Quaternary International xxx (2016) 1–15

Contents lists available at ScienceDirect

Quaternary International

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

Terrestrial and aquatic ecosystem responses to early Holocene rapid climate change (RCC) events in the South Carpathian Mountains, Romania

Ilona Pál [a, b, *], Krisztina Buczkó [c], Ildikó Vincze [a, b], Walter Finsinger [d], Mihály Braun [e], Tamás Biró [f], Enikő K. Magyari [b]

[a] Department of Physical and Applied Geology, Eötvös Loránd University, H-1117 Budapest, Pázmány Péter stny. 1/C, Hungary
[b] MTA-MTM-ELTE Research Group for Paleontology, H-1117 Budapest, Pázmány Péter stny. 1/C, Hungary
[c] Hungarian Natural History Museum, H-1476 Budapest, P.O. Box 222, Hungary
[d] Palaeoecology, Institut des Sciences de l'Evolution (UMR 5554 CNRS/UM/IRD/EPHE), Place E. Bataillon, 34095 Montpellier, France
[e] Department of Inorganic and Analytical Chemistry, University of Debrecen, H-4010 Debrecen, P.O. Box 21, Hungary
[f] Hungarian Academy of Sciences, Research Center for Humanities, Institute of Archaeology, H-1014, Budapest, Úri u. 49, Hungary

A R T I C L E I N F O

Article history:
Received 25 March 2016
Received in revised form
27 October 2016
Accepted 3 November 2016
Available online xxx

Keywords:
Rapid ecosystem response
Pollen
Charcoal
Diatom
Preboreal oscillation
10.2 event
8.2 event

A B S T R A C T

As demonstrated by an increasing number of palaeoclimatic and palaeoecological studies, rapid climate change events (RCCs) occurred frequently in the Holocene and their timing correlates well in the European records. Changes in vegetation composition and environmental conditions were significant during these RCC events. In this study we use high resolution pollen, stomata, micro- and macrocharcoal, macrofossil, siliceous algae, biogenic silica and organic content analyses from two alpine lake sediments (Lake Brazi, 1740 m a.s.l.; Lake Gales, 1990 m a.s.l.) in the Retezat Mts, South Carpathian Mountains, Romania. Our aim is to study ecosystem responses to RCCs between 12,000 and 7000 cal yr BP using high-resolution proxy analyses of the relevant sediment sections. We detected several significant changes in the terrestrial vegetation composition and aquatic ecosystems in case of both lakes. Complex ecosystem responses were found in connection with the early Holocene RCC intervals. Most prominently, the 10.2 ka climatic change likely fostered the extinction of *Larix decidua* from the shore of Lake Brazi, while climatic change during the 8.2 ka event facilitated the establishment of *Carpinus betulus* in the lower deciduous mixed oak forests, due to decreasing growing season temperatures, frequent summer droughts and associated recurrent fire events. Taken together, most of the significant pollen compositional changes reflected the periodic spread of pioneer deciduous tree taxa (mainly *Fraxinus excelsior* and *Corylus avellana*) during the early Holocene RCCs. In all cases, this change was connectable to increased regional fire activity and the temporary increase of herbs. The most significant change in the lake-ecosystems was often the short-lived spread of various planktonic diatom species, mainly the members of genus *Aulacoseira*. Sudden appearance and large-scale percentage increase of these taxa suggested higher water-depth and/or intensified water turbulence.

1. Introduction

Short-term climatic fluctuations, so-called rapid climate change events (RCCs), occurred abruptly and repeatedly during the Holocene. They were more frequent in the early Holocene (between ~11,700 and 7000 cal yr BP, Smith et al., 2011) and less frequent during the mid- and late Holocene (after 7000 cal yr BP, Mayewski et al., 2004). These centennial-scale climatic fluctuations spanned short-time periods, generally 100–300 years (Stocker, 2000; Alley et al., 2003; Mayewski et al., 2004). According to Wanner et al. (2008, 2011), the amplitude of the Holocene RCC events has been larger than previously assumed, even though their amplitude was smaller than the climate shifts of the last glacial cycle (Rasmussen et al., 2006, 2007, 2014). They were most likely triggered by orbital variations and solar activity changes (Magny, 2007; Wanner et al.,

