^{14}C DATING ANCIENT JAPANESE DOCUMENTS

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ABSTRACT. We measured radiocarbon ages of 11 pieces of ancient Japanese documents by accelerator mass spectrometry (AMS). The purpose of this study is to compare the relationship between the calibrated ^{14}C age and the historical age of Japanese paper samples. Calibrated ages of nine pieces agree with their historical ages, indicating that Japanese ancient documents can be used for ^{14}C dating in the recent historic period. On the other hand, the ^{14}C age of paper that was used for reinforcement of a sutra is *ca.* 300 yr older than the historical age of the sutra. This shows that the sutra was repaired with old paper.

INTRODUCTION

Radiocarbon dating has provided useful information for archaeological study because it gives an absolute age (after calibration) of the ancient artifact. For age determination of culturally valuable objects, the most advantageous characteristic of AMS is its ability to measure ^{14}C ages for *ca.* 1-mg carbon samples. Because of the historical value, small size, or low carbon content of most cultural objects, there is a limit to the amount of sample submitted for ^{14}C measurement. However, the AMS method has made it possible to date such samples, thus extending the application to valuable cultural objects produced in the recent historic period.

History is a reconstruction of past human activity. This reconstruction is accomplished, in part, by gathering evidence in the form of relics or documents. The historic period is largely clarified with the help of ancient documents. Therefore, the ages of ancient documents determined by scientific methods will provide useful information for studying the historic period. ^{14}C ages should be calibrated to obtain calendar ages, because the atmospheric ^{14}C concentration in the past is a function of time. But even the calibrated age, obtained by projecting the ^{14}C age on the calibration curve, indicates only a period that the sample has been kept in a system closed from the atmosphere. For this reason, the calibrated age can be different from the historical age in which the cultural object existed as a tool. A calibrated age is usually older than an historical age. For example, the calibrated age of a statue made of the central part of a log is older than historical age when the statue was made.

The difference between calibrated age and historical age becomes more serious for more recent samples, usually because a more accurate age is required. It is important to clarify the relation between calendar age and historical age for some sorts of the cultural properties made of wood, bone and paper. This investigation intends to clarify the relation between calibrated age and historical age by AMS ^{14}C measurements of Japanese ancient documents that have known historical ages.

METHODS

Features of the Samples

We used AMS to measure the ^{14}C ages of 11 fragmentary pieces of Japanese ancient documents whose historic ages had been obtained by palaeography. The oldest sample was written during the last part of Heian period or the early part of Kamakura period (roughly corresponding to the 12th

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century AD). The youngest sample was written in the Edo period (17th–19th century AD). The historical ages of the samples are summarized in Table 1. Six samples (Sample no. 1–6) were cut out of the Buddhist sutras, two (No. 7, 8) were cut from scattered pieces of sutras, one (No. 9) was cut from a scroll, one (No. 10) was cut out of paper that was attached to the back of a sutra for reinforcement, and one (No. 11) was cut out of paper that had been made in the later part of this century from the paper used to reinforce the sample No. 10. Four samples (No. 1,2,4,5) feature Chinese characters written with brush and Chinese ink; the other samples have no ink. Each sample with Chinese characters was cut from a part of the margin, avoiding the characters in order to preserve paleographical information, and avoiding contamination by carbon used for writing the characters.

TABLE 1. List of Ancient Documents

Sample no.	Historical period	Feature of original sample
1	Last Heian–early Kamakura period (12th century)	Buddhist sutra, with Chinese characters
2	First Kamakura period (13th century)	Buddhist sutra, with Chinese characters
3	First Kamakura period (not certain) (13th century)	Buddhist sutra, no Chinese characters
4	Early Kamakura period (13th century)	Buddhist sutra, with Chinese characters
5	Nanbokutyou period (latter 14th century)	Buddhist sutra, with Chinese characters
6	Last Nanbokutyou period (last 14th century)	Buddhist sutra, no Chinese characters
7	Last Heian–early Kamakura period (12th–13th century)	Scattered piece of a Buddhist sutra, no Chinese characters
8	Last Heian–early Kamakura period (12th–13th century)	Scattered piece of a Buddhist sutra, no Chinese characters
9	Last Heian–early Kamakura period (12th–13th century)	A scroll with axis, no Chinese characters
10	Edo period (17th–19th century)	Reinforcing paper of a sutra, no Chinese characters
11	Edo period (17th–19th century)	Recycled paper from No. 10 sample, no Chinese characters

