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Distributions of “bomb ^{14}C”, biogeochemistry and elemental concentration in Hani mire peat profiles, NE China: Implications of environmental change

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ABSTRACT

Two 50–cm long peat cores from the Hani mire on the western slope of the Changbai Mountains, northeastern China, were collected for investigating physical, biological and geochemical processes of the peatland in response to recent climate change. The ^{14}C dating using accelerator mass spectrometry (AMS) on the peat cores provides “a nuclear bomb carbon curve” which is used for peat chronological construction. The sedimentation rate (SR) of Core S1 from a *Sphagnum magenllanicum* hummock in the Hani mire was about 0.98 cm/y and deposited from 1957–2008 CE, whereas the SR of Core S2 from *S. palustre* hummock (1 km apart from S1) was 1.59 cm/y and accumulated during 1976–2008. The discrepancy of the SRs may mainly be attributed to the different inorganic material supplies from surface runoff which affected growth of *Sphagnum* spp. at different sites, with lower rate corresponding to higher inorganic contents (higher Ti, Ca and Mg contents thus lower values of loss on ignition, LOI%). On the other hand, the two cores had similar values and variation trends in the pH, C/N, N and P contents, and dry bulk density (DBD), implying that the organic source and decomposition were similar under the same climatic conditions. The variations of TOC%, C/N and Pb content in the peat cores matched well with the 5-y running average of local annual precipitation record, with higher TOC% and C/N but lower Pb content corresponding to higher rainfall; and vice versa. These properties in the meso-oligotrophic peat sequences can reflect climatic changes. The recent rates of carbon accumulation (RERCA) for S1 and S2 calculated from the TOC%, DBD and SR were averaged 121.6 ± 24.3 and 175.5 ± 35.1 g/m^2/y, respectively.

1. Introduction

Peatlands which can accumulate organic matter from dead plants for thousands of years, are remarkable wetland ecosystems (Rydin and Jeglum, 2006). Peat profiles are widely used to reconstruct climate and environmental changes (e.g., Weiss et al., 1999; Hong et al., 2001, 2005, 2010; Xu et al., 2013; Rydberg and Cortizas, 2014). Many biological proxies in peat profiles have been used for reconstructing past climate change, such as humification indexes (Blackford and Chambers, 1993; Zaccone et al., 2011b), biomarker analyses (Ortiz et al., 2011), plant macrofossils (Barber et al., 2003; Väliranta et al., 2007), and testate amoebae (Payne and Mitchell, 2007; Amesbury et al., 2013). On the other hand, inorganic geochemical proxies from peat sequences have been increasingly used to obtain high-resolution climatic and environmental records (e.g., Shotyk et al., 2003, 2014; Kylander et al., 2005;

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Muller et al., 2008; Pratte et al., 2013). Due to hydraulic isolation, bogs receive all chemical constituents via direct deposition from the atmosphere and/or via atmospheric uptake by vegetation, and may provide reliable information of atmospheric inputs of trace metals that are used for reconstructing dust deposition and paleoclimate change (Aaby, 1976; Zaccone et al., 2011a; Chambers et al., 2012). For instance, a continuous record of Pb pollution in bogs during the entire Holocene was reconstructed from a ^{14}C-dated bog in the Jura Mountains of Switzerland (Shotyk et al., 1998, 2001). In Spain, a detailed identification for both natural and anthropogenic Pb sources was made (Kylander et al., 2005). In Southeast Asia, the biogeochemical processes of major and trace elements in a forested bog in Kalimantan were investigated (Weiss et al., 2002). Ferrat et al. (2012) studied a peat sequence in the eastern Qinghai-Tibetan Plateau and concluded that the Pb deposition throughout the Holocene was governed by local deposition and long-range input from natural dust sources from the arid and semi-arid areas in northern China. In northeastern China, cores from a bog were dated by ^{210}Pb and ^{137}Cs techniques and lithogenic metal elements (e.g. Ti) in peat ash were analyzed to determine the rate of atmospheric soil dust input (Bao et al., 2012). The above mentioned studies have demonstrated that biological and geochemical proxies in peat profiles can be used for reconstruction of paleoclimate and environmental changes as well as Pb pollution from the atmospheric input.

However, biological and geochemical proxies in peat archives may be affected by physical, biological and geochemical processes after deposition. For example, retention of metal elements in peat profiles can change with depths, resulting from a complex interaction of many processes such as settling, sedimentation, absorption, cation exchange, degradation, co-precipitation, microbial activity and plant uptake (Sheoran and Sheoran, 2006; Parviainen et al., 2014). These processes are affected by many environmental factors such as rainfall, temperature, pH, redox potential, ion exchange capacity, bacterial activity, and etc. Our understanding of variation patterns and their influencing factors of biological and geochemical properties remains to be improved significantly.

