

RADIOCARBON DATING AT THE INTERNATIONAL RESEARCH CENTER FOR JAPANESE STUDIES

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At the International Research Center for Japanese Studies, a conventional radiocarbon laboratory using a liquid scintillation spectrometer, LKB-Wallac 1220 Quantulus has been operating in full since 1993. By the summer of 1996, we had performed more than 300 measurements of samples concerned with paleoenvironmental reconstructions and archaeological researches. Our laboratory code is JAS (International Research Center for Japanese Studies). This is a short summary concerning experimental procedures for radiocarbon dating and our major research projects.

Key words: CONVENTIONAL C14 METHOD, LIQUID SCINTILLATION, JAS.

INTRODUCTION

Libby (1952) established the basic principles and techniques of the radiocarbon dating method. It had a major impact on archaeology, in particular on pre-history, since the lack of written records has left much to conjecture. Recently the application of the radiocarbon dating method has expanded extensively into several research fields such as recent environmental assessments and terrestrial and oceanic paleoenvironmental researches, biochemical researches, and Quaternary geology.

In 1991, a low background liquid scintillation spectrometer (LKB Wallac Quantulus 1200 model) was installed at the International Research Center for Japanese Studies. That is, a full computer-controllable, low background liquid scintillation spectrometer with an enhanced accuracy of low level counting for radiocarbon as well as other radioisotopes (^3H , ^{32}S , ^{35}S , ^{45}Ca , ^{125}I , etc.).

Using the scrutinized liquid scintillation spectrometer, we have carried out the radiocarbon dating of more than 300 samples, including approximately 100 samples of international and laboratory secondary standards and several types of background materials. The radiocarbon dating samples consist of woods, shells and paleo-soils from the core sediments of lakes, lowlands and archaeological excavations in Japan and middle east Asia (Fig. 1).

Here, I will report on the present

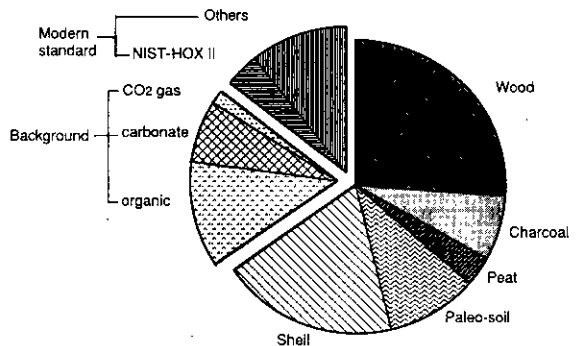


Fig. 1. The diagram indicates the sample materials handled by the JAS radiocarbon laboratory during the first 3 years. The total number of samples is about 300.

achievements of radiocarbon dating, including the limit of dating range and stability of the radiocarbon age determinations as well as our sample handling procedures.

JAS Radiocarbon dating method LKB-Wallac Quantulus-1220 liquid scintillation spectrometer

The LKB-Wallac Quantulus-1220 liquid scintillation spectrometer enhances the accuracy and reproducibility of low level counting of radiocarbon, and enables us to optimize the counting conditions. This is achieved by 1) optimized design for background reduction by passive shield of 630 kg low background lead, cadmium, and copper, and active shield by asymmetric liquid scintillation guard, 2) measurements based on multiple multichannel analyzer technology, 3) automatic random exchanges for maximum 60 samples, and 4) electronic noise suppression, high capacity of personal computer for storage and post assay validation and optimization.

The LKB-Wallac Quantulus-1220 is one of the most popular liquid scintillation spectrometers for high precision radiocarbon dating. The determinable age limit of radiocarbon age is as old as 60 ka BP. The excellent sample preparation makes it possible to determine radiocarbon ages within an uncertainty of ± 20 years.