Sample Preparation

The paper samples were covered with dust and stained with water from the surroundings. We extracted the alpha-cellulose fraction from the samples. First, the samples were washed with distilled water in a supersonic washer to exclude any possible contamination from the dust. Next we removed adsorbed components by alternating washings with 1.2 M HCl and 1.2 M NaOH solutions, each washing taking *ca.* 2–3 hr. Each treatment was repeated several times, depending on the degree of stain. Cellulose was prepared with a 0.07 M $NaClO_2$ solution under acidic conditions (adjusted with HCl). We repeated this treatment 4 or 5 times. Finally, alpha-cellulose was extracted by soaking at room temperature for *ca.* 30 min in a 17.5% NaOH solution. The alpha-cellulose was combusted to CO_2 at 950°C (using CuO). The CO_2 was purified by successive vacuum trap with liquid N_2, frozen ethyl alcohol and frozen n-pentane. The graphite (to be used for AMS) was prepared by reducing CO_2 with H_2 and Fe as catalyst at 650°C in a sealed Vycor® glass tube (Kitagawa *et al.* 1993).

^{14}C Measurement

The instrument used for this study was the Tandetron AMS at the Dating and Materials Research Center, Nagoya University (Nakamura *et al.* 1985; Nakamura and Nakai 1988). The conventional ^{14}C ages are calculated using measured $^{14}C/^{13}C$ ratios, using standard procedures (Oda 1994). The 1-σ error we used is the square root of unbiased variance of $^{14}C/^{13}C$ ratios obtained by alternative measurements on sample and standard. The $\delta^{13}C$ value used for isotopic fractionation correction was measured by a Finnigan MAT-252 mass spectrometer on the CO_2 gas before graphitization. The ^{14}C age for each sample of the ancient documents was measured 2 to 4 times, in order to improve statistics. The 1-σ error of the averaged ^{14}C ages used here includes a full statistical treatment.

Results and Discussion

Table 2 shows the ^{14}C ages and $\delta^{13}C$ results for the ancient documents. The ^{14}C ages are calibrated using the curves from Stuiver and Pearson (Stuiver and Pearson 1993; Pearson and Stuiver 1993). The calibrated age ranges are shown in Table 2. The calibrated ages of the averaged results are summarized in Figure 1. The calibrated age of the ^{14}C age is plotted as a black circle; the confidence intervals are shown as intermittent error bars. The known historical ages of the documents are shown in Figure 1 as dotted rectangles.

As can be seen in Figure 1, the calibrated ages of ancient documents are in good agreement with their corresponding historical ages, except for samples 2, 10 and 11. Samples 1–9 have different sources, *i.e.*, from a Buddhist sutra, a scattered piece of sutra or a scroll. But their use has been for writing historical information. In Japan, paper has been made mainly from Kouzo (*Broussonetia Kazinoki* Sieb.), a type of deciduous shrub. The trunk grows to *ca.* 4 m in height and *ca.* 2 cm in diameter. Japanese people normally harvested branches of Kouzo that were 3–15 yr old. In addition, new twigs grown under a year old were harvested selectively for manufacturing Japanese paper. (Older twigs yield paper of poor quality.) Because of this selection, there is no "old wood" effect. Such an effect indeed is not apparent in Figure 1, except for sample 2. The calibrated age of this sample is older than the historical age. Although Japanese paper has been normally made from twigs of Kouzo, it is known that there are some kinds of paper manufactured from waste paper. Such recycled paper is called Syukusi or Usuzumigami. Usuzumigami is usually slightly blackish due to incomplete bleaching. It would be possible to consider sample 2 to be recycled paper.

The measured age of sample No. 10 is *ca.* 300 yr too old. This sample had been used to reinforce a sutra by attachment to the back side. If brand-new paper is used for repairing a damaged ancient document, the document will become torn or creased due to the shrinking of the new paper. Therefore, old paper is commonly used for repair to prevent distortion. For this reason, the calibrated ^{14}C age of the reinforcing paper is older than the historical age when the sutra was written.

The calibrated age of sample No. 11 is a little younger than that of sample No. 10. Sample No. 11 was manufactured from sample No. 10 in the later part of this century. The difference in calibrated ages can, therefore, be caused by contamination of modern carbon in manufacturing.