In addition, peatlands are also an important terrestrial reservoir for the global carbon cycle (Clymo, 1984; Asada and Warner, 2005; Yu, 2011a). Changes in peatlands have been linked with global climate change (Hilbert et al., 2000; IPCC, 2007; Zhang et al., 2008). Therefore, it is important to understand how the development of peatlands corresponding to climate change and to what extent the peatland change influences the global C cycle (Vitt et al., 2000; Joosten and Clarke, 2002; Brown et al., 2007; Beilman et al., 2009). In order to understand the peat development corresponding to the climate change and feedback to the carbon reservoir in peatlands, as well as behaviors of biological and geochemical proxies in peat archives, it is necessary to investigate physical, chemical and biological properties in modern peat profiles with known time scales and climatic conditions. The present study aims to conduct such investigation.

The Changbai mountain region has a high abundance of peatlands in northeast China. Nearly 92.162 km^2 of peatlands with 38.92 million tons of peat were inventoried, covering about 55.2% of the total peatland area in Jilin Province, China (Chen, 2000). In this study, we present two peat cores from the Hani mire on the western slope of the Changbai Mountains. AMS ^{14}C dating was carried out on the two cores. The “nuclear bomb carbon curve” was used, for the first time, in determination of peat chronology in Asia. The concentrations of metal elements (Pb, K, Ti, Ca, Mg) and physicochemical analyses such as pH, loss on ignition (LOI), dry bulk density (DBD), total organic carbon (TOC), nitrogen (N)% and phosphorus (P)% were measured. The accurate chronology and high-resolution parameters of the peat profiles enable us to compare the peat variables with meteorological records during the past 50 years. Thus the development of the peatland and the variations of the properties in the peat profiles under known climate conditions can be investigated. The calculated recent rate of carbon accumulation (RERCA) in the peatland will be discussed for evaluation of carbon storage in the peatlands.

2. Materials and methods

2.1. Study area

Located on the western slope of the Changbai Mountains, the Hani mire (42°11′–42°14′N, 126°28′–126°33′E) is a 16.78 km^2 mesotrophic to oligotrophic peatland with an altitude of 882–900 m above sea level (Fig. 1). Landscape there is a basaltic lava platform so called Longgang lava terrace surrounded by mountain hills (Ma, 2010). The surrounding mountain hills with elevations of 960–1293 m formed the drainage basin that is slightly tilted toward the west. Originated from the Hani mire, Hani River is the major river in the area, with 137 km in length and a drainage area of 1489 km^2. Hani River is a branch of Hunjiang River that belongs to the Yalujiang River system. Since the Hani mire is in the headwater area of Hani River far away from the inhabited area, the mire is well preserved with minimal human impacts. The peatland was developed from a lava-dam lake, and the depth of the peatland is ~4.6 m on average and ~9.6 m at its deepest point (Qiao, 1993). This region belongs to a monsoonal climate zone characterized by a long cold and dry winter and a short wet summer, with ~181 frost days from November to April. The mean annual temperature is 3.2 °C, and the mean annual precipitation is 767 mm based on the 1955–2008 record of Jingyu meteorological station ~20 km away from the Hani mire (Fig. 2a). The annual temperature and precipitation records also showed that the temperature had a warming trend from 1950s to the 21st century (Fig. 2b), specifically, the averaged temperatures during 1955–1987 and 1988–2008 were 2.7 ± 0.6 °C and 4.1 ± 0.5 °C, respectively. On the other hand, the precipitation record did not exhibit a long-term trend (Fig. 2b), but showed a decadal drought period during 1975–1985 (Fig. 2b). The mire contains natural ecosystems with species diversity and abundance. Currently, dominant vegetation in the area includes *Betula fruticosa* Pall. var. *ruprechtiana*, *Ledum palustre* L. var. *angustum*, *Eriophorum vaginatum* Linn., *Sphagnum magellanicum* Brid., *Sphagnum fuscum* Klinggr., *Sphagnum palustre* Linn. and *Sphagnum capillifolium* Ehrhart (Bu et al., 2013; Zhao et al., 2014). With minimal impact of agriculture and other human activities, changes in the environments should largely be attributed to atmospheric inputs and climatic variations.

2.2. Core collection and preparation

Core S1 (42°13′39.95″N, 126°31′5.65″E), dominated by *S. magellanicum*, and Core S2 (42°13′31.93″N, 126°31′3.36″E), dominated by *S. palustre*, were collected from two hummocks of *Sphagnum* spp. about 1 km apart at the Hani mire in 2008 (Fig. 1). The hummock at S1 site is close to a forest area where surface runoff carries soil debris into the peatland, whereas S2 site does not have such a feature. The depth of hummock surface to water table is ~40 cm in S1 site and ~38 cm in S2 site during the sampling time. At each site, a peat block of 20 cm (width) × 30 cm (length) × 50 cm (depth) was excavated from the peatland. The edges (2 cm) of each section were trimmed away with a clean stainless steel scraper to avoid contamination. The samples with a 1-cm interval were taken in the field via a stainless steel knife and put into polyethylene plastic bags, and then transported to the State Environmental Protection Key Laboratory of the Wetland Ecology and Vegetation

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