

Package ‘rice’

September 2, 2024

Type Package

Title Radiocarbon Calibration Equations

Version 0.1.1

Date 2024-08-27

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Description Provides functions for the calibration of radiocarbon dates, as well as options to calculate different radiocarbon realms (C14 age, F14C, pMC, D14C) and estimating the effects of contamination. The methods follow long-established recommendations such as Stuiver and Polach (1977) <[doi:10.1017/S0033822200003672](https://doi.org/10.1017/S0033822200003672)> and Reimer et al. (2004) <[doi:10.1017/S0033822200033154](https://doi.org/10.1017/S0033822200033154)>. This package accompanies the data package 'rintcal'.

License GPL (>= 2)

Encoding UTF-8

RoxygenNote 7.3.2

Imports rintcal (>= 0.6.4), data.table, jsonlite

Suggests knitr, rmarkdown, utf8

VignetteBuilder knitr

NeedsCompilation no

Repository CRAN

Date/Publication 2024-09-02 12:30:02 UTC

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rice-package	<i>rice: Radiocarbon Calibration Equations</i>
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Description

Provides functions for the calibration of radiocarbon dates, as well as options to calculate different radiocarbon realms (C14 age, F14C, pMC, D14C) and estimating the effects of contamination. The methods follow long-established recommendations such as Stuiver and Polach (1977) [doi:10.1017/S0033822200003672](https://doi.org/10.1017/S0033822200003672) and Reimer et al. (2004) [doi:10.1017/S0033822200033154](https://doi.org/10.1017/S0033822200033154). This package accompanies the data package 'rintcal'.

Author(s)

Maintainer: Maarten Blaauw <maarten.blaauw@qub.ac.uk> ([ORCID](#))

age.F14C	<i>Calculate F14C values from C14 ages</i>
----------	--

Description

Calculate F14C values from radiocarbon ages

Usage

```
age.F14C(mn, sdev = c(), decimals = 5, lambda = 8033)
```

Arguments

mn	Reported mean of the 14C age.
sdev	Reported error of the 14C age. If left empty, will translate mn to F14C.
decimals	Amount of decimals required for the F14C value. Defaults to 5.
lambda	The mean-life of radiocarbon (based on Libby half-life of 5568 years)

Details

Post-bomb dates are often reported as F14C or fraction modern carbon. Since Bacon expects radiocarbon ages, this function can be used to calculate F14C values from radiocarbon ages. The reverse function of [F14C.age](#).

Value

F14C values from C14 ages.

Examples

```
age.F14C(-2000, 20)
```

```
age.pMC
```

Calculate pMC values from C14 ages

Description

Calculate pMC values from radiocarbon ages

Usage

```
age.pMC(mn, sdev = c(), ratio = 100, decimals = 5, lambda = 8033)
```

Arguments

mn	Reported mean of the 14C age.
sdev	Reported error of the 14C age.
ratio	Most modern-date values are reported against 100. If it is against 1 instead, a warning is provided; use age.F14C .
decimals	Amount of decimals required for the pMC value. Defaults to 5.
lambda	The mean-life of radiocarbon (based on Libby half-life of 5568 years)

Details

Post-bomb dates are often reported as pMC or percent modern carbon. Since Bacon expects radiocarbon ages, this function can be used to calculate pMC values from radiocarbon ages. The reverse function of [pMC.age](#).

Value

pMC values from C14 ages.

Examples

```
age.pMC(-2000, 20)
age.pMC(-2000, 20, 1)
```

`calBP.14C`*Find the 14C age and error belonging to a cal BP age.*

Description

Given a calendar age, the calibration curve (default `cc=1`) is interpolated and the corresponding 14C age and error are returned.

Usage

```
calBP.14C(yr, cc = 1, postbomb = FALSE, rule = 1, cc.dir = NULL)
```

Arguments

<code>yr</code>	The cal BP year.
<code>cc</code>	calibration curve for C14 (see <code>caldist()</code>).
<code>postbomb</code>	Whether or not to use a postbomb curve (see <code>caldist()</code>).
<code>rule</code>	How should R's approx function deal with extrapolation. If <code>rule=1</code> , the default, then NAs are returned for such points and if it is 2, the value at the closest data extreme is used.
<code>cc.dir</code>	Directory of the calibration curves. Defaults to where the package's files are stored (<code>system.file</code>), but can be set to, e.g., <code>cc.dir="curves"</code> .

Details

Interpolation is used, and values outside the calibration curve are given as NA. For negative cal BP ages, a postbomb curve will have to be provided.

Value

The calibration-curve 14C year belonging to the entered cal BP age

Author(s)

Maarten Blaauw

Examples

```
calBP.14C(100)
```

caldist	<i>Calculate calibrated distribution</i>
---------	--

Description

Calculate the calibrated distribution of a radiocarbon date.

Usage

```
caldist(
  age,
  error,
  cc = 1,
  postbomb = FALSE,
  thiscurve = c(),
  yrsteps = FALSE,
  cc.resample = FALSE,
  dist.res = 200,
  threshold = 0.001,
  normal = TRUE,
  t.a = 3,
  t.b = 4,
  normalise = TRUE,
  BCAD = FALSE,
  rule = 1,
  cc.dir = NULL
)
```

Arguments

age	Uncalibrated radiocarbon age
error	Lab error of the radiocarbon age
cc	Calibration curve to use. Defaults to IntCal20 (cc=1).
postbomb	Whether or not to use a postbomb curve. Required for negative radiocarbon ages.
thiscurve	As an alternative to providing cc and/or postbomb, the data of a specific curve can be provided (3 columns: cal BP, C14 age, error). Defaults to FALSE.
yrsteps	Steps to use for interpolation. Defaults to the cal BP steps in the calibration curve
cc.resample	The IntCal20 curves have different densities (every year between 0 and 5 kcal BP, then every 5 yr up to 15 kcal BP, then every 10 yr up to 25 kcal BP, and then every 20 yr up to 55 kcal BP). If calibrated ages span these density ranges, their drawn heights can differ, as can their total areas (which should ideally all sum to the same size). To account for this, resample to a constant time-span, using, e.g., cc.resample=5 for 5-yr timespanes.

