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High-resolution multi-proxy evidence for millennial- and centennial-scale climate oscillations during the last deglaciation in Jeju Island, South Korea

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ABSTRACT

Millennial- and centennial-scale climate and vegetation changes during the last deglaciation from Hanon Maar paleolake on Jeju Island, South Korea were reconstructed by high-resolution multi-proxy data (pollen, Anhysteretic Remanent Magnetization [ARM], Total Organic Carbon [TOC], Total Nitrogen [TN], Carbon/Nitrogen [C/N] ratio, carbon and nitrogen isotope compositions ($\delta^{15}N$ and $\delta^{13}C$), major element geochemistry, and sediment grain size). The resolution of our multi-proxy data was sufficiently high to enable the detection of millennial- and even centennial-scale climate change in the study area during the last deglacial transition. We found centennial-scale cold reversals between 14,650 and 12,900 cal yr BP, possibly corresponding to the Bølling–Allerød [BA] oscillations. Hanon pollen data implied that climate amelioration around 11,900 cal yr BP terminated the Younger Dryas [YD] in the study area and that a cold event around 11,300 cal yr BP probably correlated with the Pre-Boreal Oscillation [PBO] cooling event. Our results indicate that rising summer insolation and northward expanding low-latitudinal warm currents exerted a strong influence on climatological teleconnection via westerlies between the North Atlantic and the East Asian region during the last deglaciation, presumably causing a decoupling between temperature and East Asian Summer Monsoon [EASM] precipitation during the last deglaciation.

1. Introduction

Many scientists have long been intrigued by the evidence of cold reversals during the last deglaciation that was mainly found in the circum-North Atlantic region due to the dramatic abruptness of these reversals. Ice cores have provided the high-resolution records on marked climate fluctuations during the last deglaciation (e.g., Stuiver et al., 1995; North Greenland Ice Core Project Members, 2004). Similar oscillations have been observed in lacustrine and marine sediments from Europe (e.g., Brooks and Birks, 2000; Schwander et al., 2000), eastern North America (e.g., Shuman et al., 2002), and the Caribbean area (e.g., Hughen et al., 2000). Recently, the presence of equivalent climate variability in East Asia has been increasingly supported by evidence from a number of cave speleothems in China (Wang et al., 2001, 2008; Yuan et al., 2004; Dykoski et al., 2005; Cai et al., 2010) and lake sediments in coastal East Asia (Nakagawa et al., 2003, 2005; Liew et al., 2006; Parplies et al., 2008; Stebich et al., 2009; Li et al., 2013).

The Younger Dryas (YD), the most well-known deglacial climate reversal, was more than a regional event. A large body of evidence suggests that temperatures were relatively low during the YD in East Asia, as in North America and Europe (e.g., Nakagawa et al., 2003). However, issues regarding the wetness, such as the strength of the East Asian Summer Monsoon (EASM), have not been clearly solved. The amount of summer precipitation seems to have varied locally even at similar latitudes; for example, relatively wet in the middle reaches of the Yangtze River (31°28′N, 110°00′E) (Huang et al., 2012), dry in the lower reaches (32°30′ N, 119°10′E) (Wang et al., 2001), and neither wet nor dry in Lake Suigetsu (35°35′N, 135°53′E) (Nakagawa et al., 2006). Furthermore, two conflicting interpretations for the same pollen data (Stebich et al., 2009; Hong et al., 2010) sparked a heated debate over the degree of wetness during the YD in Northeast China (Hong et al., 2011; Stebich et al., 2011). In addition, other brief cold reversals in the Bølling–Allerød (BA) oscillation and the Pre-Boreal oscillation

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(PBO) during the last deglaciation have barely been investigated in the East Asian region, seemingly because shorter time-scale oscillations were dampened by orbital-scale insolation rise and the strengthening influence of warm currents.

In Korea, located in the central area of Northeast Asia, only a few paleoenvironmental data covering the period during the Last Glacial–Holocene transition have so far been produced. This lack of data has hampered the determination of the mechanisms of short-term climatic oscillations in the entire Northeast Asian region during the last deglacial period. The southern part of Jeju Island, the largest island of Korea, contains a paleo-maar lake with a sediment layer over 10 m thick. This lake sediment is currently the only paleoenvironmental archive encompassing the last deglacial period in South Korea. However, no high-resolution investigation has been conducted to analyze this sediment archive and previous studies could not therefore precisely examine millennial-scale and shorter time-scale climate fluctuations, including the YD and BA intervals (Fukuoka et al., 2001; Fukusawa et al., 2004; Chung, 2007; Lee et al., 2008).

