Package 'ananke'

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Title Quantitative Chronology in Archaeology

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Description Simple radiocarbon calibration and chronological analysis. This package allows the calibration of radiocarbon ages and modern carbon fraction values using multiple calibration curves. It allows the calculation of highest density region intervals and credible intervals. The package also provides tools for visualising results and estimating statistical summaries.

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URL https://codeberg.org/tesselle/ananke, https://packages.tesselle.org/ananke/

BugReports https://codeberg.org/tesselle/ananke/issues

Depends aion (>= 1.4.0), R (>= 4.1)

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Contents

`as.data.frame` *Coerce to a Data Frame*

Description

Coerce to a Data Frame

Usage

```
## S4 method for signature 'CalibratedAges'
as.data.frame(x, ..., calendar = get_calendar())

## S4 method for signature 'CalibratedIntervals'
as.data.frame(x, ..., calendar = get_calendar())

## S4 method for signature 'RECE'
as.data.frame(x, ..., calendar = get_calendar())

## S4 method for signature 'ProxyRecord'
as.data.frame(x, ..., calendar = get_calendar())
```

Arguments

x	An object.
...	Currently not used.
calendar	An aion::TimeScale object specifying the target calendar (see aion::calendar()). If NULL, *rata die* are returned.

Value

A data.frame with an extra time column.

Author(s)

N. Frerebeau

See Also

Other mutators: as.list(), labels(), mutators, subset()

Examples

```
## Calibrate multiple dates
cal <- c14_calibrate(
  values = c(5000, 4500),
  errors = c(45, 35),
  names = c("X", "Y")
)

head(as.data.frame(cal))
head(as.data.frame(cal, calendar = BP()))
head(as.data.frame(cal, calendar = NULL))
```

`as.list` *Coerce to a list*

Description

Coerce to a list

Usage

```
## S4 method for signature 'CalibratedIntervals'
as.list(x, ..., calendar = get_calendar())
```

Arguments

`x`	An object.
`...`	Currently not used.
`calendar`	An `aion::TimeScale` object specifying the target calendar (see `aion::calendar()`). If `NULL`, *rata die* are returned.

Value

A `list`.

Author(s)

N. Frerebeau

See Also

Other mutators: `as.data.frame()`, `labels()`, `mutators`, `subset()`

Examples

```
## Calibrate multiple dates
cal <- c14_calibrate(
  values = c(5000, 4500),
  errors = c(45, 35),
  names = c("X", "Y")
)

head(as.data.frame(cal))
head(as.data.frame(cal, calendar = BP()))
head(as.data.frame(cal, calendar = NULL))
```

`c14_calibrate` *14C Calibration*

Description

Calibrates radiocarbon ages.

Usage

```
c14_calibrate(values, errors, ...)

## S4 method for signature 'numeric,numeric'
c14_calibrate(
  values,
  errors,
  curves = "intcal20",
  names = NULL,
  positions = NULL,
  reservoir_offsets = 0,
  reservoir_errors = 0,
  from = 55000,
  to = 0,
  resolution = 1,
  normalize = TRUE,
  F14C = FALSE,
  method = c("student", "normal"),
  dfs = 100,
  drop = TRUE,
  eps = 1e-06,
  verbose = getOption("ananke.verbose")
)
```

Arguments

`values`	A `numeric` vector giving the BP ages or F14C values to be calibrated (conventional ages).
`errors`	A `numeric` vector giving the errors associated to the values to be calibrated.
`...`	Currently not used.
`curves`	A `character` vector specifying the calibration curve to be used. Different curves can be specified per sample.
`names`	A `character` vector specifying the names of the samples (e.g. laboratory codes).
`positions`	A `numeric` vector giving the position values (e.g. depths) for each age.
`reservoir_offsets`	A `numeric` vector giving the offset values for any marine reservoir effect (defaults to 0; i.e. no offset).

reservoir_errors
: A numeric vector giving the offset value errors for any marine reservoir effect (defaults to 0; i.e. no offset).

from
: length-one numeric vector specifying the earliest data to calibrate for, in cal. BP years.

to
: A length-one numeric vector specifying the latest data to calibrate for, in cal. BP years.

resolution
: A length-one numeric vector specifying the temporal resolution (in years) of the calibration.

normalize
: A logical scalar: should the calibration be normalized?