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TABLE 2. Results of ^{14}C Age Measurements on Ancient Japanese Documents

Sample no.		^{14}C age (BP)	$\delta^{13}C$ (‰)	Calibrated age (cal AD)*
1		1000 ± 38	−26.3	1011(1022)1036
		916 ± 41	−26.3	1038(1069,1071,1129,1131,1160)1186
	Average	958 ± 28		1026(1038)1055,1083( )1122,1138( )1157
2		1018 ± 42	−26.0	996(1017)1030
		912 ± 58	−26.0	1032(1161)1216
	Average	965 ± 36		1022(1034)1055,1083( )1122,1138( )1157
3		958 ± 49	−26.1	1020(1038)1163
		869 ± 38	−26.0	1162(1198)1226
		879 ± 43	−26.1	1060( )1079,1125( )1135,1158(1177)1224
	Average	902 ± 25		1054( )1084,1122( )1138,1156(1164)1184
4		744 ± 56	−26.6	1252(1283)1296
		743 ± 44	−26.6	1265(1283)1294
		687 ± 38	−26.5	1287(1296)1305,1366( )1374
		664 ± 68	−26.5	1285(1301)1396
	Average	709 ± 26		1284(1290)1297
5		571 ± 64	−25.5	1308( )1358,1381(1402)1428
		484 ± 56	−25.5	1410(1435)1450
	Average	527 ± 43		1402(1417)1435
6		728 ± 73	−25.5	1252(1286)1304,1370( )1370
		681 ± 46	−25.5	1286(1297)1309,1356( )1383
		446 ± 40	−26.0	1434(1445)1470
		434 ± 83	−26.0	1422(1448)1515,1591( )1621
	Average	571 ± 32		1325( )1336,1394(1402)1411
7		807 ± 35	−26.1	1219(1248)1278
		779 ± 39	−26.1	1228(1276)1285
	Average	793 ± 26		1229(1261)1279
8		740 ± 76	−26.4	1231(1284)1302
		732 ± 30	−26.5	1279(1286)1293
		656 ± 51	−26.5	1291(1303)1325,1335( )1394
		620 ± 65	−26.4	1296(1315,1346,1391)1407
	Average	687 ± 29		1289(1296)1303
9		904 ± 21	−26.0	1057( )1081,1123( )1137,1157(1164)1173
		842 ± 22	−26.0	1206(1221)1232
	Average	873 ± 15		1167(1189)1216
10		551 ± 38	−25.3	1398(1407)1425
		540 ± 66	−25.0	1323( )1338,1394(1410)1437
		534 ± 43	−25.0	1401(1413)1433
		530 ± 42	−25.3	1402(1415)1434
	Average	539 ± 24		1404(1411)1425
11		453 ± 48	−25.6	1430(1443)1471
		403 ± 39	−25.6	1445(1471)1509,1602( )1615
	Average	428 ± 31		1441(1449)1475

*Values in parentheses are the calibrated ages of the mean ^{14}C ages. Values outside parentheses are error ranges.

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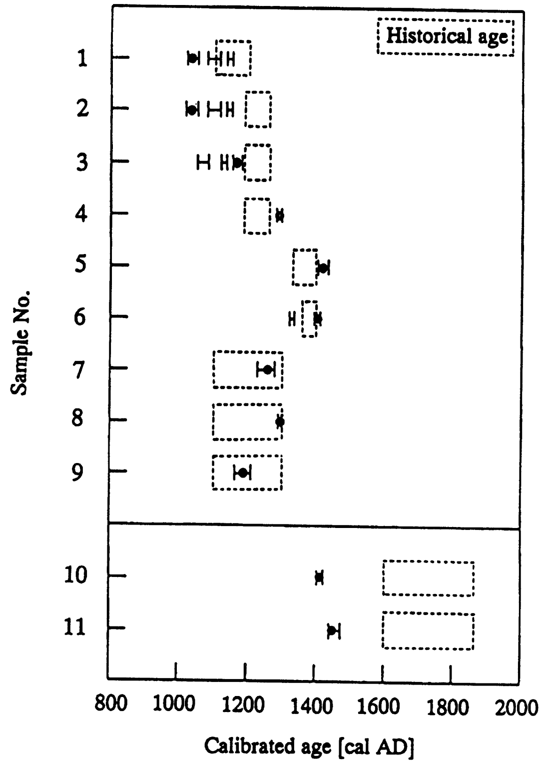

Fig. 1. Comparison of calibrated ^{14}C age and historical age of ancient Japanese documents

Conclusion

We used AMS to measure the ^{14}C ages of ancient Japanese documents and compared the results with known historical ages. We conclude that such documents are suited for ^{14}C age measurement for the recent historic period because of the negligible difference between the calibrated and historical ages.

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