dist.res	As an alternative to yrsteps, provide the amount of 'bins' in the distribution
threshold	Report only values above a threshold. Defaults to threshold=1e-6.
normal	Use the normal distribution to calibrate dates (default TRUE). The alternative is to use the t model (Christen and Perez 2016).
t.a	Value a of the t distribution (defaults to 3).
t.b	Value a of the t distribution (defaults to 4).
normalise	Sum the entire calibrated distribution to 1. Defaults to normalise=TRUE.
BCAD	Which calendar scale to use. Defaults to cal BP, BCAD=FALSE.
rule	Which extrapolation rule to use. Defaults to rule=1 which returns NAs.
cc.dir	Directory of the calibration curves. Defaults to where the package's files are stored (system.file), but can be set to, e.g., cc.dir="curves".

Value

The probability distribution(s) as two columns: cal BP ages and their associated probabilities

Examples

```
calib <- caldist(130,10)
plot(calib, type="l")
postbomb <- caldist(-3030, 20, postbomb=1, BCAD=TRUE)
```

calibrate

Plot individual calibrated dates.

Description

Calibrate individual 14C dates, plot them and report calibrated ranges.

Usage

```
calibrate(
  age = 2450,
  error = 50,
  cc = 1,
  postbomb = FALSE,
  bombalert = TRUE,
  reservoir = 0,
  prob = 0.95,
  BCAD = FALSE,
  ka = FALSE,
  cal.lab = c(),
  C14.lab = c(),
  cal.lim = c(),
  C14.lim = c(),
```

```

cc.col = rgb(0, 0.5, 0, 0.7),
cc.fill = rgb(0, 0.5, 0, 0.7),
date.col = "red",
dist.col = rgb(0, 0, 0, 0.2),
dist.fill = rgb(0, 0, 0, 0.2),
hpd.fill = rgb(0, 0, 0, 0.3),
dist.height = 0.3,
dist.float = c(0.01, 0.01),
cal.rev = FALSE,
yr.steps = FALSE,
threshold = 5e-04,
edge = TRUE,
normal = TRUE,
t.a = 3,
t.b = 4,
rounded = 1,
extend.range = 0.05,
legend.cex = 0.8,
legend1.loc = "topleft",
legend2.loc = "topright",
mgp = c(2, 1, 0),
mar = c(3, 3, 1, 1),
xaxs = "i",
yaxs = "i",
bty = "l",
cc.dir = NULL,
...
)

```

Arguments

age	Mean of the uncalibrated C-14 age.
error	Error of the uncalibrated C-14 age.
cc	Calibration curve for C-14 dates (1, 2, 3, or 4, or, e.g., "IntCal20", "Marine20", "SHCal20", "nh1", "sh3", or "mixed").
postbomb	Whether or not this is a postbomb age. Defaults to FALSE.
bombalert	Warn if a date is close to the lower limit of the IntCal curve. Defaults to postbomb=TRUE.
reservoir	Reservoir age, or reservoir age and age offset.
prob	Probability confidence intervals (between 0 and 1).
BCAD	Use BC/AD or cal BP scale (default cal BP).
ka	Use thousands of years instead of years in the plots and hpd ranges. Defaults to FALSE.
cal.lab	Label of the calendar/horizontal axis. Defaults to the calendar scale, but alternative names can be provided.

C14.lab	Label of the C-14/vertical axis. Defaults to the 14C scale, but alternative names can be provided.
cal.lim	Minimum and maximum of calendar axis (default calculated automatically).
C14.lim	Minimum and maximum of C-14 axis (default calculated automatically).
cc.col	Colour of the lines of the calibration curve. Defaults to semi-transparent dark green; <code>cc.col=rgb(0, .5, 0, 0.7)</code> .
cc.fill	Colour of the inner part of the calibration curve. Defaults to semi-transparent dark green; <code>cc.col=rgb(0, .5, 0, 0.7)</code> .
date.col	Colour of the "dot-bar" plot of the C14 date. Defaults to <code>date.col="red"</code> .
dist.col	Colour of the outer lines of the distributions. Defaults to semi-transparent grey, <code>dist.col=rgb(0, 0, 0, 0.2)</code> .
dist.fill	Colour of the inner part of the distributions. Defaults to semi-transparent grey, <code>dist.col=rgb(0, 0, 0, 0.2)</code> .
hpd.fill	Colour of the highest posterior density. Defaults to semi-transparent grey, <code>dist.col=rgb(0, 0, 0, 0.3)</code> .
dist.height	Maximum height of the C14 and calibrated distributions (as proportion of the invisible secondary axes). Defaults to 0.3.
dist.float	The probability distributions float a bit above the axes by default. Can be set to distinct heights of the axes, e.g.: <code>dist.float=c(0.05, 0.1)</code> , or to <code>dist.float=0</code> .
cal.rev	Whether or not to reverse the direction of the calendar axis.
yr.steps	Temporal resolution at which C-14 ages are calibrated (in calendar years). By default follows the spacing in the calibration curve.
threshold	Below which value should probabilities be excluded from calculations.
edge	How to treat dates are at or beyond the edge of the calibration curve. If dates are truncated, a warning is given. If they lie beyond the calibration curve, an error is given.
normal	Use the normal distribution to calibrate dates (default TRUE). The alternative is to use the t model (Christen and Perez 2016).
t.a	Value a of the t distribution (defaults to 3).
t.b	Value b of the t distribution (defaults to 4).
rounded	Rounding of the percentages of the reported hpd ranges. Defaults to 1 decimal.
extend.range	Range by which the axes are extended beyond the data limits. Defaults to 5%.
legend.cex	Size of the font of the legends. Defaults to 0.8.
legend1.loc	Where the first legend (with the calibration curve name and the uncalibrated date) is plotted. Defaults to topleft.
legend2.loc	Where the second legend (with the hpd ranges) is plotted. Defaults to topright.
mgp	Axis text margins (where should titles, labels and tick marks be plotted).
mar	Plot margins (amount of white space along edges of axes 1-4).
xaxs	Whether or not to extend the limits of the horizontal axis. Defaults to <code>xaxs="i"</code> which does not extend the limits.
yaxs	Whether or not to extend the limits of the vertical axis. Defaults to <code>yaxs="i"</code> which does not extend the limits.