F14C
: A logical scalar: should the calibration be carried out in F14C space? If TRUE, values must be expressed as F14C.

method
: A character string specifying the distribution assumed for the 14C ages. It must be one of "student" (the default) or "normal. Only used if F14C is FALSE.

dfs
: A character vector giving the degrees-of-freedom values for the student t-distribution associated with the calibration calculation. Only used if method is "student".

drop
: A logical scalar: should years with zero probability be discarded? If TRUE (the default), results in a narrower time range.

eps
: A length-one numeric value giving the cutoff below which calibration values will be removed.

verbose
: A logical scalar: should extra information be reported (e.g. warning message for dates out of calibration range)?

Value

A CalibratedAges object.

Note

Adapted from **Bchron** BchronCalibrate() by Andrew Parnell and **rcarbon** calibrate() by Andrew Bevan and Enrico Crema.

Author(s)

N. Frerebeau

References

Bronk Ramsey, C. (2008). Radiocarbon Dating: Revolutions in Understanding. *Archaeometry*, 50:249-275. doi:10.1111/j.14754754.2008.00394.x.

See Also

Other radiocarbon tools: F14C, c14_combine(), c14_curve(), c14_ensemble(), c14_plot, c14_sample(), c14_spd(), c14_uncalibrate(), rec_plot

Examples

```
## Calibrate a single date
cal <- c14_calibrate(300, 20)
plot(cal, panel.first = graphics::grid())

## Calibrate multiple dates
cal <- c14_calibrate(
  values = c(5000, 4500),
  errors = c(45, 35),
  names = c("X", "Y")
)
plot(cal, panel.first = graphics::grid())


## Out of 14C range?
out <- c14_calibrate(130, 20)
plot(out)
```

`c14_combine` *Combine 14C*

Description

Combines radiocarbon dates.

Usage

```
c14_combine(values, errors, ...)

## S4 method for signature 'numeric,numeric'
c14_combine(values, errors, groups = NULL)
```

Arguments

`values`	A `numeric` vector giving the BP ages to be calibrated.
`errors`	A `numeric` vector giving the standard deviation of the ages to be calibrated.
`...`	Currently not used.
`groups`	A `factor` in the sense that `as.factor(groups)` defines the the groups to combine with. If `NULL` (the default), all dates are combined. `NA`s will be treated as isolated dates.

Value

A `data.frame` with the following columns:

`groups`	Group names

ages	Combined 14C ages
errors	Combined 14C standard deviations
chi2	Chi-squared test statistic
p	Chi-squared test p-value

Author(s)

N. Frerebeau

References

Ward, G. K. and Wilson, S. R. (1978). Procedures for Comparing and Combining Radiocarbon Age Determinations: A Critique. *Archaeometry* 20(1): 19-31. doi:10.1111/j.14754754.1978.tb00208.x.

See Also

Other radiocarbon tools: `F14C`, `c14_calibrate()`, `c14_curve()`, `c14_ensemble()`, `c14_plot`, `c14_sample()`, `c14_spd()`, `c14_uncalibrate()`, `rec_plot`

Examples

```
## Replicate Ward and Wilson (1978), p. 28
polach1972 <- data.frame(
  samples = c("ANU-7", "ANU-7", "ANU-7", "W-1571", "ANU-5",
              "C-800", "L-698D", "FSU-3", "Tx-44"),
  ages = c(14550, 15000, 13700, 14650, 11700, 10860, 11840, 11245, 10700),
  errors = c(270, 600, 300, 500, 260, 410, 100, 450, 210)
)

c14_combine(
  values = polach1972$ages,
  errors = polach1972$errors,
  groups = polach1972$samples
)
```

---

c14_curve *14C Calibration Curve*

Description

14C Calibration Curve

Usage

```
c14_curve(name, ...)

## S4 method for signature 'character'
c14_curve(name)

## S4 method for signature 'CalibratedAges'
c14_curve(name)
```

Arguments

name	A character vector naming calibration curves (see details).
...	Currently not used.

