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Holocene fire-regime changes near the treeline in the Retezat Mts. (Southern Carpathians, Romania)

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ABSTRACT

To investigate Holocene vegetation and fire-disturbance histories in the treeline ecotone, macroscopic charcoal, plant-macrofossil, and pollen records from two lacustrine sediment records were used. Lake Lia is on the southern slope and Lake Brazi is on the northern slope of the west-east-oriented Retezat Mountain range in the Romanian Carpathians. The records were used to reconstruct Holocene fire-return intervals (FRIs) and biomass burning changes. Biomass burning was highest at both study sites during the drier and warmer early Holocene, suggesting that climate largely controlled fire occurrence. Fuel load also influenced the fire regime as shown by the rapid biomass-burning changes in relation to timberline shifts. Overall, the number of inferred fire episodes was smaller on the northern than on the southern slope. FRIs were also comparatively longer (1000–4000 years) on the northern slope where *Picea abies*-dominated woodlands persisted around Lake Brazi throughout the Holocene. On the southern slope, where *Pinus mugo* was more abundant around Lake Lia, FRIs were significantly shorter (80–1650 years). A period of frequent fire episodes occurred around 1900–1300 cal yr BP on the southern slope, when chironomid-inferred summer temperatures increased and the pollen record documents increased anthropogenic activity near the treeline. However, the forest clearance by burning to increase grazing land was subdued in comparison to other European regions.

1. Introduction

Understanding the factors that influence the natural variability of disturbance regimes is important for ecosystem conservation and restoration purposes. In European mountain regions, fire is increasingly acknowledged as a natural agent of disturbance. However, the higher disturbance frequency predicted for the next century in high-elevation ecosystems (Wastl et al., 2012) may pose new challenges to fire management in Europe (Valese et al., 2014). Two main factors make fire an increasingly relevant ecological factor in European mountain ecosystems. Timberlines (i.e. the line delimiting closed forests) that were shifted downslope by the creation of summer pastures and meadows for intensified grazing activities (Baur et al., 2007; Tinner, 2007) are predicted to shift upwards again due to abandonment of agricultural practices in economically marginal areas and the effects of climate warming on the treeline ecotone (Gehrig-Fasel et al., 2007; Schwörer et al., 2014). The resulting higher forest connectivity and biomass availability (fuel) in the future treeline ecotone will facilitate the spread of fires. Secondly, the potentially higher frequency of exceptional droughts due to climate change in some areas (e.g. Southern and Central Europe) (Schär et al., 2004) may increase the frequency of favourable weather conditions for fire ignition and spread.

Vegetation responses to environmental changes are extremely complex, and this complexity may be more striking due to interactions between vegetation composition and environmental

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conditions such as climate and fire-disturbance regimes (Gavin et al., 2006; Higuera et al., 2009). Although climatic factors are generally considered to be the predominant driver of fire regimes (Daniau et al., 2012), vegetation composition and woodland cover can modulate the effects of climate by controlling the type and structure of fuel available for combustion (Higuera et al., 2009; Gil-Romera et al., 2014). Palaeoecological records allow short-term instrumental and documentary records to be extended back over several millennia and make it possible to investigate the natural variability of fire regimes, the human dimension of fire regimes (Bowman et al., 2011), and vegetation–fire interactions, through the analysis of pollen, plant macrofossils, and charcoal particles stored in sedimentary archives (Stähli et al., 2006; Morales-Molino et al., 2015).

The Retezat Mountains (Southern Carpathians, Fig. 1) are an interesting area to investigate long-term vegetation–fire–climate interactions. Forest fires are not widespread in the Romanian Carpathians and are considered as a negligible cause of ecosystem disturbances today (Knorn et al., 2013). In keeping with this, previous charcoal records from a high-elevation site in the Southern Carpathians (Lake Brazi: Feurdean et al., 2012; Finsinger et al., 2014), showed that fires were frequent during the drier early Holocene, and that fire activity was less during recent millennia when humans were potentially clearing the treeline ecotone. This temporal pattern of charcoal records markedly contrasts with the strong biomass-burning increase recorded in the Alps at the Neolithic/Bronze Age transition (about 4000 cal yr BP in the Alpine region), when humans cleared the forest to create summer pastures and meadows and effectively shifted the fire regime outside its natural range of variability (Valese et al., 2014). It also contrasts with charcoal records from the lowland Transylvanian plain where fire frequency markedly increased at about 3000 cal yr BP (Feurdean et al., 2013a). Long-term charcoal records show that fire occurrence can be highly variable both spatially and temporally and that fires are less likely to occur and to spread on more humid northern exposures due to the control of local climatic factors on fuel load and flammability (Whitlock and Larsen, 2001; Carcaillet et al., 2009; Barrett et al., 2013). The Lake Brazi record is located on the northern slope of the range. Hence, it may only be reflecting local fire occurrences on the less fire-prone northern slope of the mountain range.

