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Original Investigations

Reconstruction ability of dendrochronology in dating avalanche events in the Giant Mountains, Czech Republic

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ABSTRACT

Dendrogeomorphology represents an appropriate method for dating past avalanche events using tree-ring widths and their anatomical structure. Here, we present dendrochronological dating of avalanche events in the Giant Mountains, Czech Republic. The goals of this study were to reconstruct past avalanche activity in the Giant Mountains, and to evaluate the dating ability of dendrochronological methods by means of comparing documentary-evidenced and dendrochronologically dated avalanche events. In total, 320 cores and 12 cross-sections were extracted from 99 trees bordering four avalanche paths. We identified 1378 markers indicating possible avalanche events. Using both the number and reliability of markers, 20 very probable and 29 probable avalanche events were dated, spanning the period 1904–2012. These results significantly expand the list of directly observed avalanches compiled since the 1960s in the studied region and provided a unique possibility to validate dating results. Dendrochronological dating was relatively successful at identifying large avalanches, with 55% of such events correctly dated. However, small snow mass transports limited to the central parts of the paths were often not detected. Dendrochronological dating was also efficient at estimating spatial differences in avalanche frequency. It is concluded that dendrochronology proved to be an appropriate method to reconstruct the avalanche history of small avalanche paths of medium-altitude mountains with frequent avalanche events.

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Introduction

Seasonal snow cover and avalanches are important parts of ecosystems in mountainous areas (Jones et al., 2001). Avalanches also represent a natural hazard (Tacnet et al., 2014). Ecological importance, potential material losses and human injuries stimulate research on past avalanche frequency and extent (Stoffel and Bollschweiler, 2008; Stoffel et al., 2010). Avalanche studies often lack information about past events, which can be compensated for by using written archives or eyewitness accounts. However, it has been shown that events causing material losses or injuries are often overestimated, whereas the frequency and extent of avalanches in unpopulated areas are strongly underestimated (Stoffel and Bollschweiler, 2008, 2009; Corona et al., 2012b). In comparison, absolute dating techniques, such as dendrochronology, lead to more objective results (Lang et al., 1999).

Dendrochronology was first used to reconstruct past avalanche events in Glacier National Park, Montana (e.g., Butler and Malanson, 1985). This method became very popular in the early 2000s for mountainous environments around the world, e.g., North America (Hebertson and Jenkins, 2003; Butler and Sawyer, 2008; Germain et al., 2010), the Alps (Casteller et al., 2007; Corona et al., 2010, 2012a, 2012b), the Pyrenees (Muntán et al., 2009), the Andes (Mundo et al., 2007; Casteller et al., 2009, 2011) and the Himalayas (Laxton and Smith, 2009). Avalanches were dated using various markers of growth disturbances in tree-rings. Because an avalanche can cause mechanical damage to individual trees (e.g., decapitation, wounds and inclination) they will exhibit decreased cambial activity in subsequent years, producing reduced (narrow) tree-rings after such events. However, other individuals (especially juveniles with flexible stems) can survive the event without substantial damage, and benefit from the decreased competition in the subsequent growing season. Such trees produce wider tree-rings after the event (Shroder, 1978; Casteller et al., 2007, 2009; Reardon et al., 2008; Corona et al., 2010, 2012b). Due to their stem inclination and their attempt to return to a vertical orientation, trees start to form eccentric growth and, consequently, produce eccentric tree-rings (Casteller et al., 2007, 2009; Garavaglia and Pelfini, 2011; Decaulne et al., 2012; Wistuba et al., 2013). Former avalanche activity can also be identified through anomalous

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anatomical wood structures, e.g., rows of traumatic resin ducts (Stoffel, 2008; Gaertner and Heinrich, 2009), reaction wood (Heinrich and Gaertner, 2008; Stoffel and Bollschweiler, 2009) and callus tissue (Dubé et al., 2004; Casteller et al., 2007). Anatomical indicators of growth disturbance events are useful for dating with intra-seasonal resolution. Therefore, avalanches can be differentiated from other mass-wasting processes, e.g., rockfalls (Stoffel and Hitz, 2008) or debris flows (Stoffel et al., 2006; Szymczak et al., 2010). However, there are risks that must be considered, such as the delayed formation of traumatic resin ducts (Stoffel and Perret, 2006; Stoffel and Hitz, 2008; Gaertner and Heinrich, 2009) or over-representation of recent injuries when callus tissues and wounds are dated (Stoffel and Perret, 2006; Kogelnik-Mayer et al., 2011). In addition to sampling living trees, cross dating of accumulated dead wood in the avalanche path or its runout zone can be used to determine the year of the last tree-ring and to date all macroscopic and microscopic markers previously mentioned (Reardon et al., 2008).