bty	Draw a box around the graph ("n" for none, and "l", "7", "c", "u", "j" or "o" for correspondingly shaped boxes).
cc.dir	Directory of the calibration curves. Defaults to where the package's files are stored (system.file), but can be set to, e.g., cc.dir="curves".
...	Other plotting parameters.

Details

Type `calibrate()` to see how a date of 2450 ± 50 14C BP gets calibrated (the calibration curve happens to show a plateau around this 14C age). To calibrate a different date, provide its reported mean and error (1 standard deviation error as reported by the radiocarbon laboratory) as follows: `calibrate(mean, error)`, e.g., for a date of 130 ± 10 14C BP, type `calibrate(age=130, error=10)` or, shorter, `calibrate(130, 10)`.

In case the date has a reservoir effect or age offset, e.g. of 100 14C years, provide this as follows: `calibrate(130, 10, reservoir=100)`. If you want to include an uncertainty for this offset, provide this as follows, e.g., for an uncertainty of 50yr, `calibrate(130, 10, reservoir=c(100, 50))`. The uncertainty for the age offset will then be added to the error (by taking the square root of the sum of the squared error and the squared offset uncertainty). If the carbon of your sample has mixed marine/terrestrial sources, instead apply the marine offset using `mix.curves` and calibrate the date using that custom-built curve (`cc="mixed"`).

If you prefer to work with, e.g., 68 % as opposed to the default 95 % confidence intervals, type: `calibrate(130, 10, prob=0.68)` or `calibrate(130, 10, , 0.68)` (the commas between the brackets indicate the position of the option; the standard deviation is the fourth option of the `calibrate` function). The calibrated distribution can be calculated for every single calendar year (`yrsteps=1`) within a wide range of the 14C date. Probabilities below a threshold (default `threshold=0.0005`) will be neglected.

By default the northern hemisphere terrestrial calibration curve is used (`cc=1` or `cc1="IntCal20"`). To use alternative curves, use `cc=2` (`cc2="Marine20"`), `cc=3` (`cc3="SHCal20C"`), `cc=4` (`cc4="mixed.14C"`), or specify a postbomb curve (e.g., `cc="nh1"`).

`Calibrate` works in cal BP (calendar years before AD 1950) by default, but can work with cal BC/AD through the option `BCAD=TRUE`.

By default the Gaussian distribution is used to calibrate dates. For use of the t distribution (Christen and Perez 2016) instead, set `normal=FALSE` provide values for `t.a` and `t.b` (defaults to `t.a=3` and `t.b=4`).

Calibrated distributions are usually reduced to their 68% or 95% calibrated ranges, taking into account the asymmetric and multi-peaked shape of these distributions. Calibrated ranges at 68% will obviously result in narrower confidence intervals, and a perceived higher precision, than 95% ranges. However, given the often asymmetric and multi-modal nature of calibrated distributions, the probability that the 'true' calendar date lies outside the 1 standard deviation hpd ranges is considerable (c. 32%). Therefore the use of 95% calibrated ranges is preferable, and default.

Negative radiocarbon ages are calibrated with postbomb curves, but the user needs to tell which curve to use. For example, to use the first of the three northern hemisphere curves, provide the option `cc="nh1"`, `cc="nh2"`, `cc="nh3"`, while for southern hemisphere samples, use `cc="sh1-2"` or `cc="sh3"`.

A graph of the calibration is produced, and it can be adapted in several ways. The limits of the horizontal (calendar scale) and vertical (14C scale) axes are calculated automatically but can be

changed by providing alternative values for the options `cal.lim`, `C14.lim`. The titles of both axis can be changed by providing alternative titles to `cal.lab` and/or `C14.lab`. The heights of the distributions of the 14C and calibrated ages can be set to alternative values using `dist.height` (default 0.3 which plots the distribution up to 30% of the height of the entire graph). Parameters for white space around the graph can be changed (default `mar=c(3.5, 2, 2, 1)` for spacing below, to the left, above and to the right respectively), as can the spacing for the axis labels (`mgp=c(2, 1, 0)`). By default, the axes are connected at the lower left, `bty="l"`. Check the R documentation of `par()` for more options.

The colours of the 14C date, the calibration curve, the distributions, and the highest posterior density (hpd) ranges, can be changed by providing an alternative colour in `date.col`, `cc.col`, `dist.col`, and/or `hpd.col`, respectively. The default colours are transparent grey for the dates probability distributions (`dist.col=rgb(0, 0, 0, 0.3)` and `sd.col=rgb(0, 0, 0, 0.5)`; change the last value of `rgb` for different greyscale values), red for the uncalibrated mean and error bars (`date.col="red"`), and transparent green for the calibration curve (`cc.col=rgb(0, 0.5, 0, 0.7)`). R's `rgb()` function expects values between 0 and 1 for red, green and blue, respectively, followed by a value for the semi-transparency (also between 0 and 1). Some graphic devices such as postscript are unable to use transparency; in that case provide different colours or leave the fourth value empty.

