Moss, northern England	Plant macrofossils (DCA)	Major change to wetter/cooler conditions	4.4 ka; 10 radiometric ^{14}C dates of bulked material from 3 to 8 cm stratigraphic depth, no tephrochronology.
Barber (2007)	Review of studies (1976–2005) from a number of sites across Ireland and northern Great Britain, as well as elsewhere in NW Europe	Plant macrofossils (DCA), testate amoebae (TF), humification (%T)	Changes to cooler/wetter conditions	Range from 4.62 to 3.99 ka; high variability in chronological strategy between studies, tephrochronology limited to one study
Mauquoy et al. (2008)	Butterburn Flow, northern England	Testate amoebae (TF); plant macrofossils (DHI)	Moderate wet shift	c. 4.15 ka; 14 AMS ^{14}C dates, no tephrochronology.
Daley and Barber (2012)	Walton Moss, northern England	Testate amoebae (TF), plant macrofossils (DCA/NMDS/DHI), humification (%T)	Rapid shift to wetter conditions	c. 4.2 ka; 13 AMS ^{14}C dates, no tephrochronology.