Most studies that have used dendrochronological dating of avalanche events have been conducted in high-mountain environments with prevalent fresh-snow or powder avalanches (Reardon et al., 2008; Corona et al., 2012a, 2012b) or in old forests with episodic avalanche events (Schläppy et al., 2013). Our study is, however, focused on the evaluation of the efficiency of dendrochronological avalanche dating on permanent avalanche tracks in a mountain area where relatively small but frequent avalanches prevail. The objectives of this study are therefore to: (i) reconstruct avalanches in the Giant Mountains using dendrochronology; and (ii) compare the results of the dendrochronological study with a list of observed avalanche events, the so-called "avalanche catalogue" (Spusta and Kociánová, 1998; Spusta et al., 2003, 2006), which spans the last 50 years.

Material and methods

Study area

The Důl Bílého Labe valley (50° 44′ N, 15° 40′ E) is a deeply incised valley of the Bílé Labe stream, which is located in the central Giant Mts., Czech Republic (Fig. 1a). The elevation of the upper catchment basin, where all studied avalanche paths are located, spans from 1015 to 1555 m. The catchment basin relief consists of steep valley sides with an average slope of approximately 25°

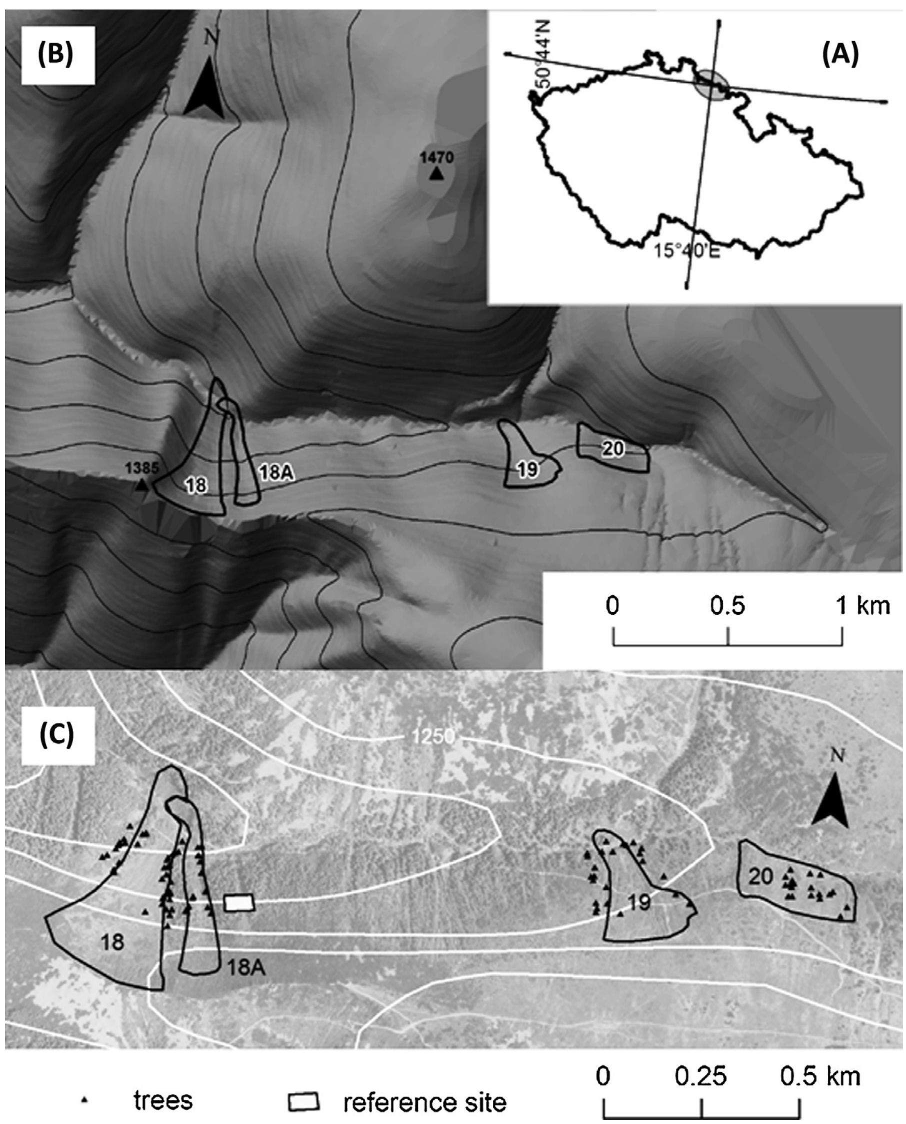

Fig. 1. Location of the study area. (A) The position of Giant Mts. in the Czech Republic. (B) Terrain model of Důl Bílého Labe Valley with avalanche paths. (C) Paths with positions of individual sampled trees.

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