Value

A graph of the raw and calibrated C-14 date, the calibrated ranges and, invisibly, the calibrated distribution and hpd ranges.

Examples

```
calibrate()
calibrate(130, 10)
cal <- calibrate(2550, 20, reservoir=100)
cal; plot(cal[[1]])
calibrate(130, 10, prob=0.68)
calibrate(age=130, error=10, BCAD=TRUE)
calibrate(4450, 40, reservoir=c(100, 50))
```

contaminate

Simulate the impact of contamination on a radiocarbon age

Description

Given a certain radiocarbon age, calculate the observed impact of contamination with a ratio of material with a different 14C content (for example, 1

Usage

```
contaminate(y, sdev = c(), fraction, F14C, F14C.er = 0, decimals = 5)
```

Arguments

y	the true radiocarbon age
sdev	the error of the true radiocarbon age
fraction	Relative amount of contamination. Must be between 0 and 1
F14C	the F14C of the contamination. Set at 1 for carbon of modern radiocarbon age, at 0 for 14C-free carbon, or anywhere inbetween.
F14C.er	error of the contamination. Defaults to 0.
decimals	Rounding of the output. Since details matter here, the default is to provide 5 decimals.

Value

The observed radiocarbon age and error

Author(s)

Maarten Blaauw

Examples

```
contaminate(5000, 20, .01, 1) # 1% contamination with modern carbon
# Impacts of different amounts of contamination with modern carbon:
real.14C <- seq(0, 50e3, length=200)
contam <- seq(0, .1, length=101) # 0 to 10% contamination
contam.col <- rainbow(length(contam))
plot(0, type="n", xlim=c(0, 55e3),
     xlab="real", ylim=range(real.14C), ylab="observed")
for(i in 1:length(contam))
  lines(real.14C, contaminate(real.14C, c(), contam[i], 1, decimals=5), col=contam.col[i])
contam.legend <- seq(0, .1, length=6)
contam.col <- rainbow(length(contam.legend))
text(52e3, contaminate(50e3, c(), contam.legend, 1), labels=contam.legend, col=contam.col, cex=.7)
```

D14C.F14C

Transform D14C into F14C

Description

Transform D14C into F14C

Usage

```
D14C.F14C(D14C, t)
```

Arguments

D14C	The Delta14C value to translate
t	the cal BP age

Details

As explained by Heaton et al. 2020 (Radiocarbon), ^{14}C measurements are commonly expressed in three domains: Delta14C, F14C and the radiocarbon age. This function translates Delta14C, the historical level of Delta14C in the year t cal BP, to F14C values. Note that per convention, this function uses the Cambridge half-life, not the Libby half-life.

Value

The corresponding F14C value

Examples

```
D14C.F14C(-10, 238)
```

```
draw.ccurve
```

```
Draw a calibration curve.
```

Description

Draw one or two of the calibration curves, or add a calibration curve to an existing plot.

Usage

```
draw.ccurve(
  cal1 = c(),
  cal2 = c(),
  cc1 = "IntCal20",
  cc2 = NA,
  cc1.postbomb = FALSE,
  cc2.postbomb = FALSE,
  BCAD = FALSE,
  cal.lab = NA,
  cal.rev = FALSE,
  c14.lab = NA,
  c14.lim = NA,
  c14.rev = FALSE,
  ka = FALSE,
  add.yaxis = FALSE,
  cc1.col = rgb(0, 0, 1, 0.5),
  cc1.fill = rgb(0, 0, 1, 0.2),
  cc2.col = rgb(0, 0.5, 0, 0.5),
  cc2.fill = rgb(0, 0.5, 0, 0.2),
  add = FALSE,
  bty = "l",
  cc.dir = NULL,
  legend = "topleft",
  ...
)
```

Arguments

cal1	First calendar year for the plot. Defaults to 0 cal BP.
cal2	Last calendar year for the plot. Defaults to 55,000 cal BP.
cc1	Name of the calibration curve. Can be "IntCal20", "Marine20", "SHCal20", or for the previous curves "IntCal13", "Marine13" or "SHCal13". Can also be "nh1", "nh2", "nh3", "sh1-2", "sh3", "nh1_monthly", "nh2_monthly", "nh3_monthly", "sh1-2_monthly", "sh3_monthly", "Kure", "LevinKromer" or "Santos" for postbomb curves.
cc2	Optional second calibration curve to plot. Can be "IntCal20", "Marine20", "SHCal20", or for the previous curves "IntCal13", "Marine13" or "SHCal13". Defaults to nothing, NA.
cc1.postbomb	Use postbomb=TRUE to get a postbomb calibration curve for cc1 (default cc1.postbomb=FALSE).
cc2.postbomb	Use postbomb=TRUE to get a postbomb calibration curve for cc2 (default cc2.postbomb=FALSE).
BCAD	The calendar scale of graphs and age output-files is in cal BP (calendar or calibrated years before the present, where the present is AD 1950) by default, but can be changed to BC/AD using BCAD=TRUE.
cal.lab	The labels for the calendar axis (default age.lab="cal BP" or "BC/AD" if BCAD=TRUE), or to age.lab="kcal BP" etc. if ka=TRUE.
cal.rev	Reverse the calendar axis.
c14.lab	Label for the C-14 axis. Defaults to 14C BP (or 14C kBP if ka=TRUE).
c14.lim	Axis limits for the C-14 axis. Calculated automatically by default.
c14.rev	Reverse the C-14 axis.
ka	Use kcal BP (and C14 kBP).
add.yaxis	Whether or not to plot the second calibration. Defaults to add.yaxis=FALSE.
cc1.col	Colour of the calibration curve (outline).
cc1.fill	Colour of the calibration curve (fill).
cc2.col	Colour of the calibration curve (outline), if activated (default cc2=NA).
cc2.fill	Colour of the calibration curve (fill), if activated (default cc2=NA).
add	Whether or not to add the curve(s) to an existing plot. Defaults to FALSE, which draws a new plot
bty	Draw a box around a box of a certain shape. Defaults to bty="1".
cc.dir	Directory of the calibration curves. Defaults to where the package's files are stored (system.file), but can be set to, e.g., cc.dir="curves".
legend	Location of the legend (only activated if more than one curve is plotted). Plotted in the topleft corner by default. Use legend=c() to leave empty
...	Any additional optional plotting parameters.