Pretreatment

The form and the intensity of pretreatment depends on the type, quality and quantity of samples. Each sample was carefully examined to avoid contamination: plant roots were removed, pieces of charcoal were hand-picked or sieved out of the soil and the outer layer of bones, wood and shell was removed mechanically and chemically. The treatment is described for the six types of materials which we dealt with most frequently and which were likely to be contaminated. The standard method used at the International Research Center for Japanese Studies is as follows.

1. Wood

Fossil wood is the most suitable for radiocarbon dating. Recent wood consists of various fractions: resin, sugar, lipids, hemicellulose, lignin (about 30 %) and cellulose (70 %). It is well known that the latter two are most suitable compounds for radiocarbon dating. The others are more or less soluble and mobile, and may infiltrate rapidly into tree and wood samples from the surrounding sediments. Fig. 2 shows our routine treatment procedure for wood samples, which was a method reported by Olsson (1980) and Mook and Strenman (1983). This method is referred to the AAA (Acid-Alkali-Acid) treatment. The overall yield after AAA treatment is 40-50 %, depending on the ages. The final carbon content after AAA treatment is about 50 %. For ^{14}C calibration work on tree-ring, and high precision

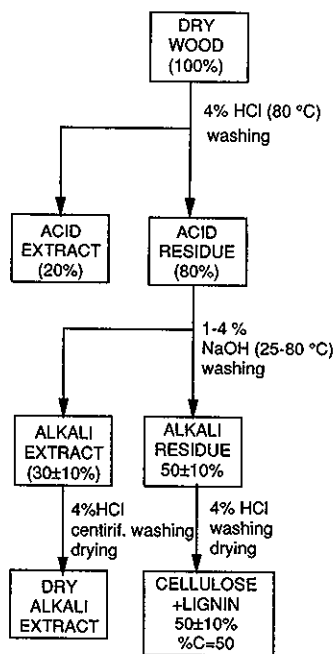


Fig. 2. The scheme shows the chemical treatments on wood and charcoal samples for ^{14}C dating (AAA treatment).

radiocarbon dating based on a wiggle matching which are used for multiple data to be matched to a radiocarbon calibration curve (Ferguson *et al.*, 1966; Pearson, 1986), tree samples were prepared to pure cellulose. In that case, the final yield of cellulose is as small as 25 to 40 %, compared with about 50 % of the yield after AAA treatment. A number of steps are involved in the procedure of the extraction of pure cellulose (Kitagawa and Wada, 1993; Kitagawa and Matsumoto, 1993; 1995). The subcomponents; resin, lipid pectin, etc. were first removed with a benzene/ethanol mixture using soxhlet extrector, and followed by repeated delignification with sodium chlorite, NaClO_2 , in acetic acid solution at 60-80 °C. Finally, the alkali (17.5 % NaOH or KOH solution) at room temperature was applied to delignification residue and then pure cellulose (α -cellulose) was extracted. The extracted cellulose was treated with diluted HCl solution at 80°C for several hours to remove the CO_2 which was absorbed during the alkali treatment.

2. Charcoal

Charcoal samples are as popular as wood samples in archaeological reserach. After physical removal of roots, clay, sand, etc. by hand picking and sieving, charcoal is subjected to the same procedure as wood (AAA treatment). The concentration of the alkali solution (KOH or NaOH solution) is 0.1 to 1 %, depending on the age and the sample quantity. The final carbon content of charcoal is about 70 % which indicated nearly complete removal of contamination. The ash content was generally below 5 % when the sand and clay were effectively removed.

3. Peat

Recent peat is a mixture of lignite, resins, carbohydrates, lipids and cellulose. During the decomposition of peat, several kinds of organic compounds are formed. Groups of compounds are distinguished on the basis of their solubility in acid or alkali solutions. The most stable chemicals are fulvic acid, humic acid and humine. The former two are more mobile in ground water. The precipitation of the mobile fractions in lower stratigraphical layers causes an apparent rejuvenation of ^{14}C samples in this layer.

