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Pleistocene wind system in eastern Austria and its impact on landscape evolution

Krisztina Sebe [a,b,*], Reinhard Roetzel [c], Markus Fiebig [b], Christopher Lüthgens [b]

[a] University of Pécs, Department of Geology, 7624 Pécs, Ifjúság ú. 6., Hungary
[b] Institute of Applied Geology, BOKU, University of Natural Resources and Life Sciences, Peter Jordan-Str. 70, 1190 Wien, Austria
[c] Geological Survey, Neulinggasse 38, 1030 Wien, Austria

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ABSTRACT

During cold periods in the Quaternary, the intracontinental Pannonian Basin was part of the European periglacial zone, and aeolian erosion had a profound effect in shaping the landscape. Geomorphologically most effective winds were channelled between the Alps and Carpathians and entered the Pannonian Basin from the NW. To assess the nature of meteorological conditions producing these winds, field studies were carried out in the foreland of the basin entrance, in eastern Austria.

As a result, we report on the first bedrock ventifacts from Austria and aeolian sand occurrence in the Bohemian Massif. Through a compilation of published data and field work, the distribution of ventifacts was mapped and appears to be controlled primarily by available lithologies. Palaeo-wind directions were identified using mesoforms of bedrock ventifacts, especially flutes. The acquired air flow directions are accordant with the orientation of erosional landforms on soft sediments and form a coherent system, with westerly to north-westerly winds in the west, which turn towards the entrance of the Pannonian Basin in the east. There are no directions referring to the direct influence of katabatic winds produced on the ice sheet, instead, the wind system must have been driven by synoptic-scale patterns like the polar front. The narrow distribution of wind directions suggests that the low-altitude air flow system was relatively stable even without a funnelling topography as in the Pannonian Basin, though the Alps could have acted to deflect the winds. OSL data from the Bohemian Massif indicate aeolian sand movement during the Late Pleistocene. The results provide data for aeolian transport studies, among them for loess provenance analyses and can be used as input for climate models.

1. Introduction

The Pannonian Basin is an intracontinental basin in Central Europe, surrounded by mountain ranges with elevations above 2000 m a.s.l. During the Pleistocene glacials, the basin was part of the European periglacial zone (Vandenberghe et al., 2014); the Scandinavian ice sheet closely approached the northern foot of the Carpathians during its maximum extent (Svendsen et al., 2004; Fig. 1). The Pannonian Basin showed features typical of the southern part of the periglacial zone: it was ice-free, with a cold and dry periglacial climate indicated by widespread loess sequences and the contained palaeontological record. Permafrost conditions varied from discontinuous permafrost in the northern part of the basin to a lack of cryogenic features in the south (Pécsi, 1997; Ruszkiczay-Rüdiger and Kern, submitted for publication; van Vliet-Lanoë et al., 2004). The dominant vegetation was cold steppe or steppe tundra, with a varying amount – usually only patches – of arboreal vegetation (Járainé Komlódi, 2003). Snow cover must have been thin or absent (possibly blown away), shown by permafrost phenomena requiring uncovered ground for their formation (e.g., sand wedges; Pécsi, 1997) and by the widespread presence of small ventifacts (Sebe et al., 2011a). Previous studies have shown that aeolian erosion had a profound effect in shaping the landscape, among others through producing large-scale landforms like wind corridors and mega-yardangs and removing hundreds of metres of weakly consolidated sediments (Ruszkiczay-Rüdiger et al., 2011; Sebe et al., 2011a). Winds with the highest impact on the landscape were channelled between the Alps and Carpathians and entered the Pannonian Basin from the NW and to a lesser extent also from the NE (Sebe et al., 2011a). Due to this channelling effect, air flow within the basin is strongly topography-controlled and less indicative of regional climatic conditions. However, in the geomorphic foreland of the Pannonian Basin, which is only bordered by mountain ranges in the south and open to the other three directions, there exists a possibility to infer the regional air flow conditions.

* Corresponding author.
E-mail addresses: sebe@gamma.ttk.pte.hu (K. Sebe), reinhard.roetzel@geologie.ac.at (R. Roetzel), markus.fiebig@boku.ac.at (M. Fiebig), christopher.luethgens@boku.ac.at (C. Lüthgens).

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In the periglacial belt, local winds are usually controlled by synoptic meteorological conditions, e.g., by the zone of polar front, but the impact of the ice sheet can be also considerable. On a well-developed ice sheet, radiative cooling of air over the ice and the sloping topography of the ice surface induce high pressure and temperature gradients and thus cause strong anticyclonal or katabatic wind blow off the ice. Katabatic winds are known for their extreme persistency and strength (Parish and Bromwich, 1987). The influence of katabatic winds from the Scandinavian ice shield has been clearly demonstrated more to the north in the periglacial belt, in previously glaciated areas (Christiansen, 2004; Christiansen and Svensson, 1998; Schlyter, 1995), but has also been proposed for similar and even lower latitudes than in Austria, e.g., for Ukraine (Buggle et al., 2008). It is usually not straightforward to differentiate between effects of synoptic and katabatic winds (Knight, 2008; Schlyter, 1995). Reconstructing orientations of near-surface air flows can help distinguish between these meteorological effects; a way to achieve this is to study the geomorphological and geological record. Data gained this way can provide further information on the wind climate, for instance on questions whether wind directions had been stable in the foreland as well, where no channelling effects existed, or whether the impact of wind erosion on landscape evolution had been as significant as in the basin. To identify the palaeo-wind system is necessary because it can serve as input for climate models (see e.g., Renssen et al., 2007); there is still a profound need for "ground truthing" in spite of the increasing sophistication of earth-atmosphere models (Bullard, 2010). It is also important for provenance studies of wind-transported sediments. To address these questions, aeolian studies were carried out at the entrance and the foreland of the Pannonian Basin in eastern Austria. For this aim, aeolian features, wind-polished rock surfaces (ventifacts), wind-blown sands and wind erosional landforms were investigated, which, when interpreted together and with consideration of the surrounding topography, can be used to gain data for palaeoclimatic reconstructions (Knight, 2008).