Details

The following calibration curves are available:

Curve	Reference
intcal04	Reimer et al. 2004
intcal09	Reimer et al. 2009
intcal13	Reimer et al. 2013
intcal20	Reimer et al. 2020
marine04	Hughen et al. 2004
marine09	Reimer et al. 2009
marine13	Reimer et al. 2013
marine20	Heaton et al. 2020
shcal04	McCormac et al. 2004
shcal13	Hogg et al. 2013
shcal20	Hogg et al. 2020

Value

A list of three-column data.frame:

CALBP	Calibrated age BP
AGE	Uncalibrated radiocarbon age
ERROR	Standard deviation

Author(s)

N. Frerebeau

References

Heaton, Timothy J, Peter Köhler, Martin Butzin, Edouard Bard, Ron W Reimer, William E N Austin, Christopher Bronk Ramsey, et al. (2020). Marine20 The Marine Radiocarbon Age Calibration Curve (0-55,000 Cal BP). *Radiocarbon*, 62(4): 779-820. doi:10.1017/RDC.2020.68.

Hogg, Alan G, Timothy J Heaton, Quan Hua, Jonathan G Palmer, Chris SM Turney, John Southon, Alex Bayliss, et al. (2020). SHCal20 Southern Hemisphere Calibration, 0-55,000 Years Cal BP. *Radiocarbon*, 62(4): 759-78. doi:10.1017/RDC.2020.59.

Hogg, Alan G, Quan Hua, Paul G Blackwell, Mu Niu, Caitlin E Buck, Thomas P Guilderson, Timothy J Heaton, et al. (2013). SHCal13 Southern Hemisphere Calibration, 0-50,000 Years Cal BP. *Radiocarbon*, 55(4): 1889-1903. doi:10.2458/azu_js_rc.55.16783.

Hua, Quan, and Mike Barbetti (2004). Review of Tropospheric Bomb 14C Data for Carbon Cycle Modeling and Age Calibration Purposes. *Radiocarbon*, 46(3): 1273-1298. doi:10.1017/S0033822200033142.

Hua, Quan, Mike Barbetti, and Andrzej Z Rakowski (2013). Atmospheric Radiocarbon for the Period 1950-2010. *Radiocarbon*, 55(4): 2059-2072. doi:10.2458/azu_js_rc.v55i2.16177.

Hua, Quan, Jocelyn C Turnbull, Guaciara M Santos, Andrzej Z Rakowski, Santiago Ancapichún, Ricardo De Pol-Holz, Samuel Hammer, et al. (2022). Atmospheric Radiocarbon for the Period 1950-2019. *Radiocarbon*, 64(4): 723-745. doi:10.1017/RDC.2021.95.

Hughen, K., S. Lehman, J. Southon, J. Overpeck, O. Marchal, C. Herring, and J. Turnbull (2004). 14C Activity and Global Carbon Cycle Changes over the Past 50,000 Years. *Science*, 303(5655): 202-207. doi:10.1126/science.1090300.

Hughen, Konrad A, Mike G L Baillie, Edouard Bard, J Warren Beck, Chanda J H Bertrand, Paul G Blackwell, Caitlin E Buck, et al. (2004). Marine04 Marine Radiocarbon Age Calibration, 0-26 cal kyr BP. *Radiocarbon*, 46(3): 1059-1086. doi:10.1017/S0033822200033002.