The pretreatment of peat samples for radiocarbon dating consists of the removal of sand and clay and younger roots, followed by some chemical extraction depending on the age and the state of preservation (Fig. 3).

The carbon content of peat after mechanical and chemical pretreatments is roughly 50 %, depending on the clay and sand contents. Contamination by younger roots is a serious problem because they could not be distinguished from the original peat constituents in the laboratory. However in the field, recent roots are often clearly visible because of their white appearance.

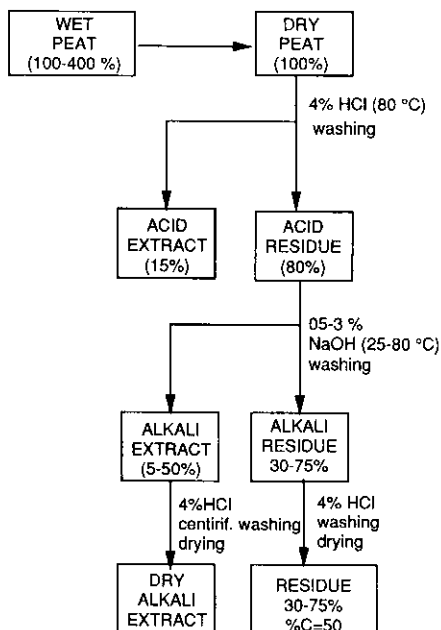


Fig. 3. The scheme shows the chemical treatments on peat samples for ^{14}C dating.

4. Organic deposits

Soil containing organic matter, in which no plant remains are recognized, consists mainly of fluvic and humic acid and humine. However, it is extremely difficult to obtain meaningful ages from that type of sample because the origins of these organic materials are unknown. Fig. 4 shows our general pretreatment method for organic deposits. Generally, alkali extracts give a minimum age.

5. Shells

The outer layer of shells may contain secondary carbonate precipitation in the soil. The carbonate is removed by rinsing with a diluted HCl solution with about 30 % sample loss. The samples were subsequently heated in water at 90 °C overnight to remove organic materials.

6. Bones and charred bones

Bones and charred bones can be related strongly with the age of archaeological events. Animal bones contain both inorganic and organic carbon. Hydroxyapatite ($\text{Ca}_5(\text{PO}_4)_2\text{Ca}(\text{OH})_2$) and calcium carbonate are the source of inorganic carbon. It is known that carbon permeability in groundwater carbonate as well as the precipitation of secondary carbonate renders it completely unsuitable for radiocarbon dating.

The organic bone matrix, i.e., collagen, is a complex of amino acids, which is remarkably resistant to high temperature and soil acid, although in (sub-) tropical soils, bones decompose more rapidly through bacterial actions. The extraction is essential according to Longin (1970)(see also Olssen *et al.*, 1974 in detail). At present, the extraction system of collagen from bone and charred bone samples for radiocarbon dating is in preparation.

In charred bones, the contribution of charred collagen to the total carbon is very low (about 0.5 to 3 %). This increases the effect of a possible humic contamination on the ^{14}C age. The chemical treatment is somewhat different from that described for uncharred bone. The charred bone was treated with a 10 % HCl solution at 80 °C to dissolve the phosphate, carbonate and soluble contamination, and then with a 1 to 3 % alkali solution at 20 to 80 °C, depending on the quantity of available sample. In general, both the residue after alkali treatment and alkali extract are dated.

