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Research paper

The construction of a reliable absolute chronology for the last two millennia in an anthropogenically disturbed peat bog: Limitations and advantages of using a radio-isotopic proxy and age–depth modelling

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A B S T R A C T

The main aim of this paper is to present the pitfalls connected with the construction of reliable chronologies for anthropogenically disturbed peatlands over the last two millennia based on ^{210}Pb and ^{14}C dating, i.e. the period of the strongest human impact on these ecosystems. The following hypotheses have been formulated: i) parts of peatlands suspected to be affected by peat extraction may possess traces of mechanical disturbances undetectable using different analyses based on biota proxy; ii) failure to consider information included in radionuclide date inversions may contribute to the establishment of misleading chronologies. To test these hypotheses, different scenarios of chronology based on high resolution ^{210}Pb and ^{14}C dating from a peat core retrieved from the Puścizna Krauszowska bog (southern Poland) have been analysed. Nowadays, this mire is intensively exploited by humans; however, it contains remains of dome considered undisturbed, from which the core presented in this paper was collected. The set of dates revealed the presence of marked ^{14}C date inversions (mechanical disturbances) which, if inappropriately interpreted before the age–depth modelling process, may lead to the establishment of misleading chronologies, and thus an incorrect interpretation of biota proxy records, e.g. pollen. Those sections of peat profiles with prominent age inversions and/or strong discrepancies between the peat accumulation rate and bulk density should be rejected from age–depth modelling, even if interpretable chronologies can be obtained.

1. Introduction

Ombrotrophic, rain-fed peatlands are invaluable archives, which provide information about past environmental changes. Many proxies, including biotic indicators, geochemistry and physical–chemical properties, are tools for reconstructions of past processes recorded on a decadal to millennial time scale (e.g. Shotyk, 1996; Mauquoy, 2002; Lamentowicz et al., 2008a, 2009b; Gałka et al., 2014). Even though different configurations of analyses are employed to solve palaeoecological problems, establishing a reliable time scale is one of the most crucial steps for the explanation of past environmental changes. The most frequently applied and universal technique to provide accurate ages for deposits from the last ca. 50,000 years is the ^{14}C dating method (e.g. Piotrowska et al., 2011; Michczyński, 2011). To establish the age of younger peat deposits, a method using natural and artificial radionuclides has been developed (Appleby, 2001). However, dating with ^{210}Pb should be used with caution, because of the partial mobility of this radionuclide after deposition (Parry et al., 2013; van der Plicht et al., 2013), and the results should be compared with other techniques. In addition, post-bomb radiocarbon dating has come to be used more often, because it provides very valuable and reliable dates (e.g. van der Linden et al., 2008; Piotrowska et al., 2011). In practice, it is hardly feasible to perform dating for samples from every depth of a profile, and consequently agedepth modelling, i.e. a sophisticated statistical technique of reliable age interpolation on sections of profiles not covered by radiocarbon dating, is implemented. One of the important obstacles in constructing a peat chronology that can possibly be encountered is the fact that bogs have been

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exploited for many centuries. Human activity on bogs, such as draining, peat harvesting, using them as pasturelands and others, may have caused severe disturbances making the peat sequences useful only to a limited extent in terms of palaeoecological reconstructions. Disturbances in peat sequences might be demonstrated through unnatural inversions of ^{14}C dates and/or significant decreases in age values (especially sediment gaps) (Turetsky et al., 2004, 2011; Fiałkiewicz-Kozieł et al., 2014). Therefore, the age–depth modelling process might be used as a tool for detecting different disturbances in peat sequences.

In this paper it is hypothesized that: i) parts of peatlands suspected to be affected by peat extraction may possess traces of mechanical disturbances undetectable by different analyses based on biota proxy; ii) overlooking information included in radionuclide date inversions may contribute to the establishment of misleading chronologies. To test both hypotheses, different peat core chronology scenarios for the last two millennia were analysed based on a high resolution age–depth model (altogether 28 ^{210}Pb and ^{14}C dates); they were compared with the results of a pollen analysis (Kołaczek et al., 2010) and the bulk composition, i.e. bulk density, and mineral fraction of peat (ash content) and the degree of decomposition. Bulk density and the degree of decomposition are firm indicators of wet/dry shifts in bog history and can be used for radiocarbon wiggle-match dating (Chambers et al., 2010). Therefore, they may reveal inconsistencies between changes in the accumulation rate of peat inferred from the modelled chronology and ones suggested by the physical properties of peat (comp. Fiałkiewicz-Kozieł et al., 2014).

