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Vegetation and climate histories between MIS 63 and 53 in the Early Pleistocene in central Japan based on plant macrofossil evidences

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A B S T R A C T

Among the Early Pleistocene fluvial sediments in Japan that yield plant macrofossils, the Uonuma Group in the Niigata sedimentary basin provides the most continuous profile without any conspicuous hiatuses and is therefore suitable for high-resolution reconstructions of environmental and vegetation histories based on tephro- and magneto-stratigraphy. Based on the species composition of plant macrofossil assemblages, along with previously reported results on sedimentary environments and pollen records, we performed a reconstruction of changes in paleovegetation and paleotemperatures between MIS 63 and 53. Macrofossil assemblages identified from 33 samples include 89 arboreal and 88 herbaceous taxa in total, of which 9 taxa are extinct from Japan. Assemblages from the peat deposits in fluvial backmarshes during glacial stages are composed mainly of wetland herbaceous plants, whereas those from the sandy channel-fill deposits are characterized by a higher diversity in life forms and habitat preferences. During the interval from MIS 63 to 53, paleotemperatures fluctuated between a coldest-month mean temperature of −4.6 °C and −0.9 °C and between a mean annual temperature of 6.6 °C and 11.0 °C, which is within the present range for cool-temperate, deciduous broad-leaved forests in Japan. MIS 60 was the coldest of the glacial stages with temperatures nearly equivalent to those during the last glacial maximum. Major plant extinctions in and around MIS 60 were not recorded in the sedimentary basin in response to the temperature decline. The relatively indistinct floral changes in and around MIS 60 are attributed to easier recovery of flora by migration from glacial refugia in the southern basins after termination of the glacial stage. Interglacial temperatures during MIS 57, 55, and 53 were higher than during MIS 63, 61, and 59. The presence of a maritime environment during the interglacial periods between MIS 57 and 53 may have resulted from a greater extent of marine transgression and heat provided by the Tsushima Warm Current flowing into the Sea of Japan after MIS 59.

1. Introduction

The Early Pleistocene is characterized by conspicuous glacial–interglacial climate changes on a 41-ka cycle, accompanied by the development of ice sheets in the northern hemisphere (Lisiecki and Raymo, 2005). The climatic changes influenced the distribution of terrestrial plants and vegetation at mid-latitudes in the northern hemisphere (Zagwijn, 1960; Bertini et al., 2010; Popescu et al., 2010) and caused local extinction of plants in Europe (van der Hammen et al., 1971; Martinetto et al., 2017) and Japan (Momohara, 1994, 2016). Decreased temperatures during glacial stages promoted the expansion of boreal vegetation into lowland areas of central Japan (Yamakawa et al., 2017). Quantitative reconstructions of terrestrial climate are important for understanding how plant biogeography developed in response to environmental changes during the Early Pleistocene. The components of plant macrofossil assemblages, which can be identified at the species level, enable quantitative climate reconstructions based on the climatic requirements inherent to each taxon (Mosbrugger and Utescher, 1997).

Among the Early Pleistocene fluvial sediments in central Japan that yield rich and well-preserved plant macrofossils, the Uonuma Group in the Niigata sedimentary basin provides the most continuous profile without any conspicuous hiatuses and is therefore

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suitable for high-resolution reconstructions of environmental and vegetation histories (Kazaoka et al., 1986; Momohara, 2016). This group includes many tephra layers that can be used for correlation with outcrops containing marine sections in the basin, some of which also occur in other basins. Such widespread tephras are also used for correlations with marine isotope stages using calcareous nannofossil stratigraphy and magnetostratigraphy. A rough general plant biostratigraphy of this group has previously been established based on macrofossils and pollen (Yamanoi, 1970; Yamanoi and Nitobe, 1970; Yamanoi et al., 1970; Nitobe, 1977; NFPRG and NPRG, 1983). However, past paleovegetation reconstruction studies in the sedimentary basin were limited to the upper horizons (Yamanoi, 1973) and no paleotemperature reconstructions or biostratigraphic correlations with marine isotope stages have been conducted.

The Uonuma Group sediments lying above the Olduvai subchron include two widespread tephras: the Tsujimatagawa tephra bed, which corresponds to the Eb-Fukuda (Ebistoge-Fukuda) tephra bed (ca. 1.7 Ma), and the Om–SK110 tephra bed (ca. 1.6 Ma) (Satoguchi and Nagahashi, 2012). The section of the profile located between the top of the Olduvai subchron and the SK110 tephra includes several important events for floral reconstructions and environmental evolution in central Japan. The plant macrofossil records from horizons above the Eb-Fukuda tephra in the central Kinki District indicate that cool-temperate plants began to expand into lowland areas in response to glacial climate conditions (Momohara, 2016). A marine faunal sequence in Kanazawa (Loc. 5 in Fig. 1A), located ca. 200 km southwest of Uonuma Hills, demonstrates that frequent inflows of the Tsushima Warm Current into the Sea of Japan began during the interglacial period around ca. 1.7 Ma (Kitamura and Kimoto, 2006). Because these environmental events may have impacted the plant biogeography of central Japan, a detailed profile of this study site based on plant macrofossils can elucidate the floral and climatic changes that occurred during this stage.