2. Study area and methods

2.1. Geomorphological and geological setting

The study area (Fig. 1) lies between the Alps and the Western Carpathians and in their immediate northwestern foreland. The entrance area to the Pannonian Basin is occupied mainly by the Vienna Basin, enclosed by protruding low ranges of the two mountain chains. The foreland extends in relief from the lowlands of the Danube alluvial plain to low mountains of the Bohemian Massif. While literature was screened for ventifact data for the entire eastern part of Austria, the scope of detailed field investigations was restricted by appropriate lithologies (see Section 2.2 on methods) to a few regions in eastern Austria. One is located in the Bohemian Massif (Fig. 1) in the northwestern part of Lower Austria close to the Czech border, in the surroundings of Litschau, Schrems and Gmünd. Two other areas are situated at the transition between the Vienna Basin and the Pannonian Basin: the Leitha Mountains northwest of Lake Neusiedl on the boundary between Lower Austria and Burgenland (Fig. 1) and the Hainburg Hills, approx. 45 km east of Vienna and 15 km west of Bratislava, close to the Slovakian border. The last region is the Marchfeld, the alluvial plain of the Danube north of the river between Vienna and the confluence of the Danube with the March (Morava) in the east.

The hilly area around Litschau belongs to the Bohemian Massif, where the Variscan Eisgarn granite prevails. This granite is injected by several decimetre- to metre-thick dykes of granite porphyry and quartz. In depressions of the granite erosional relicts of sandy and clayey sediments of the Cretaceous Klikov Formation were preserved, which have a wide distribution in the western South Bohemian Basin in the Czech Republic (Schnabel et al., 2002; Waldmann, 1950). Along small rivers and brooks Pleistocene sandy and gravelly sediments from fluvial terraces with windblown intercalations and small dunes occur, and above the Eisgarn granite Late Pleistocene to Holocene bogs with

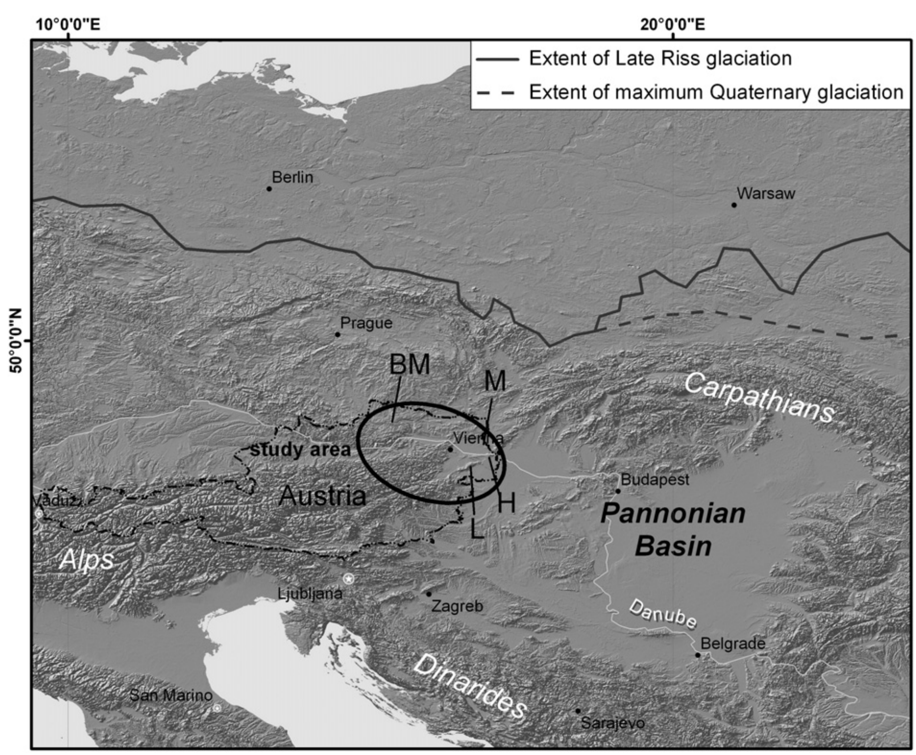

Fig. 1. Overview of the study area. BM — Bohemian Massif; H — Hainburg Hills; L — Leitha Mts.; M — Marchfeld. Ice sheet limits from Svendsen et al. (2004).