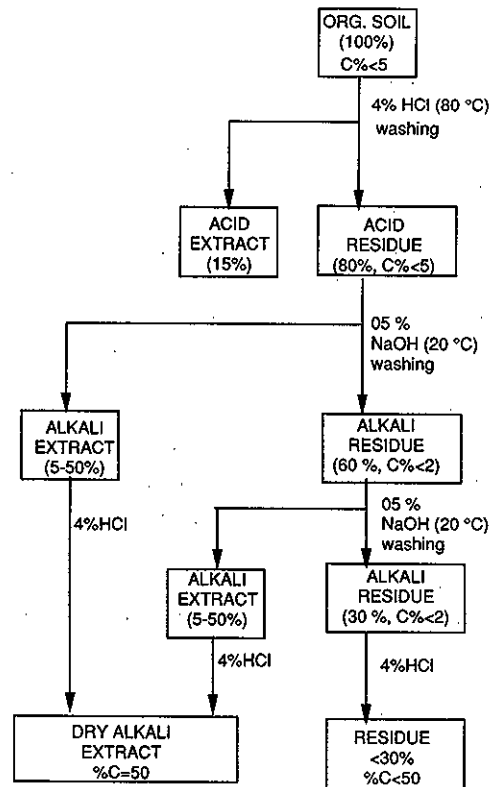


Fig. 4. The scheme shows the chemical treatments on organic deposits for ^{14}C dating.

Methanol synthesis

For radiocarbon measurements using β counting by the liquid scintillation method, carbon is

chemically converted to a suitable form. Generally, CO₂ from samples is converted to benzene, resulting in precise ¹⁴C measurements (*e.g.* ANU, 1985). However, the synthetic process seems to be rather complex and time consuming. It is difficult to convert a large number of samples in a short time. In our laboratory, the carbon in samples has been converted to methanol as the final product for β counting by the liquid scintillation spectrometry because of the quicker conversions.

CO₂ from samples was converted to methanol by the relatively simple reactions outlined by Nystrom *et al.* (1948).



where R is butyl carbitol.

The methanol synthetic method shown in Equation (1) and (2) for radiocarbon dating was initially reported by Yamada *et al.* (1966). The combustion of organic matters is carried out by the flow system of pure oxygen. The CO₂ and other impurities are liberated during the combustion of organic samples by passing through purification traps which consist of AgNO₃ solution, H₂SO₄ with K₂Cr₂O₇ and silicagel. The purified CO₂ with O₂ as a carrier gas passes through a mixture of lithium aluminum hydride (LiAlH₄) and diethyl carbitol which is cooled down to 0 °C, and then butyl carbitol is added slowly after the combustion was completed. The methanol is extracted from the mixture by means of a general distillation method. CO₂ in carbonate materials from shells and corals and calcretes is liberated using diluted HCl and is introduced directly to a mixture of LiAlH₄ and diethyl carbitol with Helium carrier gas. Usually 1 mol of carbon, 1 mol of LiAlH₄, 750 ml of diethyl carbitol and 500 ml of butyl carbitol were used in this process. The processing time was typically 2 hours for methanol synthesis including combustion of organic matters or decomposition of carbonate, and about 1 hour for methanol distillation.

Scintillation cocktail and setting of liquid scintillation spectrometer

The mixture of 10 ml of methanol and 0.1 g of butyl-PDB (b-PDB) in 10-ml xylene is placed in a 20 ml 6 Cu-Teflon. The maximum sample weight is 8 g methanol, corresponding to about 3 g of carbon. The radiocarbon window of the LKB-Wallac Quantulus 1220 liquid scintillation spectrometer for a radiocarbon dating was determined by the highest figure of merit (FM=A_{MOD}√B) of both modern activity A_(MOD) and background activity (B). The optimal window for counting of ¹⁴C is 40-400 channel of the width of 361 channel (FM=25). The net ¹⁴C activity is 25.40 counts per minute (cpm) for modern standard of NIST-HOxII (SRM 4990C) and 1.03 cpm for the reference background methanol without ¹⁴C.

