Wiggle-match dating of tree rings and its application to geochronology

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1. 14C age and calendar date

Radiocarbon (14C) dating is based on present concentration of 14C atom which was incorporated into a sample together with stable carbon isotopes, 12C and 13C, at the time of its formation. The production rate of 14C has been changed due to modulations of intensity of cosmic rays coming into atmosphere, by temporal variations of geomagnetic intensity and solar activities. The fluctuations of 14C abundance in the atmosphere have been revealed by using annual rings of trees, which have preserved atmospheric CO2 in the past by carbon fixation through photosynthesis. Up to now, 14C variations in atmospheric CO2 have been established for nearly 12,400 yr by using annual rings of huge trees collected from some limited areas in the world. The 14C variation records are extremely important now to translate 14C ages measured for geological and archeological samples to calendar dates. For the translation, normally named as calibration, of the temporal scale, IntCal98 (Stuiver et al. 1998) or IntCal04 (Reimer et al. 2004) data sets are used widely. Recently, most of 14C ages for archeological and geological samples are calibrated to calendar years for chronological discussion, in particular for those with calibrated ages younger than 26,000 cal BP.

2. 14C wiggle matching

A 14C wiggle matching normally use 14C ages of more than several annual rings of a sample tree. As described above, radiocarbon community possesses internationally accepted data sets that describe a general relation between 14C ages and tree ring ages, known as IntCal98 and IntCal04. Taking account of the age gaps of successive 14C-analyzed rings of a sample tree, the respective sample 14C ages are compared with the ones of the IntCal98 or IntCal04 calibration data set, by shifting the annual ring number on the calibrated age axis, and finally the calendar age of the outer most ring of the wood is dtermined. Up to now, 14C wiggle matching has been applied to determine accurate ages of tree woods for the studies on volcanology, archeology and cultural-property sciences.

3. Application of 14C wiggle matching

As an example of 14C wiggle matching applications, a charred wood trunk collected from a pyroclastic flow deposit produced in the 10th century on the foot of Baitoushan Volcano, locating on the border between North Korea and the People’s Republic of China, was analyzed. The ash layer from volcanic fall accompanied by the deposit is recognized clearly in the northern part of Japan and denoted as B-Tm (Baitoushan-Tomakomai) tephra. A wood sample collected from Baitoushan Volcano in 2001 with 102 annual rings, was used for 14C dating. The annual rings were divided into 82 pieces.

The 35 charcoal annual-ring samples were processed by acid-alkali-acid treatments and converted to graphite in a routine method. The 14C, 13C and 12C were measured with a HVEE Tandetron at Nagoya University. The obtained 14C dates were compared with the IntCal98 14C calibration data by wiggle matching. We obtained a probability distribution of one clear peak that corresponded to the time when the outermost ring was grown most probably in 935 cal AD, with uncertainty of +8 and -5 yr for 95% confidence.