Kueppers, Lara M., John Southon, Paul Baer, and John Harte (2004). Dead Wood Biomass and Turnover Time, Measured by Radiocarbon, along a Subalpine Elevation Gradient. *Oecologia*, 141(4): 641-651. doi:10.1007/s004420041689x.

McCormac, F G, A G Hogg, P G Blackwell, C E Buck, T F G Higham, and P J Reimer (2004). Shcal04 Southern Hemisphere Calibration, 0-11.0 cal kyr BP. *Radiocarbon*, 46(3): 1087-1092. doi:10.1017/S0033822200033014.

Reimer, P J, M G L Baillie, E Bard, A Bayliss, J W Beck, P G Blackwell, C Bronk Ramsey, et al. (2009). IntCal09 and Marine09 Radiocarbon Age Calibration Curves, 0-50,000 Years cal BP. *Radiocarbon*, 51(4): 1111-1150. doi:10.1017/S0033822200034202.

Reimer, Paula J, William E N Austin, Edouard Bard, Alex Bayliss, Paul G Blackwell, Christopher Bronk Ramsey, Martin Butzin, et al. (2020). The IntCal20 Northern Hemisphere Radiocarbon Age Calibration Curve (0-55 cal kBP). *Radiocarbon*, 62(4): 725-757. doi:10.1017/RDC.2020.41.

Reimer, Paula J, Mike G L Baillie, Edouard Bard, Alex Bayliss, J Warren Beck, Chanda J H Bertrand, Paul G Blackwell, et al. (2004). Intcal04 Terrestrial Radiocarbon Age Calibration, 0-26 cal kyr BP. *Radiocarbon*, 46(3): 1029-1058. doi:10.1017/S0033822200032999.

Reimer, Paula J, Edouard Bard, Alex Bayliss, J Warren Beck, Paul G Blackwell, Christopher Bronk Ramsey, Caitlin E Buck, et al. (2013). IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0-50,000 Years cal BP. *Radiocarbon*, 55(4): 1869-1887. doi:10.2458/azu_js_rc.55.16947.

Stuiver, Minze, Paula J. Reimer, Edouard Bard, J. Warren Beck, G. S. Burr, Konrad A. Hughen, Bernd Kromer, Gerry McCormac, Johannes van der Plicht, and Marco Spurk (1998). INTCAL98

Radiocarbon Age Calibration, 24,000-0 cal BP. *Radiocarbon*, 40(3): 1041-1083. doi:10.1017/S0033822200019123.

Stuiver, Minze, Paula J. Reimer, and Thomas F. Braziunas. (1998). High-Precision Radiocarbon Age Calibration for Terrestrial and Marine Samples. *Radiocarbon*, 40(3): 1127-1151. doi:10.1017/S0033822200019172.

See Also

Other radiocarbon tools: F14C, c14_calibrate(), c14_combine(), c14_ensemble(), c14_plot, c14_sample(), c14_spd(), c14_uncalibrate(), rec_plot

Examples

```
## IntCal20
intcal20 <- c14_curve("intcal20")
head(intcal20[[1]])

## IntCal
intcal <- c14_curve(c("intcal09", "intcal13", "intcal20"))
lapply(X = intcal, FUN = head)
```

---

c14_ensemble *Radiocarbon Event Count*

Description

Radiocarbon Event Count

Usage

```
c14_ensemble(object, ...)

## S4 method for signature 'CalibratedAges'
c14_ensemble(
  object,
  from = NULL,
  to = NULL,
  by = 10,
  n = 100,
  calendar = BP(),
  progress = getOption("ananke.progress")
)
```

Arguments

object	A CalibratedAges object.
...	Currently not used.

from	length-one numeric vector specifying the earliest data to calibrate for (in cal BP years).
to	A length-one numeric vector specifying the latest data to calibrate for (in cal BP years).
by	A length-one numeric vector specifying the temporal resolution (in years) of the calibration.
n	An integer specifying the number of item to choose randomly.
calendar	An aion::TimeScale object specifying the target calendar (see aion::calendar()). Defaults to aion::CE(). If NULL, *rata die* are returned.
progress	A logical scalar: should a progress bar be displayed?

