

Construction of tree-ring cellulose oxygen isotope chronology in central Japan during last millennium

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<<Introduction>> So far, most of high-resolution paleoclimate reconstructions in Japan have been restricted after 17th century and climate changes in Middle Age of Japan (11-16th centuries) have not been clarified well although numerous famines and warfare occurred at that time. Because tree ring samples can be recovered even from the Middle Age as old architectural wood and excavated archaeological wood, we may create millennium scale of tree-ring chronologies including the Middle Age. In this study, we focus on the tree-ring cellulose oxygen isotope ratios which demonstrate similar inter-annual variations among different species and individuals, reflecting summer hydroclimate. We construct nearly millennium length of its chronology in central Japan and discuss its chronological, climatological and historical significances.

<<Material and Methods>> In this study, we analyzed three wood samples. (1) Cypress tree cut in 1960s at Nakatsugawa, Gifu (810 rings, Nagoya University Museum), (2) Cedar tree collapsed in October, 2009 at Ise, Mie (481 rings, Ise-Jingu Shrine), (3) Cypress old architectural wood at Okuwa, Nagano (351 rings, Chiko-Ji Temple). Each wood sample was cut into 1mm thickness of thin plates and directly applied for chemical treatments for cellulose extraction. After separation of each year ring under binocular microscope using a design knife, the cellulose fragment was wrapped by Ag foil in duplicate for each year ring and applied for oxygen isotope measurement using TCEA/IRMS (Xu et al., 2011). Among the three samples analyzed, the radiocarbon measurements of sample (3) have revealed that it was living during 11-14th centuries. Although we have known the felling years of sample (1) and (2), those samples were applied for cross dating together with sample (3) by comparison of their tree-ring cellulose oxygen isotope time-series with those of a cedar tree at Uda, Nara and two cypress trees at Agematsu, Nagano whose calendar years have been fixed by traditional dendrochronological methods as 1611-1756 AD (Yamaguchi et al., 2010) and 1730-2005 (Nakatsuka, 2010), respectively.

<<Results and Discussions>> First, we compared the data from sample (1) with those of cedar at Uda, Nara and cypress at Agematsu, Nagano and found very good matching periods ($r=0.62$ ($p=9.98 \times 10^{-12}$) and $r=0.57$ ($p=7.22 \times 10^{-14}$)), indicating that sample (1) corresponds to the period from 1121 to 1930 AD. Second, we made the isotopic time-series of sample (2) overlap those of sample (1) and cedar at Uda, Nara, resulting in highly matching periods ($r=0.44$ ($p=1.23 \times 10^{-10}$) and $r=0.57$ ($p=7.89 \times 10^{-11}$)), and confirmed that the innermost ring of sample (2) corresponds to 1529 AD. Third, the living period of sample (3) was determined by comparison of its oxygen isotope time-series with those of sample (1) ($r=0.66$ ($p=3.14 \times 10^{-22}$)), so that it covers from 1034 to 1384 AD which coincides with the ¹⁴C age. The high correlations of tree-ring oxygen isotope time-series among all different species and locations not only suggest that the time-series reflect past summer hydroclimate but also indicate an fact that the time-series of tree-ring oxygen isotope ratios from 11th to 20th centuries can be applied for annually resolved dating of any wood samples of any species from last millennium in central Japan.

The time-series of tree-ring oxygen isotope ratios of sample (1) shows large variability with 50-120 yrs periodicities during 12-16th centuries, suggesting the potential linkage between climate changes and social upheaval during the Middle Age in Japan. The multi-decadal variations during 13-14th centuries coincide well with those of oxygen isotope time-series of stalagmite in China and India (Zhang et al., 2008; Berkelhammer et al., 2010), indicating that the large variability of tree-ring oxygen isotope ratios in central Japan reflects the variations of summer monsoon activity, covering all over Asia including Japan, China and India.

Keywords: tree ring, cellulose, oxygen isotope, dating, central Japan, middle age