Quaternary International 415 (2016) 241–252

Contents lists available at ScienceDirect

Quaternary International

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

Permafrost or seasonal frost? A review of paleoclimate proxies of the last glacial cycle in the East Central European lowlands

Zsófia Ruszkiczay-Rüdiger*, Zoltán Kern

Institute for Geological and Geochemical Research, Research Centre for Astronomy and Earth Sciences, MTA, Budaörsi út 45, H-1112 Budapest, Hungary

ARTICLE INFO

Article history:
Available online 8 August 2015

Keywords:
Paleoclimate
Periglacial
Permafrost
Pannonian Basin
Central Europe
Last glacial maximum

ABSTRACT

Our critical revision of the sedimentological characteristics and genetic interpretation of relict periglacial soil deformation features (cryoturbations and sand wedges) suggests that the continuous permafrost zone did not necessarily reached the lowland areas of the Pannonian Basin, as suggested by previous studies. The discontinuous permafrost zone most probably penetrated the north-western part of the study area for a certain period, but most of the lowlands might have been affected only by sporadic/isolated permafrost and/or deep seasonal frost. The re-evaluated climate conditions implied by the periglacial soil structures and other proxies for a periglacial environment of the area do not constrain such a narrow zone of extremely low mean annual air temperature (MAAT) and mean annual precipitation (MAP). The compilation of the climate thresholds suggested by the observed and revised interpretation cryoturbation features and thermal contraction cracks with other paleoclimate proxies converge on 0 ± 2 °C MAAT and 300–490 mm MAP on the lowland areas of the Pannonian Basin during the coldest phase of the last glacial. These values indicate a temperature drop of ≅10 ± 2 C° and a precipitation decrease of 30–50% relative to modern conditions.

1. Introduction

The existence of permafrost in the Pannonian Basin in the past is a matter of a long lasting debate. Several fossil periglacial features, mostly sand-filled sedimentary wedges, interpreted as ice-wedge casts, and cryoturbation features have been described and treated as traces of previous climate conditions and as indicators of past perennially frozen ground (Kerekes, 1939; Pécsi, 1961, 1997; Dylik, 1963; Tarnocai and Schweitzer, 1998; Kovács et al., 2007; Fábián et al., 2014).

Currently, the Pannonian Basin is permafrost-free. Sporadic occurrence of permafrost is restricted to the surrounding mountain belt (Kern et al., 2004; Dobiński, 2005; Gądek and Leszkiewicz, 2012; Vespermeanu-Stroe et al., 2012). The lowland areas lie within the temperate climate zone, having a humid continental climate with warm summer ("Cfb" in Köppen-Geiger climate classification; Kottek et al., 2006). Present mean annual air temperature (MAAT) of the lowlands in the Pannonian Basin is 9–11 °C. Mean air temperature of the coldest month (MTCO) is 0 to −3 °C; while mean air temperature of the warmest month (MTWA) ranges from 18.5 to 21.5 °C. Mean annual precipitation (MAP) in the lowlands is 500–750 mm with values above 650 mm relevant only in the western part of the study area (Mersich et al., 2001).

There are large discrepancies between the reconstructed southern boundaries of the permafrost in Europe during the last glacial (Vandenberghe and Pissart, 1993 and references therein; Van Vliet-Lanoë et al., 2004; Vandenberghe et al., 2014). The Pannonian Basin, between 45°–48°N, is situated in the ~300 km-wide zone of uncertainty of these models. Some reconstructions suggested that permafrost prevailed over practically the entire basin (Poser, 1948; Maarleveld, 1976; Velichko, 1982); while others proposed that only part of it belonged to the permafrost zone (Maruszczak, 1987; Vandenberghe et al., 2012). The weak points of these reconstructions are 1) they refer to ancient descriptions of periglacial phenomena, which were supposed to be indicative of past permafrost conditions and/or 2) data extrapolation ignoring the special geographical position of the Pannonian Basin, a large lowland surrounded by mountains of the Alps, Carpathians and Dinarides (Fig. 1), which modulated the zonal permafrost extension and was able to overprint regionally the continental-scale spatial trends. The effect of the topography has been considered only in the model of Van Vliet-Lanoë et al. (2004). The significance of the basin

* Corresponding author.
E-mail addresses: rrzsofi@geochem.hu (Z. Ruszkiczay-Rüdiger), kern@geochem.hu (Z. Kern).

http://dx.doi.org/10.1016/j.quaint.2015.07.027
1040-6182/

topography in climate is supported by the malacological and pollen analyses, suggesting a more favourable climate in the southern part of the Pannonian Basin even during the cold maxima of the last glacial than in other parts of Europe (Sümegi et al., 2013).

The extension of the permafrost zone in the Pannonian Basin was reconstructed mostly based on the assumption of the existence of large cryoturbations, ice-wedge casts (Pécsi, 1961, 1997; Dylik, 1963; Tarnocai and Schweitzer, 1998; Fábián et al., 2014) and sand wedges (Kovács et al., 2007). On this basis, some authors suggested extreme cold and arid conditions for the area with MAAT as low as −8.3 °C to −17 °C and MAP <100 mm (Tarnocai and Schweitzer, 1998; Kovács et al., 2007). Recently a MAAT decrease of 15 C° (MAAT: −5 °C to −7 °C) and similarly low precipitation has been suggested for the coldest period of the last glacial cycle (Fábián et al., 2014). However, the existence of these extreme conditions is not supported by other paleoclimate proxies of the Pannonian Basin (Willis et al., 2000; Magyari, 2002, 2011; Pazonyi, 2004, 2011; Bradák et al., 2010, 2011; Varsányi et al., 2011; Sümegi et al., 2013).