Value

A plot of the calibration curve

Examples

```
draw.ccurve()
draw.ccurve(1000, 3000, cc2="Marine20")
draw.ccurve(1800, 2020, BCAD=TRUE, cc2="nh1", cc2.postbomb=TRUE)
draw.ccurve(1800, 2010, BCAD=TRUE, cc2="nh1", add.yaxis=TRUE)
```

draw.contamination *Draw contamination impacts*

Description

Show how contamination with different fractions of modern carbon affect observed C-14 ages.

Usage

```
draw.contamination(
  from = 0,
  to = 50000,
  ka = TRUE,
  age.res = 500,
  xlim = c(),
  ylim = c(),
  colours = rainbow(age.res),
  max.contam = 0.1,
  contam.F14C = 1,
  contam.legend = max.contam * c(1/100, (1:5)/50, (1:4)/5, 1),
  legend.pos = 0.07,
  legend.cex = 0.6,
  grid = TRUE,
  xaxs = "i",
  yaxs = "i"
)
```

Arguments

from	Minimum 14C age for the plot. Defaults to 0
to	Maximum 14C age for the plot. Defaults to 50e3.
ka	Use C14 kBP. Defaults to TRUE.
age.res	Resolution of age scale. Defaults to 500, which results in smooth curves. Higher numbers will take longer to draw.
xlim	Limits of the horizontal axis.
ylim	Limits of the vertical axis.
colours	Colours of the percentages. Defaults to rainbow colours.
max.contam	Maximum contamination level as a fraction of the sample. Defaults to 0.1 (10%).

contam.F14C	14C activity of the sample. Defaults to 'modern' 14C, F14C=1.
contam.legend	Percentages for which numbers will be plotted.
legend.pos	horizontal position beyond which the percentage values will be plotted
legend.cex	font size of the legend
grid	Whether to plot a grid. Defaults to TRUE
xaxs	Whether or not to extend the limits of the horizontal axis. Defaults to xaxs="i" which does not extend.
yaxs	Whether or not to extend the limits of the vertical axis. Defaults to yaxs="i" which does not extend.

Value

A plot of real and observed (contamination-impacted) C14 ages.

Examples

```
draw.contamination()
draw.contamination(40e3, 50e3, ka=FALSE)
```

draw.D14C

Draw d14C and the calibration curve.

Description

Draw a proxy of the atmospheric 14C concentration (d14C) as well as the calibration curve.

Usage

```
draw.D14C(
  cal1 = c(),
  cal2 = c(),
  cc = rintcal::ccurve(),
  BCAD = FALSE,
  mar = c(4, 4, 1, 4),
  mgp = c(2.5, 1, 0),
  xaxs = "r",
  yaxs = "r",
  bty = "u",
  ka = FALSE,
  cal.lab = c(),
  cal.rev = FALSE,
  C14.lab = c(),
  C14.lim = c(),
  cc.col = rgb(0, 0.5, 0, 0.5),
  cc.border = rgb(0, 0.5, 0, 0.5),
  D14C.lab = c(),
```

```

D14C.lim = c(),
D14C.col = rgb(0, 0, 1, 0.5),
D14C.border = rgb(0, 0, 1, 0.5)
)

```

Arguments

cal1	First calendar year for the plot. Defaults to youngest calendar age of the calibration curve
cal2	Last calendar year for the plot. Defaults to oldest calendar age of the calibration curve
cc	The calibration curve to use. Defaults to IntCal20
BCAD	The calendar scale of graphs and age output-files is in cal BP (calendar or calibrated years before the present, where the present is AD 1950) by default, but can be changed to BC/AD using BCAD=TRUE.
mar	Plot margins (amount of white space along edges of axes 1-4).
mgp	Axis text margins (where should titles, labels and tick marks be plotted).
xaxs	Whether or not to extend the limits of the horizontal axis. Defaults to xaxs="r" which extends it by R's default.
yaxs	Whether or not to extend the limits of the vertical axis. Defaults to yaxs="r" which extends it by R's default.
bty	Draw a box around the graph ("n" for none, and "l", "7", "c", "u", "j" or "o" for correspondingly shaped boxes).
ka	Use kcal BP (and C14 kBp). Defaults to FALSE.
cal.lab	The labels for the calendar axis (default age.lab="cal BP" or "BC/AD" if BCAD=TRUE), or to age.lab="kcal BP" etc. if ka=TRUE.
cal.rev	Reverse the calendar axis (defaults to FALSE).
C14.lab	Label for the C-14 axis. Defaults to 14C BP (or 14C kBp if ka=TRUE).
C14.lim	Limits for the C-14 axis. Calculated automatically by default.
cc.col	Colour of the calibration curve (fill).
cc.border	Colour of the calibration curve (border).
D14C.lab	Label for the D14C axis.
D14C.lim	Axis limits for the D14C axis. Calculated automatically by default.
D14C.col	Colour of the D14C curve (fill).
D14C.border	Colour of the D14C curve (border).

Value

A plot of d14C and the calibration curve

Examples

```

draw.D14C()
draw.D14C(30e3, 55e3, ka=TRUE)
draw.D14C(cc=rintcal::ccurve("NH1_monthly"), BCAD=TRUE)

```

draw.dates	<i>add calibrated distributions to a plot.</i>
------------	--

Description

Add individual or multiple calibrated dates to a plot.

