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Reconciling diverse diatom-based lake responses to climate change in four mountain lakes in the South-Carpathian Mountains during the last 17 kyrs

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ABSTRACT

Climatic changes were studied using siliceous algae (diatoms and Chrysophyta stomatocysts) analyses in four mountain lakes in the Retezat Mountains in the South-Carpathian Mountains with the aim to search for synchrony in aquatic ecosystem responses. According to the basal radiocarbon dating of the lake sediment cores, these lakes were formed around 17,000–15,000 cal yr BP. High resolution diatom analyses were carried out together with loss-on-ignition (LOI) and biogenic silica (BiSi) measurements on the lakes. Comparison of the proxy results suggests that despite the different slope aspect, water-depth and basin parameters, diatom assemblage changes show clear synchrony. The most remarkable changes in the aquatic ecosystems were observed around 6500 cal yr BP on the northern slope and around 6100 cal yr BP on the southern slope during the Holocene. Evidences for sharp concomitant shifts were found between 9200–9000 and 3200-3000 cal yr BP in the siliceous algal communities on both slopes. The Late Glacial/Holocene boundary was not pronounced in the shallow lakes, but was significant in a deep lake. The signs of a dry and bipartite Younger Dryas (GS-1) were evident, but floristic changes differed in the lakes. Principal component analyses explained very similar variances along the first and second axes for three lakes, while the fourth lake (Lake Bucura) proved less sensitive to climate change due to the dominance of moss-inhabiting diatom assemblages. Lake level changes have only been reconstructed on the basis of diatom life forms in one of the deep lakes (Lake Gales). High lake levels were inferred between 9300–9000 and 3000-1700 cal yr BP. In addition to LOI, biogenic silica content (BiSi) was measured on the sediments of the northern slope and pointed to different seasonal biological productivities; increasing LOI was often coupled with low BiSi values.

1. Introduction

Lacustrine sediments play an important role in recording past environmental conditions through the preservation of biota's remains that once inhabited the lakes (Adrian et al., 2009). Siliceous microfossils are one of the most widely studied biotic remains in lake sediments; they track environmental changes owing to their diversity and abundance, combined with their sensitivity to changes in lake chemistry, water-depth, and relatively good preservation in sediments (Lotter et al., 1997, 1998, 2010, Lotter, 2003; Battarbee, 2000; Mackay et al., 2003; Schmidt et al., 2004a, 2007; Zhang et al., 2014; Ampel et al., 2015; Gao et al., 2016).

To date, there has been no coherent synthesis of the existing palaeorecords for siliceous algae in the late Quaternary that hamper paleoecological reconstructions on every biogeographical scale. Although several studies provided synthesis of diatom-based Late Glacial and Holocene paleoclimates (e.g. Mackay et al., 2003; Wilson et al., 2008; Lotter et al., 2010; Catalan et al., 2013; Moreno et al., 2014; Zhang et al., 2014; Kłapyta et al., 2015), we still require an improved understanding of the spatial variability of climate over time in order to understand the underlying climatic mechanisms.

In this paper we synthesize our ten years long paleolimnological

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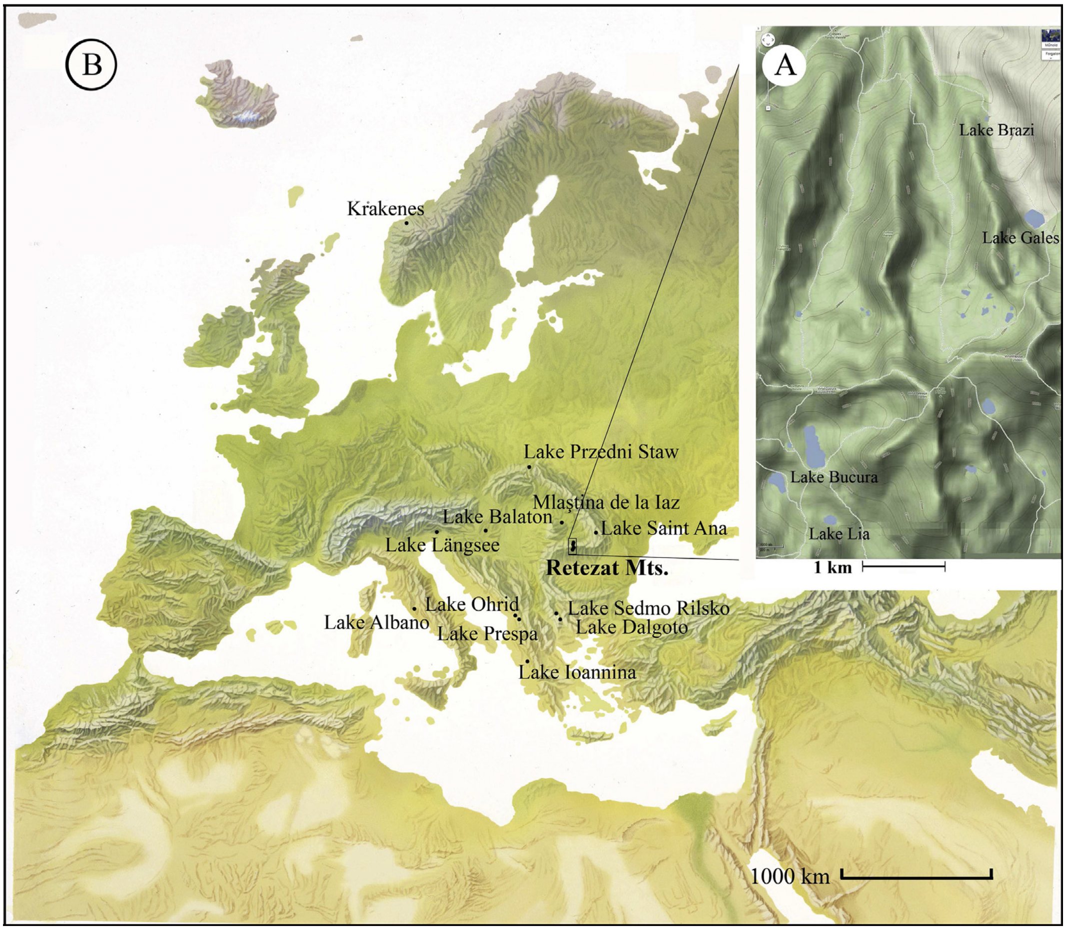