In the general procedure for measuring ¹⁴C at our laboratory, 11 vials consisting of 7 samples, 1 blank sample (synthesized from bituminous or limestone), 1 reference blank of a commercial methanol (Wako Ltd.) and 2 glass-sealed modern standard calibrated by the NIST HOxII international standard are measured at the same measurement run. For the calculation of radiocarbon ages, the ¹⁴C activities of the modern reference standard and blank samples are

calculated based on the weight mean of ^{14}C counts of two 2 glass-sealed modern standards and 1 blank sample synthesized from background material, respectively. One reference blank is used to assess both the condition of the liquid scintillation spectrometer and the contribution of contamination during the methanol synthesis, being compared with the blank sample synthesized.

Age and its error calculation

Radiocarbon age is subjected to a number of agreements and assumptions (Stuiver and Polach, 1977): 1) The natural ^{14}C activity of living organic matters has always been equal to the activity defined by the NBS oxalic acid, 2) The half-life of ^{14}C is 5568 years, 3) Calculated ages are always set prior to AD 1950 and are reported as BP and 4) The measured activity has to be corrected for isotope fractionations.

According to these assumptions and agreements, the radiocarbon data are calculated as follows. Calculated sample ages are denoted by T (time elapsed before AD 1950)

$$T = -\frac{T_{1/2}}{\ln 2} \ln A/A_0 \quad (3)$$

where $T_{1/2}/\ln 2 = 8033$ years, the mean life time of ^{14}C , and A and A_0 is the net activity of a sample and a standard material, respectively. A_0 is defined by the international reference standard for ^{14}C (NIST-HOxI or HOxII).

Because radioactive decay is a random process, repeated measurements of the same samples under similar conditions will not give the same result. Uncertainty in a measured activity is given by the standard deviation (σ). The chance of the true activity between $A + \sigma$ and $A - \sigma$ is 68 % and between $A + 2\sigma$ and $A - 2\sigma$ is 95 %. The standard deviation for counts, N, during a counting time (t_c) is \sqrt{N} . The standard deviation (σ_N) in the sample activity per time unit (minute) is:

$$\sigma_N = \frac{1}{t_c} \sqrt{N} \quad (4)$$

The standard deviation in the net ^{14}C counting rate A, σ_A , is

$$\sigma_A = \sqrt{\sigma_N + \sigma_B} \quad (5)$$

The standard deviation in the ages is calculated from the ^{14}C counting rate of $A - \sigma_A$ and $A + \sigma_A$, corresponding to $-8033 \ln(1 \pm \sigma_A/A)$.

When more than one radiocarbon measurement was made on a single sample, these replicated results are combined. In order to calculate the average value, the radiocarbon ages ($T_i \pm \sigma_{T_i}$) were converted separately into ^{14}C activity ($a_i^{14} \pm \sigma_{a_i}$).

$$a_i^{14} = e^{-T_i/8033} \quad (6)$$

$$\sigma_{a_i} = a_i^{14} (1 - e^{-\sigma_{T_i}/8033}) \quad (7)$$

The average activity (a^{14}) and its standard deviation (σ) of the sample are:

$$a^{14} = \frac{\sum_i a_i^{14} / \sigma_{ai}^2}{\sum_i 1 / \sigma_{ai}^2} \quad (8)$$

$$\sigma = \frac{1}{\sqrt{\sum_i 1 / \sigma_{ai}^2}} \quad (9)$$

The average age (T) is obtained by:

$$T = -8033 \ln a^{14}/100 \mp -8033 \ln (1 \pm \sigma / a^{14}) \quad (10)$$

JAS radiocarbon dating limit

For samples with low activity such as very old and small-sized samples, the counting rate cannot be distinguished from the background (^{14}C free). By the internationally accepted convention, the low-activity limit is taken as $A=2\sigma_A$. If $A>2\sigma_A$, the chance of a zero true activity is smaller than 2.5 % (Walanus and Pazdur, 1980). If $A>2\sigma_A$, we merely conclude that the activity is smaller than $A+2\sigma_A$ (97.5 % probability). For those low activities, age limits and sample size limits as a function of the age are calculated as follows:

$$T > -8033 \ln (A+2\sigma_A)/A_0 \quad (11)$$

or

$$T > -8033 \ln [(a^{14}+2\sigma_A)/100] \text{ years BP} \quad (12)$$

The age limit (Tmax) is then calculated from:

$$A_{\min} = 2\sigma_B B = 2\sqrt{\frac{B}{t_c}} \quad (13)$$

$$T_{\max} = 8033 \left[\ln 1/2 \sqrt{t_c} \times \frac{A_0}{\sqrt{B}} \right] \quad (14)$$

