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Detrital events and hydroclimate variability in the Romanian Carpathians during the mid-to-late Holocene

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ABSTRACT

The Romanian Carpathians are located at the confluence of three major atmospheric pressure fields: the North Atlantic, the Mediterranean and the Siberian. Despite its importance for understanding past human impact and climate change, high-resolution palaeoenvironmental reconstructions of Holocene hydroclimate variability, and in particular records of extreme precipitation events in the area, are rare. Here we present a 7500-year-long high-resolution record of past climatic change and human impact recorded in a peatbog from the Southern Carpathians, integrating palynological, geochemical and sedimentological proxies. Natural climate fluctuations appear to be dominant until 4500 years before present (yr BP), followed by increasing importance of human impact. Sedimentological and geochemical analyses document regular minerogenic deposition within the bog, linked to periods of high precipitation. Such minerogenic depositional events began 4000 yr BP, with increased depositional rates during the Medieval Warm Period (MWP), the Little Ice Age (LIA) and during periods of societal upheaval (e.g. the Roman conquest of Dacia). The timing of minerogenic events appears to indicate a teleconnection between major shifts in North Atlantic Oscillation (NAO) and hydroclimate variability in southeastern Europe, with increased minerogenic deposition correlating to low NAO index values. By linking the minerogenic deposition to precipitation variability, we state that this link persists throughout the mid-to-late Holocene.

1. Introduction

The Carpathian Mountains and bordering lowlands are one of the most rapidly reacting regions of Europe to current climatic change, with droughts, and periods of short, intense precipitation becoming more common (IPCC, 2014; Micu et al., 2015). The wider region (the Carpathian-Balkan) is located at the confluence of major atmospheric circulation patterns, with the North Atlantic system towards the west, the Mediterranean to the southwest, and the Siberian High to the east (Obreht et al., 2016 and references therein; Panagiotopoulos et al., 2005). As a result, the region should be very sensitive in recording past climate variability resulting from periodic shifts in the dominant circulation pattern. The North Atlantic Oscillation (NAO), in particular, has a major control on winter precipitation (Bojariu and Giorgi, 2005; Stefan et al., 2004; Tomozeiu et al., 2005, see Fig. 1C) and winter temperature (Bojariu and Giorgi, 2005) changes in the region.

The Carpathian-Balkan region is one of the longest-inhabited regions in Europe, with Neolithic cultures having interacted with the environment as far back as 9000 years before present (yr BP) (Bailey, 2000). An increasing number of studies have demonstrated the importance of the long-term impact of humans in the Carpathians, particularly via deforestation and high Alpine pasturing (Carozza et al., 2012; Feurdean et al., 2009; Feurdean and Astalos, 2005; Schumacher et al., 2016), activities which may have a significant impact on an area's erosional regime and sediment budget (e.g. Arnaud et al., 2012). Indeed, the Balkan Peninsula was the earliest region in Europe to domesticate animals, roughly 9000 yr BP (Larson et al., 2007), and hosted the spread of agriculture from the southeast from 7000 yr BP (Price, 2000; van Andel and Runnels, 1995). Additionally, the earliest known examples of extractive metallurgy (around 7000 yr BP) may be found throughout the region (Radivojević et al., 2010 and references therein); evidence for a long history of significant human impact.

