

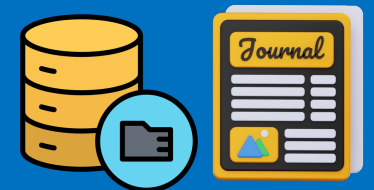
# Proper reporting and archiving of $^{14}\text{C}$ data

*Rules, metadata and common mistakes*

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**Christine Hatté**

Laboratoire des Sciences du Climat et de l'Environnement (LSCE), CEA CNRS UVSQ,  
Université Paris-Saclay, Gif-sur-Yvette, France  
Physics Institute, Silesian University of technology, Gliwice, Poland



# Why this guide?

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Because everyone thinks they know how to report a  $^{14}\text{C}$  date.  
... but it's easy to get it wrong ...

## A physics & chemistry science

Subject to IUPAC rules.  
Not “as seen elsewhere”.

## A ubiquitous method...

...hence assumed to be known.  
Half-life, reference level, units:  
all governed by strict conventions  
and not always what you might  
expect.

## Data that travel through time

Calibration curves keep evolving.  
Without raw data, no re-evaluation.  
→ FAIR principles

# Why goes wrong if you don't report properly

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→ impossible recalibration (no raw data)



→ misinterpretation (missing metadata)



→ false precision (protocol, metadata)

# 1

## Sample characterisation

*Sample context and nature of the material*

# What must be described



## Context

- Inventory ID, coordinates, stratigraphic unit, layer
- Geomorphological context
  - taphonomic processes
  - contamination risks
- Geographic setting
  - diet → calibration curve choice

## Nature & analysed fraction

- Species (botanical/zoological)
  - (e.g. old wood effect, reuse)
- Organ / tissue
  - (enamel ≠ compact bone: cell turnover)
- Measured fraction
  - cellulose, bulk carbon, specific compounds...

### ! What is actually dated:

- the cessation of carbon exchange with the atmosphere
- not its moment of use or deposition

# 2 Laboratory processing

*Protocols, quality, lab codes*

# What the lab must report



## Must be reported

- Analysed fraction (collagen, cellulose, bulk...)
- Chemistry lab code + measurement lab code
- Chemical protocol  
(+ peer-reviewed reference)
- Quality criteria (C/N, %C<sub>org</sub> ...) if any
- Measurement type: LSC /  $\beta$ -counting / AMS  
(+ peer-reviewed reference)
- Data reduction: blank, fractionation, normalization  
(+ reference if adapted)

## ⚠ Common misconceptions

### ⚠ Extraction yield $\neq$ quality

A low yield reflects natural dilution + preservation + efficiency of the chemical treatment  
-> not the quality of extracted fraction: More is not always better

### ⚠ $\delta^{13}\text{C}$ (AMS) $\neq$ natural $\delta^{13}\text{C}$

AMS  $\delta^{13}\text{C}$  includes natural fractionation + lab fractionation (e.g. graphitisation) + measurement.  
-> for internal use (lab parameter)  
-> not for public archives  
(IRMS  $\delta^{13}\text{C}$  on original sample may be reported)

# 3 Measurement results

*F<sup>14</sup>C, BP, rounding, IUPAC rules*

# Reporting raw results



## $F^{14}C$ — the only truly raw value reported following IUPAC rounding rules

or  $pMC = F^{14}C$  expressed in % if explicitly defined

Machine output:  $F^{14}C = 0.64321 \pm 0.00234$  X  
To publish ( $1\sigma$ , physics rounding):  **$F^{14}C = 0.6432 \pm 0.0023$**  ✓

or  $pMC = 64.32 \pm 0.23$

## Conventional radiocarbon age BP (optional) reported following Stuiver & Polach (1977) rounding rules

Age =  $-(5568 / \ln 2) \times \ln(F^{14}C)$

Rounding per Stuiver & Polach, 1977:  
uncertainty > 100 yr → hundred  
50–100 → ten  
< 50 → multiple of 5

Direct calculation : 8 234 ± 46 BP X  
To publish ( $1\sigma$ , physics rounding): **8 235 ± 45 BP** ✓

## ! To clarify

**$F^{14}C = 1 \neq$  atmospheric  $^{14}C$  in 1950**

Conventional value from extrapolation of pre-1650 AD measurements.

### Half life

Libby half-life = 5 568 yr (conventional)  
current estimates  $\approx 5\,700 \pm 30$  yr (Kutschera, 2019)

### Unit : BP = year Before Present

-> not yr BP  
-> not yrs BP

### Thousands separators

-> Use non-breaking spaces (not commas)

# 4 Calibration & Modelling

*Curves, software,  $\Delta R$ , intervals*

# Calibration — mandatory reporting



## Calibration checklist

- Calibration curve + reference (IntCal20, SHCal20, Marine20, Bomb21...)
- Software + version + reference (OxCal, ChronoModel, Bacon, Calib, ...)
- $\Delta R$  used + data source
- Intervals at 95.4% as [a – b] (not  $A \pm x$  !)  
Option : intervals at 68%
- **All** disjoint sub-intervals + their respective probability
- Option : median if single interval; pseudo-medians otherwise
- Notation: cal BP, AD/BC or CE/BCE (be consistent!)

### ⚠ To clarify

#### $\Delta R_{13}$ vs $\Delta R_{20}$ : not interchangeable!

$$R(t,z) = R \pm \Delta R_{13}(t,z)$$

Local deviation from global mean reservoir  
(~400 yr)

depends on location AND time

$$R(t,z) = R_{20}(t) \pm \Delta R_{20}(z)$$

Global variability embedded in the curve.

$\Delta R_{20}$  = local deviation only.

#### Marine $\Delta R$ database updated regularly

→ Provide full references and  $\Delta R$  values used

#### Calibration intervals

Calibration intervals are not Gaussian,

→  $1\sigma$  or  $2\sigma$  cannot be quoted

# Geochronological modelling



## Must be reported

- Software + version + reference
- Functions used (phase, sequence, boundary...)
- Parameters and stratigraphic constraints
- Validation indices + their definition
- Modelling code available (reproducibility)

## ⚠ Displayed precision vs actual resolution

Heterogeneous matrices (sediments, bones, ....)  
→ carbon integrated over decades.  
→ round interval bounds (Millard 2014)

*Ex.: 772–888 AD → 770–890 AD*

### OxCal

- A\_model & A\_overall
- < 60 → warning signal
- Uniform distribution assumed within phases

### ChronoModel

- MCMC acceptance rates
- Gelman-Rubin criterion
- No uniform prior within phases

### Bacon

- MCMC diagnostics (trace plots)
- Effective sample size (ESS)
- Autocorrelation / mixing

## Checklist — what must appear in the article and store in database



- ✓ Sample ID & nature (species, organ)
- ✓ Analysed fraction (collagen, cellulose...)
- ✓ Chemistry lab code + measurement lab code
- ✓ Chemical protocol with published reference
- ✓ Quality criterion (C/N, %Corg...) if any
- ✓ Measurement type with published reference
- ✓ Data reduction with reference if adapted

✓  $F^{14}\text{C} \pm 1\sigma$  (physics rounding)



✓ Conventional age BP  $\pm 1\sigma$  (S&P77 rounding)

✓ Calibration curve + reference

✓ Software + version + reference

✓  $\Delta R$  used ( $\Delta R_{13}$  or  $\Delta R_{20}$ ) + source

✓ Intervals [a–b] at 95.4% & all sub-intervals

✓ If modelling: functions + validation indices + code



**$^{14}\text{C}$  dates don't speak for themselves. Ask a geochronologist (we are friendly!)**