* Corresponding author. Department of Physical and Applied Geology, Eötvös Loránd University, H-1117 Budapest, Pázmány Péter stny. 1/C, Hungary.
E-mail address: palilona@caesar.elte.hu (I. Pál).

http://dx.doi.org/10.1016/j.quaint.2016.11.015
1040-6182/

2008, 2011). The importance of freshwater forcing in triggering changes in the Atlantic meridional overturning circulation (AMOC) was also stressed in association with the late glacial and Holocene RCC events (Clark et al., 2001, 2002; Teller et al., 2002; Vellinga and Wood, 2002; Mayewski et al., 2004; Holmes et al., 2011; Bigg et al., 2012).

The results of different palaeoclimate proxy studies, including glacier fluctuation (Denton and Karlén, 1973; Denton et al., 2005), ice core records (O'Brien et al., 1995) and marine sediment records (Bond et al., 1997, 1999) have been used to estimate centennial-scale Holocene climate variability, particularly in Europe and North America. Likewise, continental lake sediment records from Europe provided insights into the characteristics of the environmental conditions and biotic responses during several early Holocene RCCs (Karlén and Kuylenstierna, 1996; Haas et al., 1998; Tinner and Lotter, 2001; Williams et al., 2002; Mayewski et al., 2004; Veski et al., 2004; Kofler et al., 2005; Joerin et al., 2006; Magny, 2007; Magny et al., 2007; Randsalu-Wendrup et al., 2012; Drăguşin et al., 2014; Gałka et al., 2015; Grindean et al., 2015; Stivrins et al., 2015). Lake level studies were useful to determine rapid variations in the hydrological cycle and connect them with the Holocene rapid climate change events (Magny, 2004, 2007, 2013; Magny et al., 2007; Gałka and Apolinarska, 2014).

1.1. *Timing and characteristics of the early Holocene RCCs*

A typical feature of the early Holocene rapid climate change events was their association with large volume freshwater outbursts and ice rafted debris (IRD) events in the North Atlantic Region (Bond et al., 1997, 2001; Teller et al., 2002). Freshwater outbursts happened at times of solar activity minima (Björck, 1995; Barber et al., 1999; Clark et al., 2001; Teller et al., 2000, 2002; Teller and Leverington, 2004; Magny, 2004, 2007; Magny et al., 2007; Fleitmann et al., 2008) or immediately preceded them (Muscheler et al., 2000). Succeeding cooling events in the North-Atlantic region were marked in Europe by higher lake levels (between 11,250 and 11,050, 10,300–10,000, 9550–9150 and 8300–8050 cal yr BP) at mid-latitudes, whereas high- and low-latitudes (thus Northern and Southern Europe) were characterized by decreasing lake-levels (Fig. 1a, and Magny, 2004, 2007). As a result, Europe appears to have been characterized by a tripartite hydrological division during the RCC events (Fig. 1a; Magny et al., 2003, 2007; Magny, 2007). Higher lake levels at mid-latitudes suggested wetter conditions due to intensified cyclonic activity because of the stronger thermal gradient between high (Azores High) and low (Icelandic Low) northern latitudes (Fig. 1a; Magny, 2004, 2007). On the other hand, Northern and Southern Europe were characterized by decreasing lake levels, on the basis of which Magny (2007) inferred that climatic conditions became drier in these regions due to decreasing precipitation during the RCC events. Conversely, meltwater pulses that happened during periods of solar activity maxima resulted in no changes in the North-western and Western European lake levels (Magny, 2007; Magny et al., 2007).

