



[Client Services](#)

[Fees](#)

[Turnaround](#)

[Sample Preparation Information](#)

[Online Sample Submission](#)

[Radiocarbon Data & Calculations](#)

[Calculate Fm with a revised ¹³C correction factor](#)

[Calculate ¹⁴C from a given collection year](#)

[General Statement of ¹⁴C](#)

[Procedures](#)

[Research Initiatives](#)

[» NOSAMS General Statement of ¹⁴C Procedures](#)

Process Blanks

Process blanks are radiocarbon-free material that is prepared using the same methods as samples and standards. These blank measurable amounts of ¹⁴C from contamination introduced during chemical preparation, collection or handling. Organic material processing, are limited to younger ages by their corresponding process blank. Due to counting and measurement errors for the errors are higher for very old samples. Thus, ages are limited by the age of the process blanks (more on that below) and by the ¹⁴C measurement.

Blank corrected fraction modern

For large samples, the blank corrected fraction modern (F_m_c) is computed from the expression:

$$F_m_c = F_m - F_m_b \frac{F_m_s - F_m}{F_m_s}$$

Where F_m_b , F_m and F_m_s represent the ¹⁴C/¹²C ratios of the blank, the sample and the modern reference, respectively.

For small samples, blank contribution as a fraction of sample mass becomes a more important term, so a mass balance blank correction is performed as follows:

$$F_m_{mbc} = F_m_{corr} + (F_m_{corr} - F_m_b) \frac{M_b}{(M - M_b)}$$

Where M is sample mass, and M_b and F_m_b are the mass and F_m of the blank.

Fraction Modern is a measurement of the deviation of the ¹⁴C/¹²C ratio of a sample from "Modern." Modern is defined as 95%

Radiocarbon Data & Calculations

In AMS, the filamentous carbon or "graphite" derived from a sample is compressed into a small cavity in an aluminum "target" which acts as a cathode in the ion source. The surface of the graphite is sputtered with heated, ionized cesium. The ions are extracted and accelerated in the AMS system. After acceleration and removal of electrons, the ions are magnetically separated by mass and the ¹²C and ¹³C ions are measured in Faraday Cup. Simultaneously the ¹⁴C ions are recorded in a gas ionization (USAMS) or solid state detector. That ratios of ¹⁴C to ¹³C and ¹²C may be recorded. These are the raw signals that are ultimately used to calculate radiocarbon age.

From a contemporary sample, about 250 ¹⁴C counts per second are collected. It is expected that a 11,140 year old (2 half-lives) sample that 125 or 63 counts per second would be collected. If you simply measure older samples for longer times, there are practical limits to the minimum sample size that can be measured. At the present time, for a 1 milligram sample of graphite, this limiting age is about 50,000 years, if set only by the sample size. However, limiting ages or "backgrounds" are also determined by process blanks which contribute to the ¹⁴C signal.

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the internationally agreed upon definition of 0.95 times the specific activity of OX-I normalized to $\delta^{13}\text{C}_{\text{VPDB}} = -19$ per mil. This 1950) $^{14}\text{C}/^{12}\text{C}$ ratio of $1.176 \pm 0.010 \times 10^{-12}$ (Karlen, et. al., 1968); all results are normalized to -25 per mil using the $\delta^{13}\text{C}_{\text{VPDB}}$. The value used for this correction is specified in the report of final results.

$\delta^{13}\text{C}$ Correction

In addition to loss through decay of radiocarbon, ^{14}C is also affected by natural isotopic fractionation. Fractionation is the term uptake of one isotope with respect to another. While the three carbon isotopes are chemically indistinguishable, lighter ^{12}C atoms are taken up before the ^{13}C atoms in biological pathways. Similarly, ^{13}C atoms are taken up before ^{14}C . The assumption is that the fractionation of ^{14}C is twice that of ^{13}C , reflecting the difference in mass. Fractionation must be corrected for in order to make use of radiocarbon measurements for all parts of the biosphere. In order to remove the effects of isotopic fractionation, the Fraction Modern is then corrected for the original $\delta^{13}\text{C}$ were -25 per mil (the $\delta^{13}\text{C}$ value to which all radiocarbon measurements are normalized.) The fractionation correction is measured by the AMS system. Using this measurement also corrects for any mass-dependent fractionation within the AMS system.