Fig. 1. Location of the four studied lakes (Lake Brazi, Lake Lia, Lake Gales and Lake Bucura) in the Retezat Mountains in the South-Carpathian Mountains (A) and selected paleoenvironmental records used for comparison (B): Lake Krakenes (Bradshaw et al., 2000), Lake Przedni Staw (Marciniak, 1986), Lake Balaton (Korponai et al., 2010, Lake Längsee (Schmidt et al., 2002)), Lake Saint Anna (Magyari et al., 2009b), Lake Albano (Ryves et al., 1996; Guilizzoni et al., 2002), Lake Ohrid, Lake Prespa (Cvetkoska et al., 2015), Lake Sedmo Rilsko (Lotter, and Hofmann, 2003), Lake Dalgoto (Štefanova et al., 2003; Ognjanova-Rumenova et al., 2009), Lake Ioannina (Wilson et al., 2008), Mlaştina de la Iaz (Diaconu et al., 2016). Relief artist: Kenneth Townsend. Original owner: RR Donnelley and Sons Cartographic Services http://www.shadedreliefarchive.com/Europe_townsend.html.

study on siliceous algae in the Retezat Mountains, South Carpathians, Romania (Fig. 1.). We focus primarily on siliceous algae assemblages from four lake sediment records and look for common patterns in the succession of the diatom assemblages.

1.1. Background of the diatom research in the Retezat Mountains

The first record about the diatom flora of the Retezat Mountains was published by Halász (1943). This study dealt with the moss-dwelling diatoms of Lake Zenoga. Péterfi (1993) summarized all previously published algological data covering more than twenty years. The first attempt for a diatom based palaeoenvironmental reconstruction with detailed taxa list in late Quaternary was published by Péterfi (1974). In this foretime study Péterfi revealed the main diatom assemblage zones of Zanoguta peat bog, taking into consideration the pH and life form preferences of the recovered diatom taxa. His data were interpreted together with the previously published pollen analytical results and lithostratigraphy, so the first multi-proxy study in the Retezat Mountains dates to 1974.

1.2. The PROLONG project

A multi-proxy study of mountain lake sediments from the Retezat Mountains (Southern Carpathians) started in 2007 using paleolimnological and paleoecological methods. Four lakes (Lake Brazi, Lake Gales, Lake Lia and Lake Bucura) were chosen for the study (Fig. 1.). The main parameters of the studied lakes are presented in Table 1. Some details about the studied cores are available in Table 2. These sediment records have provided information on climatic and biotic changes (e.g. terrestrial vegetation, tree- and timberline changes, water-pH, trophic level changes, soil geochemistry, chironomid, ostracod and cladocera community changes) for the last *ca.* 17,000 years, and several high-resolution studies were already published. Most of them however concentrated on Lake Brazi, lying on the northern slope and has lowest altitude (1740 m a.s.l.) with well-preserved siliceous microfossils in the sediment representing both the Late Glacial and the Holocene (e.g. Buczkó et al., 2009, 2012, 2013a; Magyari et al., 2009a, 2012, 2013; Korponai et al., 2011; Tóth et al., 2012, 2015; Braun et al., 2013; Pál et al., 2016a,b). Lake Gales is the second best studied lake in the same multi-proxy project. Up to now, vegetation responses to rapid warming and cooling events during the Late Glacial and Holocene have been published on the basis of high-resolution pollen, conifer stomata and plant macrofossil analyses from Lake Gales (Magyari et al., 2012), and preliminary results of siliceous algae (Soróczki-Pintér et al., 2012, 2013, 2014) aside from the papers published in this special issue dedicated to the PROLONG project.