Despite significant improvements in the last decades, high-

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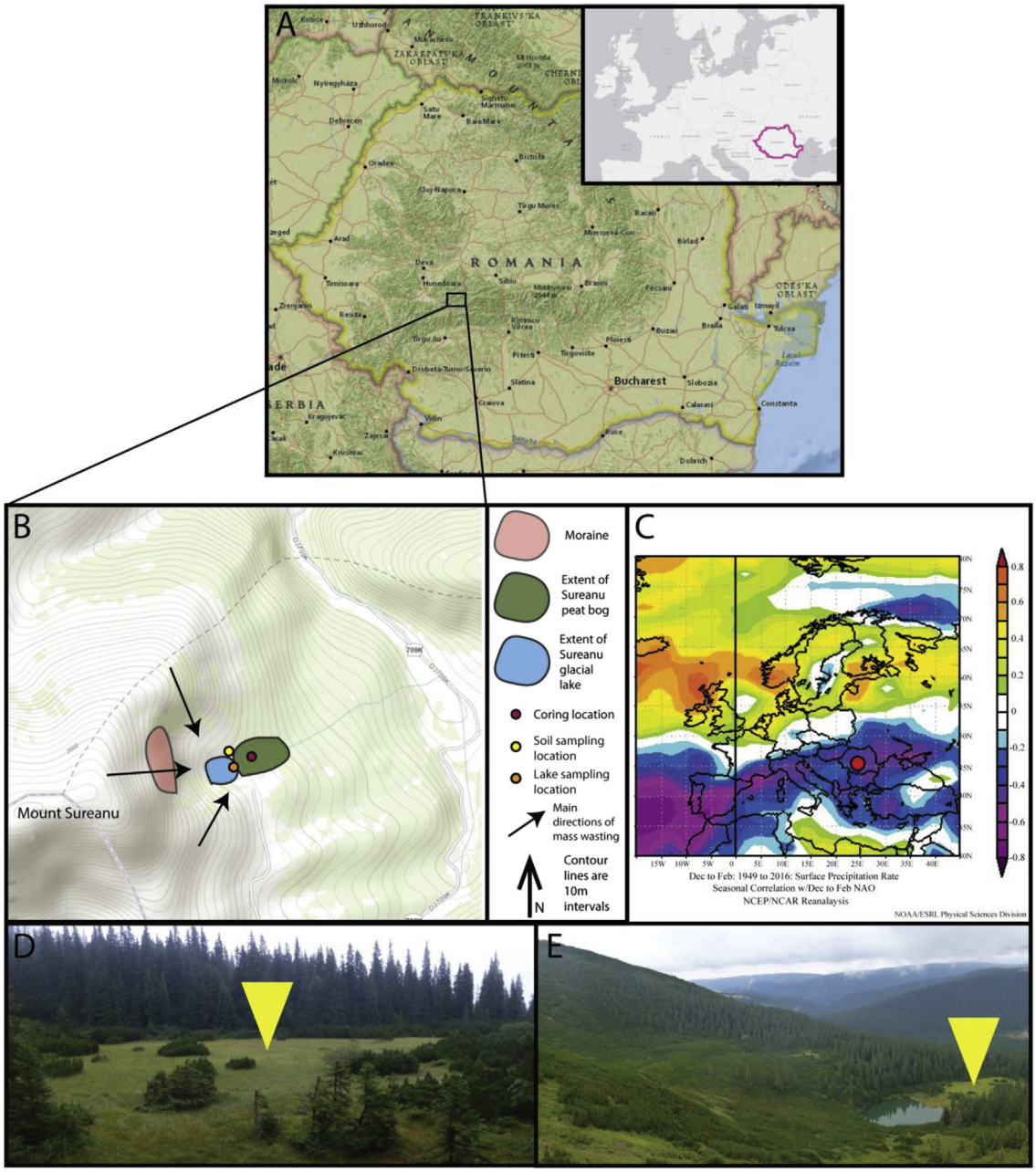

Fig. 1. Location of Sureanu bog (A). B: Topographical map indicating location of bog, lake (Iezerul Sureanu), moraine, all sampling sites and flow directions of mass wasting. C: Correlation of high North Atlantic Oscillation (NAO) index to winter precipitation, indicating reduced precipitation at times of intense NAO in Eastern Europe. Location in the Southern Carpathians denoted by red circle. D: Closer view of bog, indicating location of coring site (yellow arrow). E: View looking down onto site, with coring site indicated by yellow arrow. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

resolution and especially multi-proxy palaeoclimate records from the Carpathian region in Romania are still rare (Buczkó et al., 2013; Magyari et al., 2009, 2012, 2014; Haliuc et al., 2017). Individual proxies have been used to produce a number of long-term records, especially pollen (Feurdean et al., 2008a,b; Schumacher et al., 2016; Tanţău et al., 2011 and references therein), speleothems (Onac et al., 2002; Constantin et al., 2007; Drăguşin et al., 2014) and other palaeoecological and geochemical proxies (Brückner et al., 2010; Magyari et al., 2013; Schnitchen et al., 2006; Tóth et al., 2015). Most studies display strong inter-site variability, even when in close proximity to one another (e.g. Feurdean et al., 2008a,b), an indication of the complexity of the regional climate, one which has been defined primarily by natural controls (e.g. Tóth et al., 2015). In addition, the environment has been heavily influenced by major anthropogenic disturbances (Schumacher et al., 2016). Furthermore, a tree ring reconstruction of summer temperatures over the past 1000 years in the Eastern Carpathians (Popa and Kern, 2009) shows an interesting lack of correlation to similar records from central Europe (e.g. Büntgen et al., 2011a,b), particularly during periods of rapid climate change (Medieval Warm Period (MWP), Little Ice Age (LIA)). This is indicative of strong regional forcing of climate in the Romanian Carpathians in particular and south-eastern Europe in general (Roberts et al., 2012). This is further evidenced by pollen-based reconstructions across the continent,