From these relations, it is obvious that the age limit is higher for lower background and longer time. Fig. 5 shows age limit as a function of sample size (counting time is 2000 min., background of 1.03 cpm). The age limit depends on carbon amounts contained in dated samples. In 2000 min. of our general counting time, we can determine the age of very old samples, ca. 50,000 years BP., with 3g. In the case of older samples, we have also changed the counting time because, if a sample counting time is increased by 4ⁿ, the age limit is shifted by n half-life (=n x 5568).

For small samples (F times too small), the limit of ^{14}C dating is decreased by:

$$T_{\max} = 8033 \ln \left[1/2 \sqrt{t_c} \times \frac{A_0}{\sqrt{B}} \times \frac{1}{F} \right] \quad (15)$$

When we determine the radiocarbon age of small-sized samples, we count the sample for a longer time.

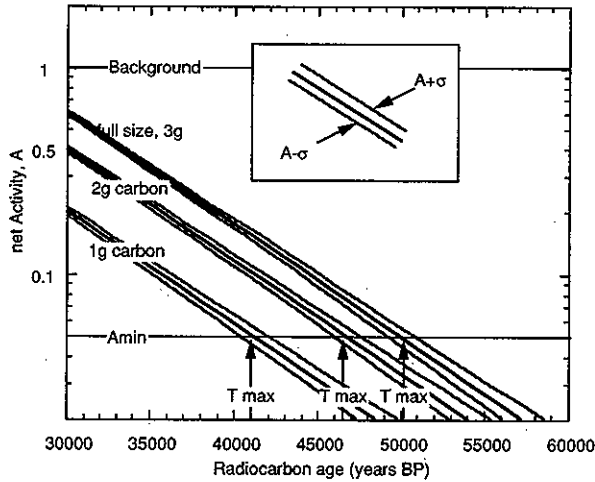


Fig. 5. Semi-logarithmic plot of the decreasing ^{14}C activity in time. The dating limit, T_{max} , is defined for a minimum measured, 2σ .

Correction of isotope fractionation

In the calculation of an radiocarbon age, a correction of isotopic fractionation must be applied. The isotopic fractionation is defined as the relative difference in the isotope ratios between the two compounds:

$$\epsilon^{13} = \left(\frac{(^{13}\text{C}/^{12}\text{C})_{\text{sample}}}{(^{13}\text{C}/^{12}\text{C})_{\text{reference}}} - 1 \right) \times 10^3 \text{ (‰)} \quad (16)$$

Similarity of isotope ratios ($^{13}\text{C}/^{12}\text{C}$) is presented as a relative deviation from the standard ratio. The values are generally quoted in per mil (‰). The internationally agreed standard for carbon isotope is PDB, carbonate from a belemnite collected in the North America PeeDee formation (Craig, 1957).

$$\delta^{13}\text{C} = \left(\frac{(^{13}\text{C}/^{12}\text{C})_{\text{sample}}}{(^{13}\text{C}/^{12}\text{C})_{\text{PDB}}} - 1 \right) \times 10^3 \text{ (‰)} \quad (17)$$

The equivalent definition for ^{14}C is:

$$\epsilon^{14} = \left(\frac{A^{14}_{\text{sample}}}{A^{14}_{\text{reference}}} - 1 \right) \times 10^3 \text{ (‰)} \quad (18)$$

Between these two ϵ values we have the relation:

$$\epsilon^{14} = 2 \epsilon^{13} \quad (19)$$

This means that the difference of the original ^{14}C content is twice as much as the $\delta^{13}\text{C}$ difference between two samples. Moreover, the same is true for any $\delta^{13}\text{C}$ changes of sample treatments in the laboratory. Consequently, measuring the stable carbon isotope composition takes care of any

isotopic fractionation to which the sample has been subjected by nature or in the laboratory.