Puścizna Krauszowska (PK), an ombrotrophic peatland in the Orawa-Nowy Targ Depression (southern Poland), was selected as the focus of the research. This bog was strongly influenced by peat extraction in the past, but the remains of a dome without visible traces of disturbances are still present (Łajczak, 2006). The research presented in this paper is one of few trials of age–depth modelling for sites in the entire area of the Polish Carpathians (comp. Margielewski et al., 2011; Michczyński, 2011; Michczyński et al., 2013). Hence, the pitfalls connected with the construction of absolute chronologies for the anthropogenically disturbed peatlands for this area are still poorly recognized. To the best of the knowledge of the authors, this is only the second article considering this problem not only from this area but also from all Central-Eastern Europe (apart from the research by Fiałkiewicz-Kozieł et al., 2014). Nevertheless, it is the first trial to use ^{14}C inversion as a proxy for palaeoecological research on ombrotrophic peatlands in Central-Eastern Europe, and this might be useful for such research in Northern Hemisphere.

2. Material and methods

2.1. Site description and field methods

Puścizna Krauszowska (PK) is an ombrotrophic bog that belongs to a vast complex of peatlands in southern Poland, i.e. the Orawa-Nowy Targ Depression (Fig. 1; Łajczak, 2007).

During the last two millennia the domes of bogs have perhaps occasionally been used as pasturelands, probably since the 13th century AD. However, intensive peat exploitation on the Puścizna Krauszowska has become significant since the 19th century AD, when the first drainage works were carried out and peat extraction was accelerated. In recent times, the exploitation of the peatlands has decreased and ditches have become overgrown (Łajczak, 2006). The remaining dome is considered to be undisturbed, which might be indicated by the vegetation and morphology (Łajczak, 2007; authors' personal observation). The vegetation is composed of a set of taxa characteristic of poor acid mires, i.e. *Andromeda polifolia*, *Ledum palustre*, *Oxycoccus palustris*, *Vaccinium uliginosum* and *Sphagnum* mosses (Kołaczek et al., 2010).

To minimize the possibility of the presence of any disturbances in the peat column, a coring location was chosen in the centre of the dome (613 m a.s.l., 49°28′06″ N, 19°56′18″ E), ca. 15 m from the nearest place with traces of exploitation. The profile (labelled PK0) was collected in June 2008 using a Wardenaar corer (made from stainless steel) of dimensions 10 × 10 cm × 100 cm (Wardenaar, 1986) and afterwards was put in cold storage at 4 °C.

2.2. Bulk composition

The peat monolith was divided into 1-cm slices using a stainless steel knife. For the purpose of measuring bulk density (BD), fresh

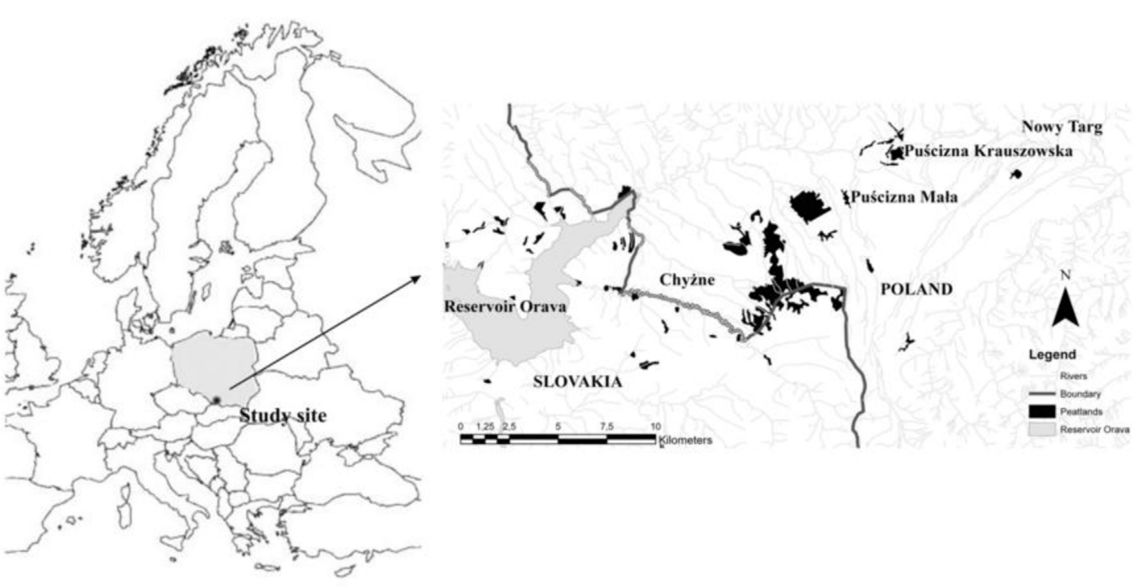

Fig. 1. Location of the study site. The investigated peatland is located near the Polish–Slovak border.