Usage

```
draw.dates(  
  age,  
  error,  
  depth,  
  cc = 1,  
  postbomb = FALSE,  
  reservoir = c(),  
  normal = TRUE,  
  t.a = 3,  
  t.b = 4,  
  prob = 0.95,  
  threshold = 0.001,  
  BCAD = FALSE,  
  draw.hpd = TRUE,  
  hpd.lwd = 2,  
  hpd.col = rgb(0, 0, 1, 0.7),  
  cal.hpd.col = rgb(0, 0.5, 0.5, 0.35),  
  mirror = TRUE,  
  up = FALSE,  
  draw.base = TRUE,  
  col = rgb(0, 0, 1, 0.3),  
  border = rgb(0, 0, 1, 0.5),  
  cal.col = rgb(0, 0.5, 0.5, 0.35),  
  cal.border = rgb(0, 0.5, 0.5, 0.35),  
  add = FALSE,  
  ka = FALSE,  
  rotate.axes = FALSE,  
  ex = 1,  
  normalise = TRUE,  
  cc.resample = 5,  
  age.lab = c(),  
  age.lim = c(),  
  age.rev = FALSE,  
  d.lab = c(),  
  d.lim = c(),  
  d.rev = TRUE,  
  labels = c(),  
  label.x = 1,
```

```

label.y = c(),
label.cex = 0.8,
label.col = border,
label.offset = c(0, 0),
label.adj = c(1, 0),
label.rot = 0,
cc.dir = NULL,
dist.res = 100,
...
)

```

Arguments

age	Mean of the uncalibrated C-14 age (or multiple ages).
error	Error of the uncalibrated C-14 age (or ages).
depth	Depth(s) of the date(s). Can also be their relative positions if no depths are available.
cc	Calibration curve for C-14 dates (1, 2, 3, or 4, or, e.g., "IntCal20", "Marine20", "SHCal20", "nh1", "sh3", or "mixed"). If there are multiple dates but all use the same calibration curve, one value can be provided.
postbomb	Whether or not this is a postbomb age. Defaults to FALSE.
reservoir	Reservoir age, or reservoir age and age offset.
normal	Use the normal distribution to calibrate dates (default TRUE). The alternative is to use the t model (Christen and Perez 2009).
t.a	Value a of the t distribution (defaults to 3).
t.b	Value b of the t distribution (defaults to 4).
prob	Probability confidence intervals (between 0 and 1).
threshold	Report only values above a threshold. Defaults to threshold=0.001.
BCAD	Use BC/AD or cal BP scale (default cal BP).
draw.hpd	Whether or not to draw the hpd ranges as a line
hpd.lwd	Width of the line of the hpd ranges
hpd.col	Colour of the hpd rectangle for all dates or radiocarbon dates
cal.hpd.col	Colour of the hpd rectangle for cal BP dates
mirror	Plot distributions mirrored, a bit like a swan. Confuses some people but looks nice to the author so is the default.
up	If mirror is set to FALSE, the distribution can be plotted up or down, depending on the direction of the axis.
draw.base	By default, the base of the calibrated distributions is plotted. This can be avoided by supplying draw.base=FALSE as an option.
col	Colour of the inside of the distribution
border	Colour of the border of the distribution
cal.col	Colour of the inside of distribution of non-radiocarbon dates that didn't need calibration

<code>cal.border</code>	Colour of the border of the distribution of non-radiocarbon dates that didn't need calibration
<code>add</code>	Whether or not to add the dates to an existing plot. If set to <code>FALSE</code> (default), a plot will be set up.
<code>ka</code>	Whether or not to plot ages as thousands of years. Defaults to <code>ka=FALSE</code> .
<code>rotate.axes</code>	By default, the calendar age axis is plotted on the horizontal axis, and depth/position on the vertical one. Use <code>rotate.axes=TRUE</code> to rotate the axes.
<code>ex</code>	Exaggeration of the height of the distribution, defaults to <code>ex=1</code> .
<code>normalise</code>	If <code>TRUE</code> , the age distributions are normalised by plotting each distribution with the same total area. Precise dates will therefore peak higher than less precise dates (default). If <code>normalise=FALSE</code> , the peak of each date will be drawn at the same height.
<code>cc.resample</code>	The <code>IntCal20</code> curves have different densities (every year between 0 and 5 kcal BP, then every 5 yr up to 15 kcal BP, then every 10 yr up to 25 kcal BP, and then every 20 yr up to 55 kcal BP). If calibrated ages span these density ranges, their drawn heights can differ, as can their total areas (which should ideally all sum to the same size). To account for this, resample to a constant time-span, using, e.g., <code>cc.resample=5</code> for 5-yr timespans.
<code>age.lab</code>	Title of the calendar axis (if present)
<code>age.lim</code>	Limits of the calendar axis (if present)
<code>age.rev</code>	Reverse the age axis. Defaults to <code>TRUE</code>
<code>d.lab</code>	Title of the vertical axis (if present)
<code>d.lim</code>	Limits of the vertical axis (if present)
<code>d.rev</code>	Reverse the y-axis. Defaults to <code>TRUE</code>
<code>labels</code>	Add labels to the dates. Empty by default.
<code>label.x</code>	Horizontal position of the date labels. By default draws them before the youngest age (1), but can also draw them after the oldest age (2), or above its mean (3).
<code>label.y</code>	Vertical positions of the depths/labels. Defaults to 0 (or 1 if <code>label.x</code> is 3 or 4).
<code>label.cex</code>	Size of labels.
<code>label.col</code>	Colour of the labels. Defaults to the colour given to the borders of the dates.
<code>label.offset</code>	Offsets of the positions of the depths/labels, giving the x and y offsets. Defaults to <code>c(0,0)</code> .
<code>label.adj</code>	Justification of the labels. Follows R's <code>adj</code> option: A value of "0" produces left-justified text, "0.5" (the default) centered text and "1" right-justified text.
<code>label.rot</code>	Rotation of the label. 0 by default (horizontal).
<code>cc.dir</code>	Directory of the calibration curves. Defaults to where the package's files are stored (<code>system.file</code>), but can be set to, e.g., <code>cc.dir="curves"</code> .
<code>dist.res</code>	Resolution of the distribution polygons. Defaults to <code>dist.res=100</code> .
<code>...</code>	Additional plotting options