The stable carbon isotope ratio ($\delta^{13}\text{C}$ value) of initial samples and the corresponding products of methanol were measured (Fig. 6). Methanol was converted to CO_2 in a evacuated sealed tube with CuO wire. The CO_2 was analyzed by a stable isotope mass spectrometer. Results showed up to +5‰ variable fractionation. The amount of the isotopic fractionation tends to decrease as methanol yields increased. The isotopic fractionation of nearly 200 samples was about 1‰ on average. Therefore in the most cases, we corrected the isotope fractionation based on $\delta^{13}\text{C}$ value of the initial samples and by the internationally accepted definition, so that all the results are normalized at -25‰ for $\delta^{13}\text{C}$.

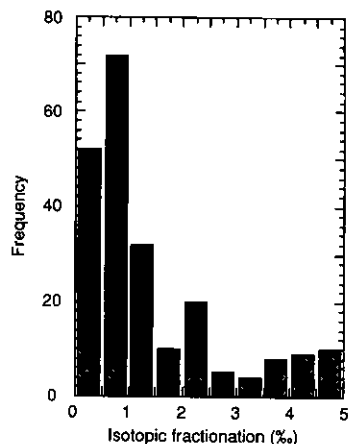


Fig. 6. Isotope fractionation, $\Delta^{13}\text{C}(\text{‰}) = \delta^{13}\text{C}$ (methanol) - $\delta^{13}\text{C}$ (initial) as a function of the distilled fraction.

Accuracy and precision of radiocarbon dating

Table 1 shows the results of three series of samples from coconut charcoal which is the present laboratory secondary standard. Each series was counted for 4000 min. Results show that the standard deviation of the average of series of measurement was equal to the statistical uncertainty, being a level of *ca.* 0.5 ‰, corresponding to an uncertainty of ± 40 years, and systematic error on the determined ($= \sigma/n$, where *n* is number of measurements) and the value is smaller than 0.15 ‰, corresponding to about ± 10 years.

In order to determine reproducibility of our radiocarbon dating, two IAEA intercomparison standards (Rozanski *et al.*, 1992) were measured: C3 (cellulose) and C6 (ANU sucrose). Table 2 shows the ^{14}C activity (^{14}C percentage of modern carbon; pMC) and stable carbon isotope ratio of two IAEA intercomparison standard measurements with the reported values by conventional (proportional gas counting method) and Accelerator Mass Spectrometry (AMS) method at the Groningen University, the Netherlands (Plicht, *et al.* 1995). Our results show an excellent agreement with those of the AMS and the conventional method of the Groningen Radiocarbon laboratory (Table 2). We deduced that there was no difference between the results of two laboratories, and if any, it was as small as 0.1 percent modern carbon (pMC), corresponding to less than 10 years of ^{14}C age.

Series	Fractionation of modern Charcoal/NIST-HOxII			
	Maximum	Minimum	Average $\pm 1\text{s}$ (numbers)	Uncertainty(%)
1	0.7754 \pm 0.7596	0.7596 \pm 0.0054	0.7654 \pm 0.0052(7)	0.68
2	0.7835 \pm 0.0072	0.7691 \pm 0.0046	0.7755 \pm 0.0041(6)	0.53
3	0.7741 \pm 0.0042	0.7621 \pm 0.0066	0.7689 \pm 0.0039(7)	0.51
Average			0.7700 \pm 0.0041(3)	0.53

Table 1. Results of ^{14}C accuracy test.

