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Chronology of the Late Weichselian glaciation in the Bohemian Forest in Central Europe

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ABSTRACT

A glacial chronology based on in situ-produced ^{10}Be surface exposure dating of moraines in the Bohemian Forest (Central Europe) was established. Eleven exposure ages obtained for moraine boulders in the Prášilské Lake and Laka Lake valleys (Czech Republic) were complemented by ^{10}Be ages from Kleiner Arbersee (Germany) recalculated according to recently calibrated production rates in the Northern Hemisphere. The glacial phases in the Bohemian Forest occurred during the Last Glacial Maximum around 24.1 ± 2.5, 23.6 ± 2.4, 21.8 ± 2.0 and 19.5 ± 2.1 ka. Following phases of local glaciation occurred during the Northern Hemisphere deglaciation period around 16 ka and 14 ka. The last indicated phase may correlate with Older Dryas. The glacial chronology of the Bohemian Forest is in agreement with local glaciation chronologies in the Giant Mts. (Krkonoše Mts.) and the Eastern Alps.

1. Introduction

During the Last Glaciation, Central Europe was a periglacial corridor (Tyráček, 1995) between the Scandinavian Ice Sheet and the Alpine glacier area (Fig. 1A). Evidence of the Last Glacial Maximum (LGM), represented by aeolian sand sheets and loess deposits at lower altitudes (Kasse, 2002; Frechen et al., 2003; Starnberger et al., 2011), is particularly important. There is little data older than 15 ka available for the Bohemian Massif in Central Europe (Pokorný, 2002; Svobodová et al., 2002; Jankovská, 2006; Huber et al., 2009; Engel et al., 2010). In addition to aeolian sediments, dated sequences of glacial landforms have become an important source of information about the LGM in mountain regions, such as the Alps (Ivy-Ochs et al., 2008; Kerschner and Ivy-Ochs, 2008) and the Carpathians (Rinterknecht et al., 2012; Makos et al., in press).

Within the above mentioned periglacial corridor, local glaciers developed in Hercynian mountain regions such as the Vosges (Mercier and Jeser, 2004), the Harz (Rother, 1995), the Giant (Krkonoše) Mountains (Braucher et al., 2006; Carr et al., 2007; Engel et al., 2011) and the Bohemian Forest (Šumava, Bavarian Forest) (Raab and Völkel, 2003; Reuther, 2007; Mentlík et al., 2010) (Fig. 1B). The glaciation of the Bohemian Forest was recognized in the mid-19th century based on a variety of landforms shaped by glaciers (Partsch, 1882; Bayberg, 1886; Rathsburg, 1928, 1932; Preihäusser, 1934). Although a relative glacial chronology of the northwestern Bohemian Forest for the Late Weichselian has been proposed (Mentlík et al., 2010), numerical data for the northern flank of the Bohemian Forest are still unavailable. Additionally, the existing surface exposure ages from the Kleiner Arbersee area (Reuther, 2007) represent moraines in the large cirque only. We suggest that small glaciers in deep cirques at leeward positions could respond more quickly to less significant climate deteriorations. To test these assumptions, we investigated moraine sequences within the Prášilské and Laka valleys.

The objectives of this paper are as follows: (1) to provide local ^{10}Be chronology in the northwestern part of the Bohemian Forest (the Prášilské and Laka Lake valleys), (2) to complement the chronological data from the Kleiner Arbersee valley (the southwestern Bohemian Forest) (Reuther, 2007) to establish a regional ^{10}Be chronology of the Bohemian Forest and (3) to integrate this new

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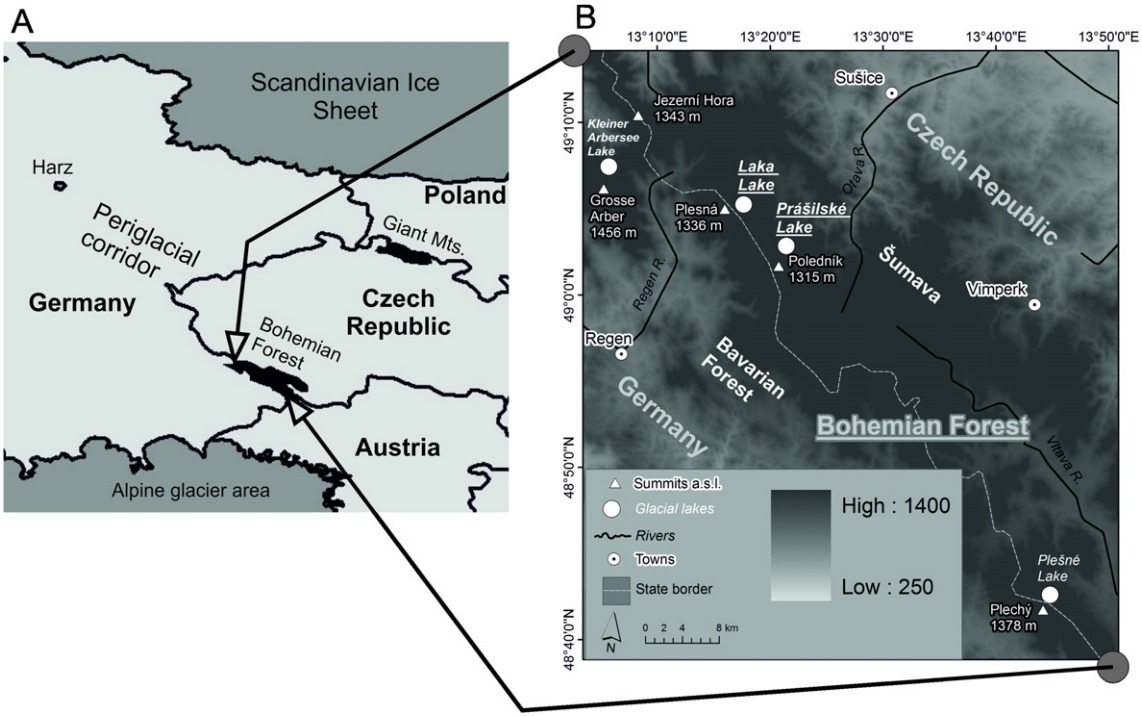

