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Black carbon concentration and isotopic composition of surface sand from deserts and dune fields in Northern China

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ABSTRACT

Black carbon (BC) is a continuum of incomplete combustion products of vegetation and fossil fuels. It can be used as a proxy for wildfires and paleovegetation reconstruction. Nevertheless, BC can be transported by wind and water via atmospheric and fluvial transport. To research the characteristics of BC in deserts and dune fields that are directly connected with the Chinese Loess Plateau (CLP) in Northern China, and to evaluate the possibility that BC in deserts and dune fields occurs as exogenous BC in the CLP, we investigated surface sand from the Mu Us dune field, the Tengger Desert, and the Badain Jaran Desert, and analyzed the stable carbon concentration and carbon isotopes of organic carbon (SOC%, $\delta^{13}C_{SOC}$) and BC (BC%, $\delta^{13}C_{BC}$). The $\delta^{13}C_{SOC}$, $\delta^{13}C_{BC}$ values ranged from −27.4‰ to −22.5‰, and −28.2‰ to −23.0‰, respectively, which mainly reflected $\delta^{13}C$ changes in surface C_3 grasses. A positive correlation was observed between $\delta^{13}C_{BC}$ and $\delta^{13}C_{SOC}$, suggesting that local vegetation mainly controls $\delta^{13}C_{BC}$. The difference between $\delta^{13}C_{BC}$ and $\delta^{13}C_{SOC}$ ranged from −0.2‰ to +3.5‰, and the difference is likely to be due to carbon isotope discrimination occurring during burning and SOC decomposition. The SOC% and BC% in these deserts and dune fields are very small (averaging 0.048% and 0.011%). The BC% of surface sand in these areas is about 5.5% of BC% in the CLP surface soils, and the Δ-$\delta^{13}C_{BC}$ value between surface sand in deserts and surface soils in CLP ranged from −0.3‰ to −6.3‰, so the change of $\delta^{13}C_{BC}$ in the CLP surface soils, deduced by exogenous BC from deserts, is less than 0.35‰. All these findings suggest that BC in deserts has a limited impact on BC in the CLP and is unlikely to affect interpretations of the BC record of wildfires and paleovegetation information in the CLP.

1. Introduction

Black carbon (BC), a general term for fire residues, is a continuum of incomplete combustion products from vegetation and fossil fuels, ranging from char, charcoal, and soot to graphite BC (Goldberg, 1985; Masiello, 2004). It exists widely in soils, ice, lake sediments, marine sediments, and the atmosphere (Schmidt and Noack, 2000; Liu et al., 2012). BC constitutes a considerable proportion (1%–60%) of soil organic carbon (SOC) (Nguyen and Lehmann, 2009). As a product of fire, BC can be used as an indicator of ancient wildfires and can aid in paleovegetation reconstruction because the relatively inert nature of BC results in long-term preservation (Masiello, 2004; Nguyen and Lehmann, 2009; Shen et al., 2011).

As BC can be transported by wind and water via atmospheric and fluvial transport, with sedimentation occurring globally through these processes (Schmidt and Noack, 2000), it is necessary to consider the possible exogenous input in detailed interpretations of the BC record. The aeolian loess-soil sequences in the Chinese Loess Plateau (CLP) have a high sedimentation rate with good continuity. Tightly coupled with climate, vegetation, and biogeochemical cycles, this area plays an important role in global climate change research (Liu, 1985; An et al., 1991; Liu and Ding, 1998; Guo et al., 2002). The use of BC concentration (BC%) and BC isotopic composition ($\delta^{13}C_{BC}$) as new proxies for paleovegetation reconstruction is an active research topic in the CLP (Ning et al., 2004; Zhou et al., 2007; Wang et al., 2012; Liu et al., 2013). The deserts and dune fields of Northern China that have persisted over geological time are the dominant dust sources of the CLP (An et al., 1991; Zhang et al., 2003; Sun et al., 2008), and they are highly sensitive to changes resulting from the East Asian monsoons, because they lie near the northern limit of monsoonal precipitation (Gao et al., 1993; Lu et al., 2005). The BC produced in these deserts and dune fields is likely to be carried along with the dust and deposited on the CLP.

However, a detailed investigation of BC characteristics in deserts and dune fields in Northern China has yet to be undertaken. It has become an urgent requirement to systematically research the BC concentration and isotopic composition of surface sand from deserts and dune fields in

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Northern China, and to assess the usage of BC carbon isotope as a proxy for vegetation changes in these deserts and the contribution of BC in these deserts to that in the CLP. In previous studies, Wang (2004) and Wang et al. (2005) found that BC in the CLP did not have obvious grading characteristics and that BC input from the dust source regions was limited. He suggested that the BC in the CLP was mainly derived from the combustion of local vegetation, and only a small part of the BC particles had been transported with the dust. Liu et al. (2013) suggested that $\delta^{13}C_{BC}$ values of surface soil in the CLP were controlled mainly by surface plants and that $\delta^{13}C_{BC}$ could effectively indicate vegetation composition within a precision range of $\pm 1.5‰$.