Sample(material)	International Research Center for Japanese Studies(LS)		Groningen University		
	$\delta^{13}\text{C}(\text{‰})$	^{14}a (pMC)	$\delta^{13}\text{C}(\text{‰})$	Conventional(gas) ^{14}a (pMC)	AMS ^{14}a (pMC)
IAEA-C3(cellulose)	-24.72	129.34 \pm 0.20	-24.68	129.30 \pm 0.12	129.87 \pm 0.48
IAEA-C6(sucrose)	-10.38	150.29 \pm 0.12	-10.38	149.82 \pm 0.06	150.36 \pm 0.41

Table 2. ^{14}C activity (percent modern carbon; pMC) and the stable carbon isotope ratio of two IAEA intercomparison standards with the values measured by conventional (proportional gas counting method) and Accelerator Mass Spectrometry method at the Groningen University

Research projects during the past four years

A major effort of radiocarbon dating at the International Research Center for Japanese Studies was devoted to lake sediment cores and peat deposits collected from various sites in Japan and middle east Asia. The long sediment cores collected from Lake Mikata (Kitagawa *et al.*, in preparation), Kkota lowland and Nakaikemi Moor (Miyamoto *et al.*, 1995, 1996), central Japan, were dated. These results show that the various analyses of those cores make it possible to reveal the detailed environmental changes in Holocene as well as the last glacial period. At present, research on paleoenvironmental reconstruction in Japan is in progress.

We and our collaborators have also been researching the environmental changes in middle east Asia such as Syria and Turkey in relation to the civilization. We carefully dated the more than 40 shell samples from the core samples (Yasuda *et al.*, in preparation) and outcrops (Naruse *et al.*, in preparation). This data is useful in reconstructing the paleoenvironmental changes around middle east Asia, and are important for well-studied archaeological sites. Also, it should be useful to understand the interesting relationship between environmental changes and human events such as deforestation and the beginning of agriculture. These efforts should reveal a relationship between the timing of environmental changes and major cultural events of the middle east Asian civilization.

We have started the radiocarbon dating of archaeological researches in Japan. We plan to construct a high resolution chronology of the Jomon period, covering the 2000 to 12000 years BP. The preliminary results of radiocarbon dating at the Sannai Maruyama site showed that there are major problems in Jomon chronology (Kitagawa, 1995). In order to understand the Jomon culture in relation to environmental changes, we must make an effort to create a valuable and accurate chronology for the Jomon period.

Conclusion and prospects

During the past four years of operation, radiocarbon dating has been mainly used for a variety of paleoenvironmental reconstructions in relation to human activity and fundamental researches for performing the high precision of ^{14}C dating. We have routinely achieved high precision of ^{14}C dating (± 50 years). In the near future, capabilities of the radiocarbon dating at the International Research Center for Japanese Studies will emphasize the following.

1. Sub-automation of sample preparation.
2. Reduction of the relative background level and high effective counting by new methods such as the Benzene counting method.
3. Isolation of suitable (bio/gio) chemical fractions for ^{14}C dating.

4. Database construction containing all relevant radiocarbon dating information and detailed sample descriptions.
5. Inter-laboratory comparison (in progress)

Finally, our radiocarbon laboratory is starting to solve the chronological problems in Japanese prehistory, in particular, in Jomon chronology. Presently collected samples may be the key for the reconstruction of the Jomon chronology. I believe that a reliable Jomon chronology will make it possible to clarify the relationship between environmental changes and the Japanese culture.

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国際日本文化研究センターにおける炭素14年代測定

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要旨：国際日本文化研究センターにおいて、高性能液体シンチレーションカウンター (LKB-Wallac 1220 Quantulus) を用い、炭素14年代測定を行ってきた。1993年以降、過去の環境解析や考古学研究のために、300試料の炭素14年代決定をおこない、その結果は研究室コード JAS を付記し報告してきた。本稿では、我々が行ってきた研究および分析手順の詳細について述べる。