In this paper we perform a paleovegetation reconstruction based on the composition of plant macrofossil assemblages, their sedimentary facies, and previously reported pollen data (Yamanoi, 1970). We then present a reconstruction of paleotemperature changes corresponding to glacial-interglacial climate cycles during the period between MIS 63 and 53 and discuss their biogeographical implications.

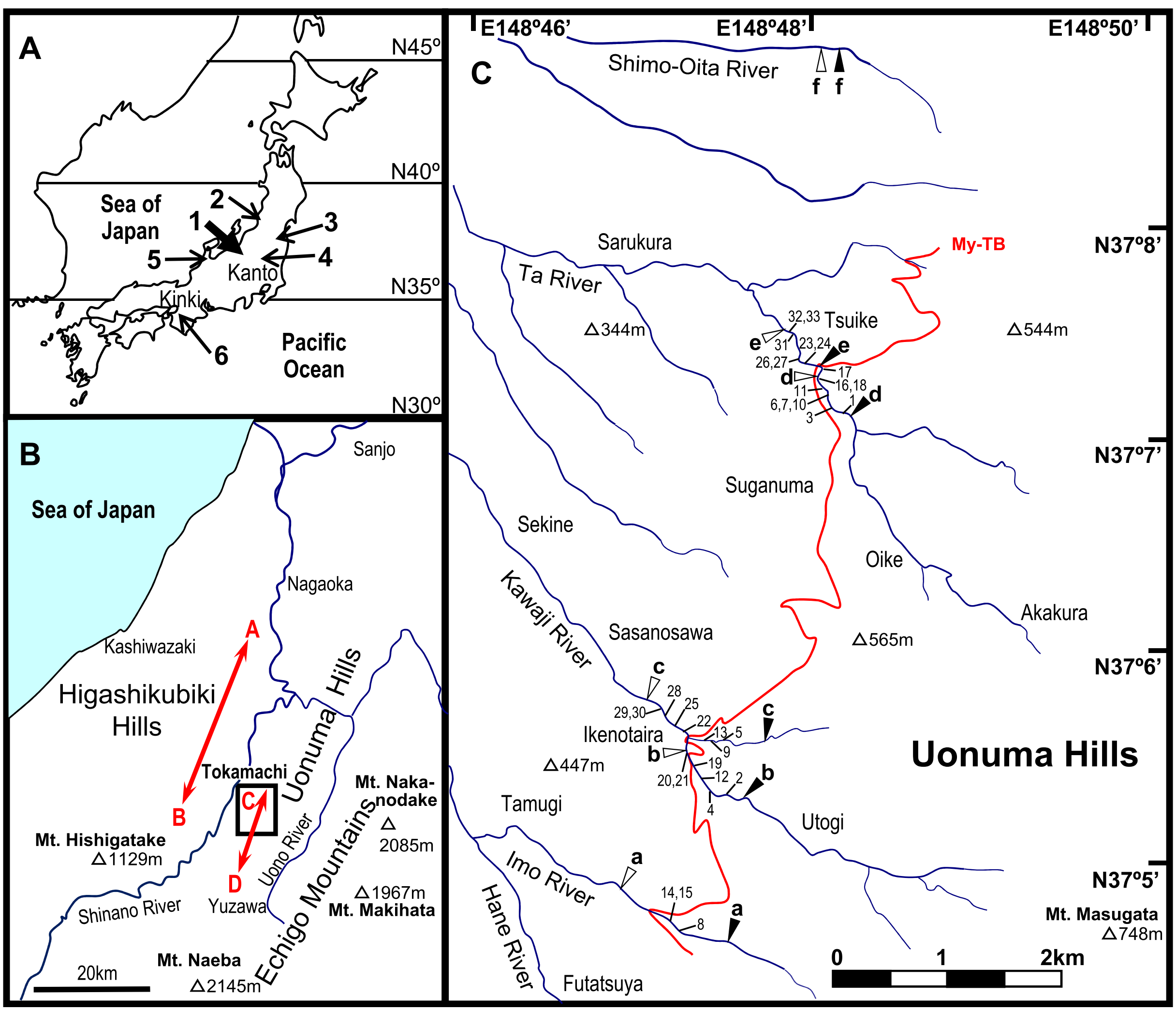

Fig. 1. Locations of Early Pleistocene plant fossil sites in the Uonuma Group, central Japan. A. Map indicating the location of the study site and other fossil localities mentioned in this paper. 1, Uonuma Group (study site); 2, Murakami; 3, Toyano; 4, Harabun; 5, Omma Formation; 6, Osaka Group and Shobudani Formation. B. Map around the study site showing the position of chronostratigraphic chart of the Uonuma Group in the Higashikubiki Hills (A–B) and Uonuma Hills (C–D) in Fig. 5. The rectangle indicates the area in Fig. 1C. C. Map indicating the positions of Sections a–f and fossil sampling sites no. 1–33 described in Fig. 2. Open wedge, top of the section; closed wedge, base of the section. The red line indicates the distribution of the Myogayama tuff breccia. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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