The Fraction Modern corrected for $\delta^{13}\text{C}$, $F_m \delta^{13}\text{C}$,

$$F_m \delta^{13}\text{C} = F_m \cdot \left[\frac{(1 - 25/1000)}{(1 + \delta^{13}\text{C}/1000)} \right]^2$$

Errors

^{14}C contained in a sample are directly counted using the AMS method of radiocarbon analysis. Accordingly, we calculate an internal error based on the total number of ^{14}C counts measured for each target ($\text{error} = \frac{1}{\sqrt{n}}$). An external error is calculated from the reproducibility of exposures for a given target. We measure the $^{14}\text{C}/^{12}\text{C}$ of a sample 10 separate times over the course of a run. The reproducibility gives us a good estimate of the true experimental error. The final reported error is the larger of the internal or external errors. It should be noted that the reported error is an estimate of the precision of our measurement of a single sample. Due to variability in sampling, and sample processing, the variability of multiple submissions of a sample are generally higher than the reported error. Measurements of secondary standards show that the deviation within a population of samples is generally 1-3 permil greater than a single sample.

Radiocarbon Age

Radiocarbon age is calculated from the $\delta^{13}\text{C}$ -corrected Fraction Modern according to the following formula:

$$\text{Age} = -8033 \ln(F_m)$$

Reporting of ages and/or activities follows the convention outlined by Stuiver and Polach (1977) and Stuiver (1980). Ages are reported as years before present (BP) and are based on the half-life of radiocarbon and are reported without reservoir corrections or calibration to calendar years. For freeware programs, see the following web site for a list of programs that will calibrate radiocarbon results to calendar years (including making reservoir corrections): [Related Information Sources](#)

The error in the age is given by 8033 times the relative error in the F_m . Therefore a 1% error in fraction-modern leads to an 80 year error in age, rounded according to the convention of Stuiver & Polach, shown below.

Rounding Convention

Age	Nearest	Error
<1000	5	<100
1000-9999	10	100-1000
10000-20000	50	>1000
>20000	100	

Limiting Ages

There are two situations that limit an age; the first is that the measured F_m is smaller than that of the corresponding process blank or background of samples on the AMS. If this is the case, then the reported age will be quoted as an age greater than the age of the process blank or background, greater than 60,000 years. The typical background age for organic combustions is 48,000 years and for inorganic carbon samples is 60,000 years. One other situation that limits the age (if not already limited by the background age) is the error of the AMS result. If twice the error (let's call this 2σ) is larger than the sample Fraction Modern, then a limiting age is reported. The limiting age is the $\ln(2\sigma)$ and rounded according to conventions outlined above.

Age > Modern

Since Modern is defined as 95% of the ^{14}C activity for AD 1950, as defined by the oxalic acid standard, sample activities can be reported as $>$ Modern, and so the ages are reported as $>$ Modern.

$\delta^{14}\text{C}$

We also report the $\delta^{14}\text{C}$ value as defined in Stuiver and Pollach (1977) as the relative difference between the *absolute internat* (1950) and sample activity corrected for age and $\delta^{13}\text{C}$. The $\delta^{14}\text{C}$ is age corrected to account for decay that took place between time of measurement so that two measurements of the same sample made years apart will produce the same calculated $\delta^{14}\text{C}$ specified in order for $\delta^{14}\text{C}$ results to be calculated.

$$\delta^{14}\text{C} = [F_m * e^{\lambda(1950 - Y_c)} - 1] * 1000$$

Where λ is $1/(\text{true mean-life})$ of radiocarbon = $1/8267 = 0.00012097$

Y_c is year of collection.

References

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