Therefore, in order to investigate the characteristics of BC in deserts and dune fields and to evaluate the presence and effects of exogenous BC in the CLP, the current study was conducted. To this end, modern surface sand in the Mu Us dune field, the Tengger Desert, and the Badain Jaran Desert, which are directly connected with the CLP in Northern China, was sampled to analyze the stable carbon concentrations and carbon isotopes of SOC and BC.

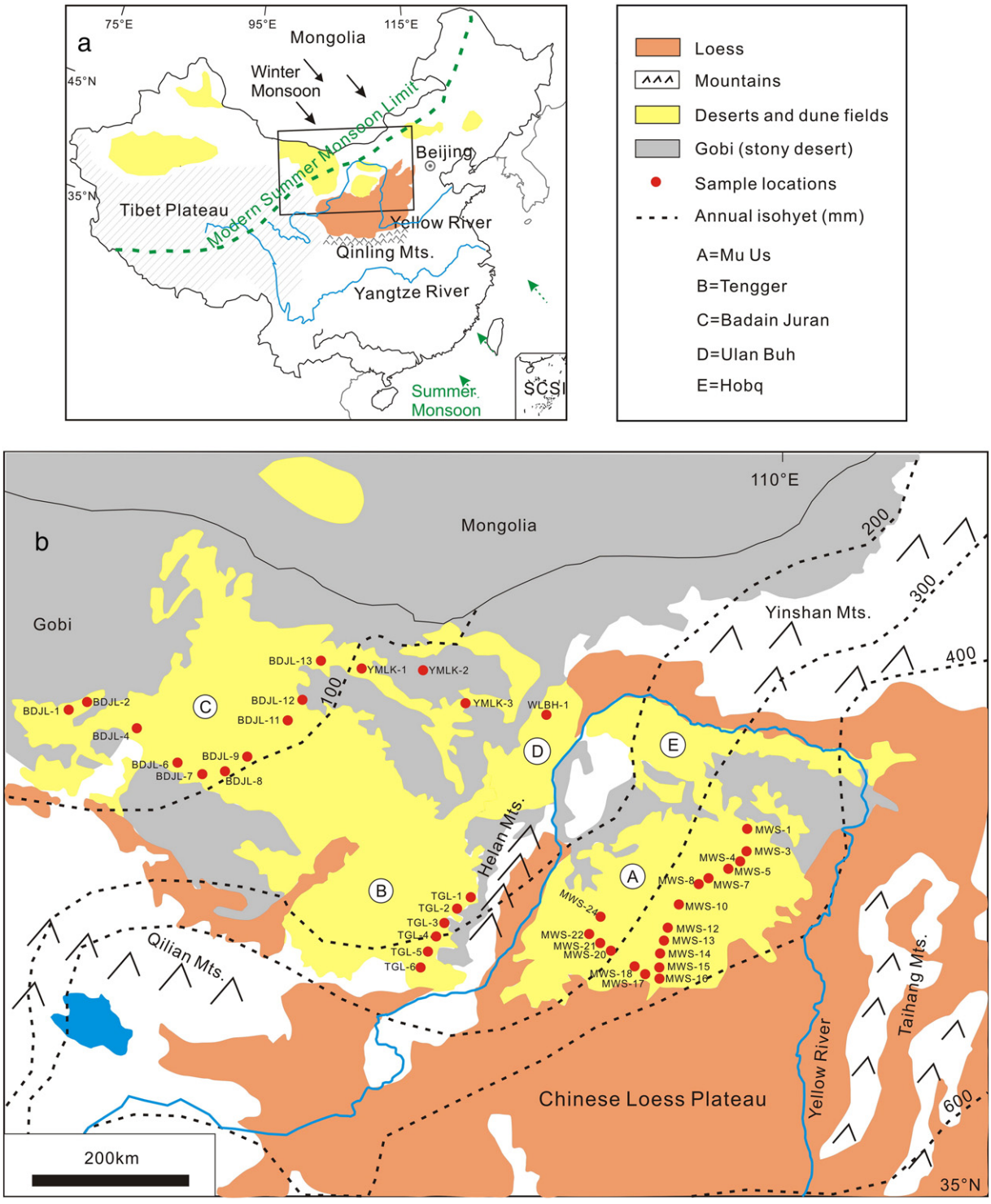

Fig. 1. Schematic map showing the position of the Mu Us dune field, the Tengger Desert, and the Badain Jaran Desert. The rectangle in (a) shows the locality of these deserts and dune fields, and the yellow parts in (b) show these deserts and dune fields. The Chinese Loess Plateau and mountains around the deserts and dune fields are shown in (b).