Value

A plot of the (calibrated) dates

Examples

```

plot(0, xlim=c(500,0), ylim=c(0, 2))
draw.dates(130, 20, depth=1)
x <- sort(runif(10, 1000, 10000)) # draw 10 random calendar ages
cc <- rintcal::ccurve() # get the calibration curve
y <- approx(cc[,1], cc[,2], x)$y # find the IntCal 14C ages
er <- .01 * y
draw.dates(y, er, 1:length(x))
draw.dates(y, er, y, d.lab="Radiocarbon age (BP)")
draw.ccurve(add=TRUE, cc1.col=rgb(0,.5,0,.5))

```

F14C.age

Calculate C14 ages from F14C values.

Description

Calculate C14 ages from F14C values of radiocarbon dates.

Usage

```
F14C.age(mn, sdev = c(), decimals = 5, lambda = 8033)
```

Arguments

mn	Reported mean of the F14C
sdev	Reported error of the F14C. Returns just the mean if left empty.
decimals	Amount of decimals required for the radiocarbon age. Quite sensitive, defaults to 5.
lambda	The mean-life of radiocarbon (based on Libby half-life of 5568 years)

Details

Post-bomb dates are often reported as F14C or fraction modern carbon. Since Bacon expects radiocarbon ages, this function can be used to calculate radiocarbon ages from F14C values. The reverse function is [age.F14C](#).

Value

Radiocarbon ages from F14C values. If F14C values are above 100%, the resulting radiocarbon ages will be negative.

Examples

```

F14C.age(1.10, 0.5) # a postbomb date, so with a negative 14C age
F14C.age(.80, 0.5) # prebomb dates can also be calculated

```

F14C.D14C	<i>Transform F14C into D14C</i>
-----------	---------------------------------

Description

Transform F14C into D14C

Usage

```
F14C.D14C(F14C, t)
```

Arguments

F14C	The F14C value to translate
t	the cal BP age

Details

As explained by Heaton et al. 2020 (Radiocarbon), ^{14}C measurements are commonly expressed in three domains: $\Delta^{14}\text{C}$, F14C and the radiocarbon age. This function translates F14C values into $\Delta^{14}\text{C}$, the historical level of $\Delta^{14}\text{C}$ in the year t cal BP. Note that per convention, this function uses the Cambridge half-life, not the Libby half-life.

Value

The corresponding D14C value

Examples

```
F14C.D14C(0.985, 222)
cc <- rintcal::ccurve()
# plot IntCal20 as D14C:
cc.Fmin <- age.F14C(cc[,2]+cc[,3])
cc.Fmax <- age.F14C(cc[,2]-cc[,3])
cc.D14Cmin <- F14C.D14C(cc.Fmin, cc[,1])
cc.D14Cmax <- F14C.D14C(cc.Fmax, cc[,1])
plot(cc[,1]/1e3, cc.D14Cmax, type="l", xlab="kcal BP", ylab=expression(paste(Delta, ""^{14}, "C")))
lines(cc[,1]/1e3, cc.D14Cmin)
```

hpd *Calculate highest posterior density*

Description

Calculate highest posterior density ranges of calibrated distribution

Usage

```
hpd(calib, prob = 0.95, return.raw = FALSE, rounded = 1)
```

Arguments

calib	The calibrated distribution, as returned from caldist()
prob	Probability range which should be calculated. Default prob=0.95.
return.raw	The raw data to calculate hpds can be returned, e.g. to draw polygons of the calibrated distributions. Defaults to return.raw=FALSE.
rounded	Rounding for reported probabilities. Defaults to 1 decimal.

Value

The highest posterior density ranges, as three columns: from age, to age, and the corresponding percentage(s) of the range(s)

Examples

```
hpd(caldist(130,20))
plot(tmp <- caldist(2450,50), type='l')
abline(v=hpd(tmp)[,1:2], col=4)
```

l.calib *Find the calibrated probability of a calendar age for a 14C date.*

Description

Find the calibrated probability of a cal BP age for a radiocarbon date. Can handle either multiple calendar ages for a single radiocarbon date, or a single calendar age for multiple radiocarbon dates.

Usage

```
l.calib(  
  yr,  
  y,  
  er,  
  cc = rintcal::ccurve(1, FALSE),  
  normal = TRUE,  
  t.a = 3,  
  t.b = 4  
)
```

Arguments

yr	The cal BP year.
y	The radiocarbon date's mean.
er	The radiocarbon date's lab error.
cc	calibration curve for the radiocarbon date(s) (see the <code>rintcal</code> package).
normal	Use the normal distribution to calibrate dates (default TRUE). The alternative is to use the t model (Christen and Perez 2016).
t.a	Value a of the t distribution (defaults to 3).
t.b	Value b of the t distribution (defaults to 4).

Details

The function cannot deal with multiple calibration curves if multiple calendar years or radiocarbon dates are entered.

Value

The calibrated probability of a calendar age for a ^{14}C age

Author(s)

Maarten Blaauw

Examples

```
l.calib(100, 130, 20)  
l.calib(100:110, 130, 20) # multiple calendar ages of a single date  
l.calib(100, c(130,150), c(15,20)) # multiple radiocarbon ages and a single calendar age
```

 older

Find the probability of a calibrated date being older than a certain age

Description

Find the probability of a calibrated date being older than an age x .

