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Application of oxygen isotopic dendrochronology to Earth Science: Its potentials and challenges

NAKATSUKA, Takeshi[1*]

[1]Research Institute for Humanity and Nature

<Introduction>

Dendrochronology has been mainly used in archaeology, but also applied to Earth Science, such as dating of past earthquake and volcanic eruption by analyzing of woods excavated from landslide or pyroclastic layers. However, there are several challenges in previous dendrochronology. (1) It is necessary to establish regional standard ring width chronology (master chronology) as long as possible for dating of woods from various periods. (2) Because climate sensitivity of tree-ring width depends on tree species, it is necessary to make master chronology for each species separately. (3) To fix accurate years of geological events, it is necessary to analyze buried woods with bark. In this presentation, I will show how oxygen isotope ratios in tree-ring cellulose can solve those challenges for applying dendrochronology to Earth Science.

<Problems in Traditional Dendrochronology>

There are several difficulties in traditional ring width dendrochronology. (1) Although there are some very long ring width chronologies of more than 10,000 years in the world, they are usually established in cold regions where ice sheet covered in glacial periods, so that it is impossible to extend the chronology beyond last glacial maximum. In Japan, woods can be often excavated in glacial layers, but ecological disturbance to tree-ring width owing to the high tree density in Japanese forest usually makes it difficult to cross-date old excavated logs so that longest ring width chronology in Japan is limited to about 3,000 years made of conifer only. (2) Most wood samples of various hardwoods cannot be dated by traditional dendrochronology in Japan because there are not tree-ring width chronologies made of hardwood. (3) Small logs with barks cannot be dated by comparison of ring width time-series due to less statistical reliability owing to small ring numbers.]

<Characteristics of oxygen isotopic dendrochronology>

Recently developed oxygen isotopic dendrochronology has following advantages and disadvantages. One of disadvantages is that it is much more time-consuming and labor intensive to measure tree-ring oxygen isotope ratios than tree-ring width. Another disadvantage is that it cannot be applied to highly degraded wood which has lost cellulose by microbial decomposition in sediment. The latter problem limits the applicability of oxygen isotopic dendrochronology to many geological and archaeological samples. On the other hand, there are several merits. Because tree-ring cellulose oxygen isotopic ratio reflects only two meteorological parameters (precipitation isotope ratios and relative humidity during growing season), its inter-annual time-series coincides very well with that in different trees of different species. Besides, its inter-annual variation correlates well with summer precipitation, making good paleo-precipitation proxy. Moreover, records on seasonal precipitation can be reconstructed by slicing of year ring and analyzing oxygen isotope ratios.

<Applicability of oxygen isotope dendrochronology to Earth Science>

By utilizing those merits of tree-ring cellulose oxygen isotope ratios, three challenges mentioned above can be solved as follows. (1) The high correlation of oxygen isotope ratio time-series between different tree individuals makes it possible to cross-date several millennia old excavated logs precisely (now the oxygen isotopic chronology has extended to 4300 years ago in Japan), so that systematic excavation of old logs may establish very long tree-ring chronology over last glacial maximum soon in Japan. (2) Because of its universality over tree-species, various wood samples in sediment layers, indicating of past earthquake and/or volcanic events, can be dated by oxygen isotope dendrochronology. (3) In combination with radiocarbon measurement, small log with bark, which has only 5-10 year rings, can be dated by referring database of intra-ring oxygen isotope ratios in the near future.

Keywords: tree ring, cellulose, oxygen isotope ratio, dendrochronology