Four RCC events are most commonly reported for the period spanning 11,700–7000 cal yr BP. The so-called Preboreal Oscillation (PBO) is a widely detected event that occurred shortly after the Younger Dryas/Holocene transition (Behre, 1978; Björck et al., 1996, 1997). It was a remarkable cooling period centered around 11,250 cal yr BP, and lasted for *c.* 150 years between 11,300 and 11,150 cal yr BP (Björck et al., 1996; Magny et al., 2007). The second prominent (lasted less than 200 years) cooling occurred around 10,300 cal yr BP (Björck et al., 2001). The third climatic oscillation was detected between 9500 and 9100 cal yr BP with a cooling anomaly around 9400 cal yr BP (Muscheler et al., 2000; Fleitmann et al., 2008). Among the early Holocene RCCs, the climatic oscillation around 8200 cal yr BP is one of the strongest and most widely detected (Alley et al., 1997; Wiersma and Renssen, 2006; Berger and Guilaine, 2009; Drăguşin et al., 2014). In North-eastern Europe, the cooling trend was centered between 8250 and 8150 cal yr BP, and the pollen-based quantitative annual temperature reconstruction showed 0.5–1.5 °C cooling that lasted for ~300 years (Veski et al., 2004; Seppä et al., 2007).

Biotic responses and the timing and amplitude of detected climatic anomalies varied within Europe depending on latitude and longitude in connection with RCC events (e.g. Björck et al., 1997; Tămaş et al., 2005; Tinner and Kaltenrieder, 2005; Seppä et al., 2007; Feurdean et al., 2008a, 2008b; Berger and Guilaine, 2009; Drăguşin et al., 2014; Gałka and Apolinarska, 2014; Soróczki-Pintér et al., 2014; Tóth et al., 2012, 2015; Gałka et al., 2015; Grindean et al., 2015), and we are still far from understanding the impact and mechanism of these climatic oscillations on a continental scale. We have particularly incomplete knowledge from the Southern Carpathian region where our study area, the Retezat Mountains, is situated. Intensive multi-proxy palaeoecological investigations started here in 2007, and since then a series of publications have dealt with the late glacial and early Holocene environmental changes offering us the possibility to investigate the early Holocene RCCs with a multi-proxy approach (Buczkó et al., 2009, 2012, 2013; Magyari et al., 2009, 2011, 2012, 2013; Korponai et al., 2011; Tóth et al., 2012, 2015; Pál et al., 2016).

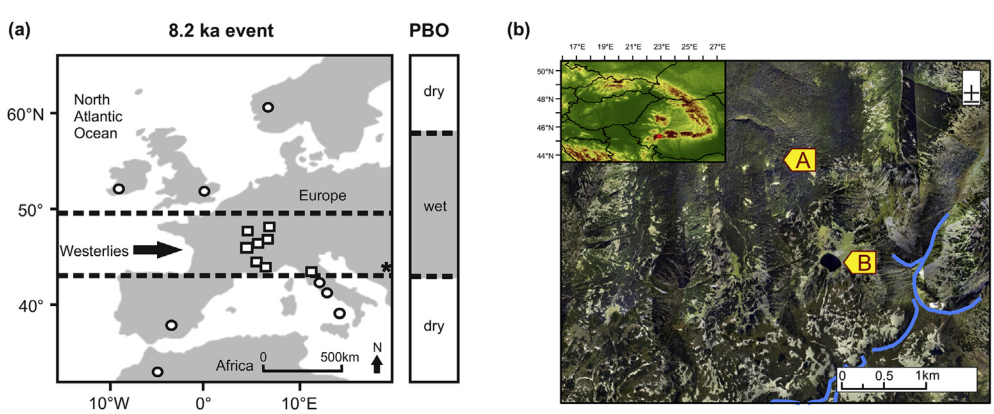

Fig. 1. Location of our study site, the Retezat Mountains (South Carpathians) in Europe marked by '*' on the 8.2 ka lake level change map (a) (modified after Magny, 2007). Encompassed by the broken lines is the mid-latitude zone characterized by wetter conditions during the 8.2 ka event (white rectangles). The northern and southern zones on the other hand, were characterized by drier conditions (white circles) (further details see Pál et al., in press). We also show the location of these zones during the Preboreal Oscillation (PBO). (b) The location of Lake Brazi (A) (1740 m a.s.l.) and Lake Gales (B) (1990 m a.s.l.) on the northern slope of the Retezat Mts.

Please cite this article in press as: Pál, I., et al., Terrestrial and aquatic ecosystem responses to early Holocene rapid climate change (RCC) events in the South Carpathian Mountains, Romania, Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2016.11.015