Find the probability that a sample is older than a certain calendar age x , by calculating the proportion of the calibrated distribution 'after' x (i.e., 1 - the summed calibrated distribution up to year x).

Usage

```
older(
  x,
  y,
  er,
  cc = 1,
  postbomb = FALSE,
  normal = TRUE,
  t.a = 3,
  t.b = 4,
  BCAD = FALSE,
  threshold = 0
)
```

Arguments

<code>x</code>	The year of interest, in cal BP by default.
<code>y</code>	The radiocarbon date's mean.
<code>er</code>	The radiocarbon date's lab error.
<code>cc</code>	calibration curve for the radiocarbon date(s) (see the <code>rintcal</code> package).
<code>postbomb</code>	Whether or not to use a postbomb curve (see <code>caldist()</code>).
<code>normal</code>	Use the normal distribution to calibrate dates (default TRUE). The alternative is to use the <code>t</code> model (Christen and Perez 2016).
<code>t.a</code>	Value <code>a</code> of the <code>t</code> distribution (defaults to 3).
<code>t.b</code>	Value <code>b</code> of the <code>t</code> distribution (defaults to 4).
<code>BCAD</code>	Which calendar scale to use. Defaults to cal BP, BCAD=FALSE.
<code>threshold</code>	Report only values above a threshold. Defaults to <code>threshold=0</code> .

Details

The function can only deal with one date at a time.

Value

The probability of a date being older than a certain calendar age.

Author(s)

Maarten Blaauw

Examples

```
older(2800, 2450, 20)
older(2400, 2450, 20)
calibrate(160, 20, BCAD=TRUE)
older(1750, 160, 20, BCAD=TRUE)
```

pMC.age	<i>Calculate C14 ages from pMC values.</i>
---------	--

Description

Calculate C14 ages from pMC values of radiocarbon dates.

Usage

```
pMC.age(mn, sdev = c(), ratio = 100, decimals = 0, lambda = 8033)
```

Arguments

mn	Reported mean of the pMC.
sdev	Reported error of the pMC.
ratio	Most modern-date values are reported against 100. If it is against 1 instead, use 1 here.
decimals	Amount of decimals required for the radiocarbon age.
lambda	The mean-life of radiocarbon (based on Libby half-life of 5568 years)

Details

Post-bomb dates are often reported as pMC or percent modern carbon. Since Bacon expects radiocarbon ages, this function can be used to calculate radiocarbon ages from pMC values. The reverse function is [age.pMC](#).

Value

Radiocarbon ages from pMC values. If pMC values are above 100%, the resulting radiocarbon ages will be negative.

Examples

```
pMC.age(110, 0.5) # a postbomb date, so with a negative 14C age
pMC.age(80, 0.5) # prebomb dates can also be calculated
pMC.age(.8, 0.005, ratio=1) # throws a warning, use F14C.age instead
```

point.estimate *Calculate a point estimate*

Description

Calculate a point estimate of a calibrated distribution - either the weighted mean, the median or the mode (maximum). Note that point estimates often tend to be very poor representations of entire calibrated distributions, so please be careful and do not reduce entire calibrated distributions to just 1 point value.

Usage

```
point.estimate(  
  calib,  
  wmean = TRUE,  
  median = TRUE,  
  mode = TRUE,  
  midpoint = TRUE,  
  prob = 0.95,  
  rounded = 1  
)
```

Arguments

calib	The calibrated distribution, as returned from caldist()
wmean	Report the weighted mean (defaults to TRUE)
median	Report the median (defaults to TRUE)
mode	Report the mode, which is the year with the maximum probability (defaults to TRUE)
midpoint	Report the midpoint of the hpd range(s)
prob	probability range for the hpd range(s)
rounded	Rounding for reported probabilities. Defaults to 1 decimal.

Value

The chosen point estimates

Examples

```
point.estimate(caldist(130,20))  
plot(tmp <- caldist(2450,50), type='l')  
abline(v=point.estimate(tmp), col=1:4)
```

younger	<i>Find the probability of a calibrated date being of a certain age or younger than it</i>
---------	--

Description

Find the probability that a sample is of a certain calendar age x or younger than it, by calculating the proportion of the calibrated distribution up to and including x (i.e., summing the calibrated distribution up to year x).

Usage

```
younger(
  x,
  y,
  er,
  cc = 1,
  postbomb = FALSE,
  normal = TRUE,
  t.a = 3,
  t.b = 4,
  BCAD = FALSE,
  threshold = 0
)
```

Arguments

<code>x</code>	The year of interest, in cal BP by default.
<code>y</code>	The radiocarbon date's mean.
<code>er</code>	The radiocarbon date's lab error.
<code>cc</code>	calibration curve for the radiocarbon date(s) (see the <code>rintcal</code> package).
<code>postbomb</code>	Whether or not to use a postbomb curve (see <code>caldist()</code>).
<code>normal</code>	Use the normal distribution to calibrate dates (default TRUE). The alternative is to use the <code>t</code> model (Christen and Perez 2016).
<code>t.a</code>	Value <code>a</code> of the <code>t</code> distribution (defaults to 3).
<code>t.b</code>	Value <code>b</code> of the <code>t</code> distribution (defaults to 4).
<code>BCAD</code>	Which calendar scale to use. Defaults to cal BP, BCAD=FALSE.
<code>threshold</code>	Report only values above a threshold. Defaults to <code>threshold=0</code> .

Details

The function can only deal with one date at a time.

Value

The probability of a date being of a certain calendar age or younger than it.

Author(s)

Maarten Blaauw

Examples

```
younger(2800, 2450, 20)
younger(2400, 2450, 20)
calibrate(160, 20, BCAD=TRUE)
younger(1750, 160, 20, BCAD=TRUE)
```

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