Oxygen isotope dendrochronology-Its principle, challenge and future-

*Takeshi Nakatsuka[1]

1. Nagoya University

Dendrochronology is one the most accurate dating method in archaeology, and utilized over the world for wood dating and climate reconstruction. It is based on the fact that variations in tree-ring width are similar between individual tees of a same species in a region influenced by a common climatic condition. However, in warm and humid regions like Japan where numerous species of trees are growing densely in the forest, its application has been limited to some long-living conifer like Japanese cedar and cypress because of following reasons. First, it is impossible to construct master chronology of tree-ring width for all species. Second, variation in tree-ring width are not very similar there between individual trees due to competition with neighboring trees. In contrast, oxygen isotope ratio ($\delta^{18}O$) of tree-ring cellulose can be used for dating irrespective of tree species because it reflects purely meteorological conditions and its master chronology made of long-living species can be applied to other species including short-living broad-leaf trees. During last decade, many analytical techniques have been invented to promote its application along with the extension of the master chronologies over Japan.

The high inter-tree correlations of tree-ring $\delta^{18}O$ are due to the fact that only two meteorological factors, precipitation $\delta^{18}O$ and relative humidity, determine water $\delta^{18}O$ in leaf where raw material of cellulose is produced, and by this mechanism, it becomes a good proxy of summer climate, important for understanding climate-society relationship in the past. In order to promote wood dating and climate reconstruction, it is necessary to establish master chronologies of tree-ring $\delta^{18}O$ as long as possible in many regions. So far, they have been extended to about 5,000 years ago over Japan, and successfully applied to date excavated wooden artifacts and old architectural woods from various areas and periods. During the process, various analytical methods have been developed to extract tree-ring cellulose from highly degraded excavated woods quickly and safely for successful dating of many archaeological samples such as rice paddy piles, waterway boards and pit dwelling pillars. However, there have remained big challenges like reconstructing of long-term climate variation and dating of numerous small woods with small ring numbers.

Tree rings generally record past climate in annual resolution, while centennial or millennial variations are more useful for archaeological studies. However, it was not easy to reconstruct long-term climate variation by tree ring because biological age trends in tree rings usually interfere long-term climate signals. Recently, a novel method to reconstruct past climate seamlessly from annual to millennial scales has been developed by integrating tree-ring oxygen and hydrogen isotope ratios (Nakatsuka et al., 2020: https://doi.org/10.5194/cp-2020-6). On the other hand, cellulose isotope ratios are being measured at intra-ring levels to clarify seasonal (spring-summer) climate variations. The intra-ring database are now created not only for modern period but also for late Yayoi and early Kofun periods because seasonal signals of isotope ratios may be useful to date small excavated woods with about 10 tree rings.

What is the ultimate goal of oxygen isotope dendrochronology? In addition to wood dating and climate reconstruction, one of the biggest contributions to archaeology must be the quantitative assessment of human activities in pre-historical era. Traditional pottery-based relative chronology in Japan cannot give us quantitative index like “pottery productivity per year”. But, tree-ring $\delta^{18}O$ can make yearly histograms of excavated wooden artifacts in a region which reflect past variations of human activity quantitatively. By comparing the data with climate variations, it is possible to elucidate in detail how climate variations did or did not influence human societies in the past.

Keywords: tree ring, oxygen isotope ratio, cellulose, dating, Paleoclimatology, excavated wood