The climate-indicator periglacial features have been, and probably will be used to evaluate the predictive ability of paleoclimate models (e.g., Isarin and Renssen, 1999; Van Huissteden et al., 2003; Vandenberghe et al., 2012). The most objective and conservative (re)interpretation of these features is crucial; otherwise one might favour an inadequate earth-system model and reject a well performing alternative because the simulated results contradict a falsely drawn proxy-based picture. A recent model suggested significant difference for global ice volume and sea level for the LGM between model variants including and excluding a permafrost module (Willeit and Ganopolski, 2015) which further stress the importance of the accurate knowledge about the past extension of permafrost. Moreover, the unconfirmed paleoclimate inferences carry a high risk of misleading subsequent paleobotanical (Magyari et al., 2014) or geomorphological (Kiss et al., 2014) studies.

The inconsistency of the different paleoclimate reconstructions in the Pannonian Basin necessarily invite a revision of relict periglacial soil deformation features of the area and to reconsider the paleoclimate indicator value of these structures based on the most recent terminology. In addition, at the warm limit of the permafrost, the criteria for differentiating between seasonal and perennial frost need further investigation (Vandenberghe et al., 2014). Our study aims to clarify the relevance of the terms used in modern periglacial literature as climate indicators and review their manifestation within the Pannonian Basin. We discuss the origin of the thermal contraction wedges present in the study area, and paleoclimate conditions necessary for their formation. The possible extent and timing of past permafrost within the Pannonian Basin are reconsidered. The objective of this paper is to provide a case study of a better differentiation of past seasonal frost and permafrost.

We use a multiproxy numerical approach to constrain the climate of the last glacial maximum (LGM; MIS 2) in the Pannonian Basin. Palynological, malacological, groundwater noble gas proxies, together with loess and mammalian stratigraphy are used to assess paleo-temperature and -precipitation. These values are compared to environmental conditions considered to be required for the development of permafrost (Péwé, 1966; Washburn, 1980; Vandenberghe and Pissart, 1993; French, 2007). This study focuses on the lowlands of the Pannonian Basin (~70–300 m above sea level); slope processes of hilly regions and the reconstruction of permafrost in the surrounding mountains of Alps, Carpathians and Dinarides lie beyond the scope of this study.

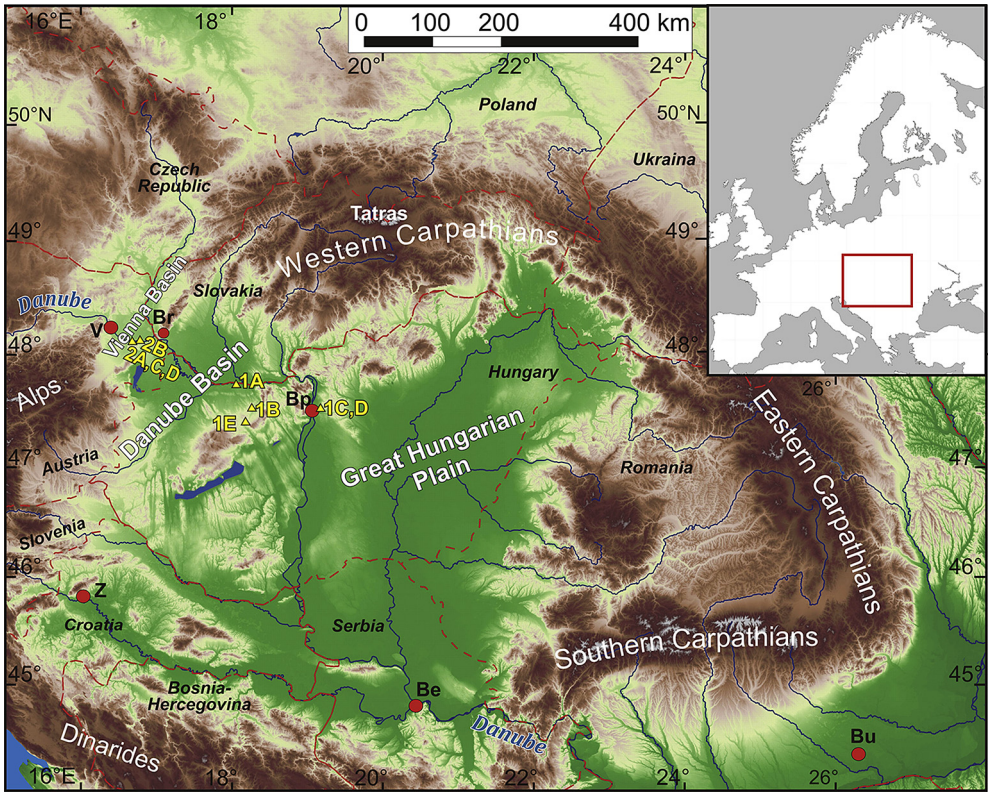

Fig. 1. Location and topography of the Pannonian Basin. This study focuses on the lowlands of the Pannonian Basin (green areas on the digital elevation model). Current state boundaries (red dashed lines) and capitals (V: Vienna, Br: Bratislava, Bp: Budapest, Z: Zagreb, Be: Belgrad, Bu: Bucharest) are shown for orientation. Yellow rectangles are the locations of the photos of Figs. 2 and 3. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)