In this study, we present a multi-proxy record (pollen, Anhysteretic Remanent Magnetization [ARM], Total Organic Carbon [TOC], Total Nitrogen [TN], Carbon/Nitrogen [C/N] ratio, carbon and nitrogen isotope compositions ($\delta^{15}N$ and $\delta^{13}C$), major element geochemistry, and sediment grain size) of the late-Pleistocene environmental change from a paleo-marr lake in Jeju Island. The study aims are 1) to provide the first high-resolution paleoenvironmental multi-proxy records on the last deglaciation in Korea, 2) to verify the existence of millennial and centennial climate oscillations such as the YD and BA, 3) to infer hypotheses regarding the characteristics of cold reversals during the last deglaciation, and 4) to compare our records with others from East Asia and the circum-North Atlantic region.

2. Regional settings

The study site of the Hanon Maar paleolake (33°14′N, 126°32′E) is located at an altitude of 53 m in the southern part of Jeju Island, South Korea (Fig. 1). Jeju Island is a shield volcano formed on the

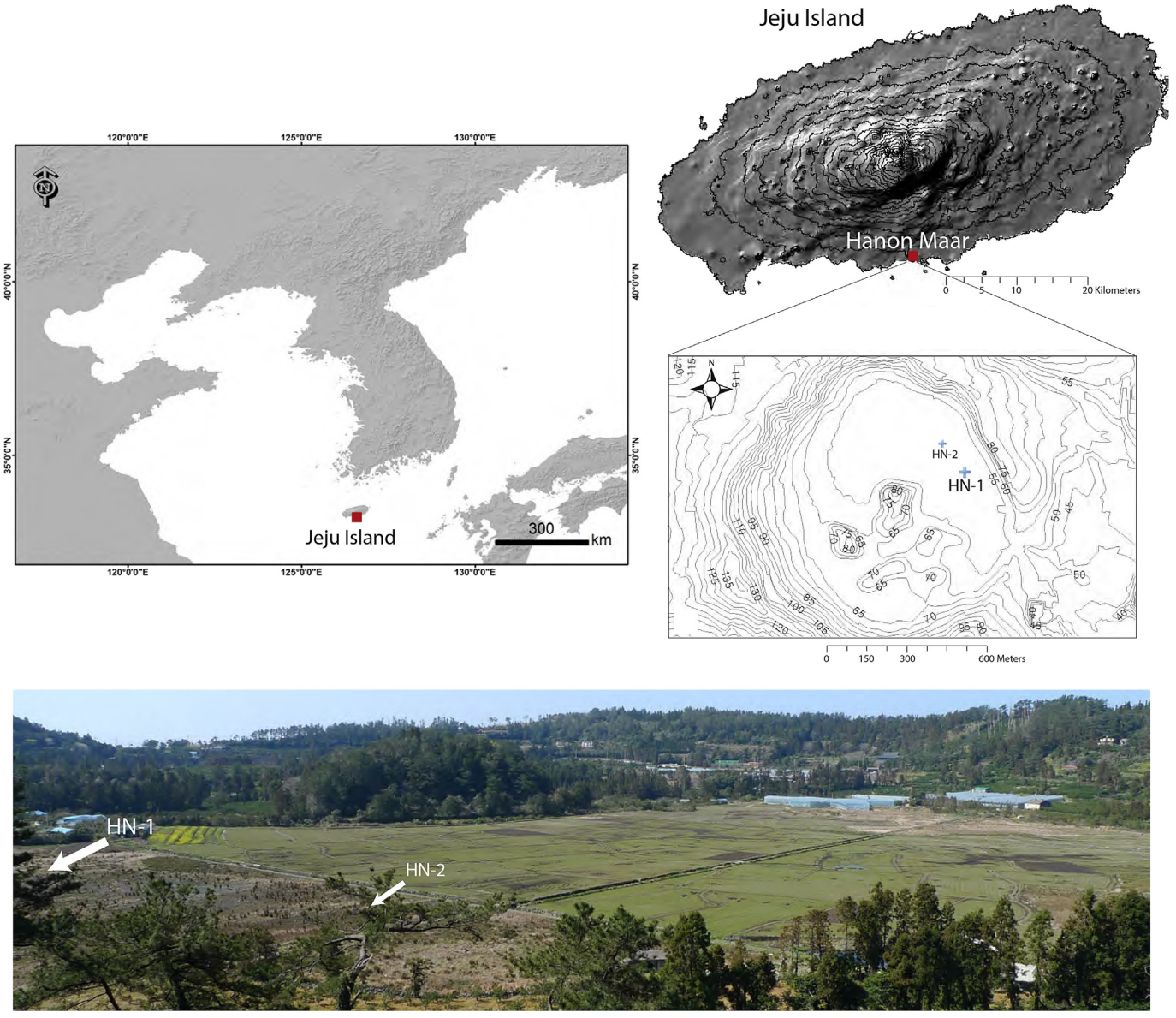

Fig. 1. Map and photo of Hanon Maar paleolake and coring locations. HN-1 sediment core was analyzed for this study. The contour interval on the map of Jeju island is 100 m.