Fig. 1. A: The Bohemian Forest within periglacial corridor in Central Europe. Glaciation limits during the Last Glacial Maximum after Ehlers (Eds.) (2011) (in grey). B: Location of the investigated sites in the Bohemian Forest.

chronology with the available glaciation chronologies along the northeast–southwest transect throughout Central Europe (Giant Mountains – Bohemian Forest – the Alps).

2. Regional settings

2.1. Study area

The Bohemian Forest is located at 48°30′ – 49°20′ N and 12°10′ – 14°20′ E. The highest summits reach over 1400 m a.s.l. at Grosser Arber (1456 m) and Grosser Rachel (1453 m) in the German part of the mountains (Fig. 1B). The highest summits in the Czech region reach over 1300 m a.s.l. (e.g. Plechý, 1378 m, Poledník, 1315 m and Jezerní Hora Mt., 1343 m). The central part of the range with an area of ~670 km^2, consists of the flat, high-elevation terrain of the Šumava Plains, at approximately 1000 m a.s.l. The slightly undulating surface is dissected by tributaries of the Donau (Danube) River (e.g. the Regen, Ilz, Große Mühl Rivers) in the southwest and by the network of the upper Vltava and Otava Rivers on the northeastern flanks. The greatest differences in surface elevation can be found along the incised valleys of major rivers and around the highest summits where cirque and valley glaciers deepened pre-glacial valley heads (Hartvich and Mentlík, 2010).

At present, a transitional Central European climate prevails in the Bohemian Forest, but the overall pattern of temperature and precipitation is strongly affected by local topography. The mean annual temperature ranges from 6.0 °C at 750 m a.s.l. to 1.3 °C at 1300 m a.s.l., and the annual isohyet of 1000 mm coincides with an altitude of 1000 m (Neuhäuslová et al., 2001).

Geomorphological investigation and sampling were conducted in the northwestern part of the Bohemian Forest in two areas with relatively well-preserved moraines (Figs. 2 and 3).

The Prášilské Lake (1079 m a.s.l., 49°04′ N, 13°24′ E) is situated in a stair-shaped cirque on the eastern slopes of Poledník Mountain (1315 m a.s.l.). While crystalline schists surround the lake, the northern part of the cirque consists of granite (Mentlík et al., 2010). Laka Lake (49°06′ N 13°19′ E; 1096 m a.s.l.) lies in the cirque on the eastern flank of Debrník (Lackenberg) Mountain (1336 m a.s.l.). The bedrock is composed mainly of paragneiss, but a small granodiorite outcrop (300 m long and 150 m wide) occurs in the cirque headwall (Mentlík, 2005).

2.2. Geomorphological evidence of glaciation

Three phases of glaciation were described in the Prášilské valley based on preserved moraines (Fig. 2). These phases are listed as follows, arranged from the relatively oldest and most extensive to the youngest and smallest (Mentlík et al., 2010).

Pras1: the small valley glacier phase, a phase of maximum ice extension (MIE), is represented by the oldest remnants of terminal and lateral moraines. The furthest position of the moraines shows the following glacier maximums: length (2060 m), width (~760 m), thickness (~54 m) and ice surface inclination ~6°.

Pras2: this phase is represented by a significant (up to 12 m high) outer (lake) moraine (Fig. 2) which developed when the whole stair-shaped cirque was occupied by a glacier.

Pras3: during this phase the glacier was restricted to the lower cirque and the inner (lake) moraine (Fig. 2) accumulated.

In the Laka valley, the presence of preserved moraines suggests at least two phases of glaciation (Mentlík, 2005). A lobe-shaped moraine assemblage, with its lowest point at 1045 m a.s.l. (MIE), blocked the valley head upon formation (Fig. 3). The lobe is clearly delimited by the steep slopes (~10 m high) of the outer lateral moraine (Mentlík, 2005). The inner lateral moraine exceeds the surface of the lobe by approximately 4 m along its eastern boundary.

In both valleys, glacial landforms are located along the eastern slopes of high-elevated flat ridges. During glacial episodes, the ridges were free of vegetation cover, forming an efficient deflation surface from which snow was blown to the valley heads at their lee-side. The presence of the high-elevated plateaus on the ridges together with climatic conditions controlled the growth of glaciers (*sensu* Partsch, 1882).