Therefore, we chose a contrasting site on the southern slope to provide temporal and spatial estimates of past fire-regime variability in the Southern Carpathian treeline ecotone. We present two well-dated multi-proxy (continuous records of macroscopic charcoal, pollen, stomata, and plant-macrofossils) reconstructions of vegetation and fire history from the Retezat Mountains, covering the past 11,000 years to determine the relationship between local fire regimes and vegetation changes at the treeline ecotone (see also Magyari, Orbán et al., in this issue; and Vincze et al., submitted for publication). We use the macroscopic charcoal record (i) to identify fire episodes and to infer fire-return intervals (FRI, i.e. the time elapsed between two successive fire episodes) using peak-detection analysis (Lynch et al., 2003; Higuera et al., 2009; Finsinger et al., 2014), and (ii) to reconstruct longer-term variations in biomass burning by means of total macrocharcoal accumulation rates (CHAR) that may reflect an integrated signal of charcoal production (depending on burnt area, amount of biomass burnt, and fuel load availability), fire frequency, and deposition and taphonomic processes such as reworking and sediment focussing (Whitlock and Larsen, 2001; Kelly et al., 2013). Because variations in total CHAR depend on the sediment-accumulation rates, we devised a new numerical method to test the influence of modelled sedimentation rates in determining long-term variations of total CHAR. These vegetation and fire proxies, together with a suite of regional climate proxies (Buczkó et al., 2013), including a chironomid-based July-air temperature reconstruction from Lake Brazi (Tóth et al., 2015), enable us to examine vegetation–fire disturbance–climate interactions.

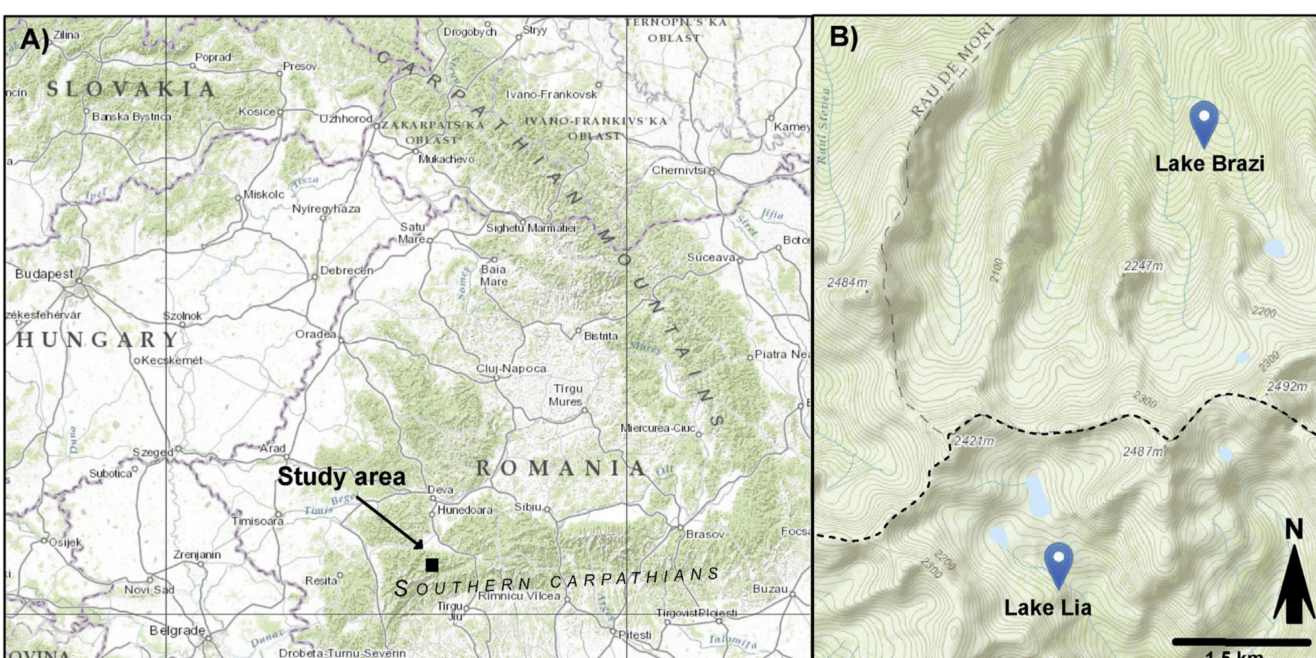

Fig. 1. Map of the location of the study area in the Carpathians (a) and the study area. Map from National Geographic's MapMaker Interactive (http://mapmaker.education.nationalgeographic.com/).