Value

An RECE object.

Note

This function is currently *experimental*.

Author(s)

N. Frerebeau

References

Carleton, W. C. (2021). Evaluating Bayesian Radiocarbon-dated Event Count (REC) Models for the Study of Long-term Human and Environmental Processes. *Journal of Quaternary Science*, 36(1): 110-23. doi:10.1002/jqs.3256.

See Also

Other radiocarbon tools: F14C, c14_calibrate(), c14_combine(), c14_curve(), c14_plot, c14_sample(), c14_spd(), c14_uncalibrate(), rec_plot

---

c14_plot *Plot Calibrated Radiocarbon Ages*

Description

Plot Calibrated Radiocarbon Ages

Usage

```
## S4 method for signature 'CalibratedAges,missing'
plot(
  x,
  calendar = get_calendar(),
  density = TRUE,
  interval = c("hdr", "credible", "none"),
  level = 0.954,
  fixed = TRUE,
  decreasing = TRUE,
  col.density = "grey",
  col.interval = "#77AADD",
  main = NULL,
  sub = NULL,
  axes = TRUE,
  frame.plot = FALSE,
  ann = graphics::par("ann"),
  panel.first = NULL,
  panel.last = NULL,
  ...
)

## S4 method for signature 'CalibratedSPD,missing'
plot(
  x,
  calendar = get_calendar(),
  main = NULL,
  sub = NULL,
  ann = graphics::par("ann"),
  axes = TRUE,
  frame.plot = FALSE,
  panel.first = NULL,
  panel.last = NULL,
  ...
)
```

Arguments

x	A CalibratedAges or CalibratedSPD object.
calendar	An aion::TimeScale object specifying the target calendar (see aion::calendar()). If NULL, *rata die* are returned.
density	A logical scalar: should density be drawn?
interval	A character string specifying the intervals to be drawn. It must be one of "hrd" (the default), "credible" or "none". Any unambiguous substring can be given.
level	A length-one numeric vector giving the confidence level. Only used if interval is TRUE.

fixed	A logical scalar: should a fixed y scale be used? If TRUE (the default), ages are equally spaced along the y axis. If FALSE, age positions are used (see c14_calibrate()).
decreasing	A logical scalar: should the sort order be decreasing?
col.density, col.interval	A specification for the plotting colors.
main	A character string giving a main title for the plot.
sub	A character string giving a subtitle for the plot.
axes	A logical scalar: should axes be drawn on the plot?
frame.plot	A logical scalar: should a box be drawn around the plot?
ann	A logical scalar: should the default annotation (title and x and y labels) appear on the plot?
panel.first	An an expression to be evaluated after the plot axes are set up but before any plotting takes place. This can be useful for drawing background grids.
panel.last	An expression to be evaluated after plotting has taken place but before the axes, title and box are added.
...	Other graphical parameters may also be passed as arguments to this function.

Value

plot() is called it for its side-effects: it results in a graphic being displayed. Invisibly returns x.

Author(s)

N. Frerebeau

See Also

Other radiocarbon tools: F14C, c14_calibrate(), c14_combine(), c14_curve(), c14_ensemble(), c14_sample(), c14_spd(), c14_uncalibrate(), rec_plot

Examples

```
## Calibrate multiple dates
cal <- c14_calibrate(
  values = c(5000, 4500),
  errors = c(45, 35),
  names = c("X", "Y")
)

## Specify calendar
plot(cal, calendar = BP())

## HDR intervals (default)
plot(cal, interval = "hdr", level = 0.95)

## Credible intervals
plot(cal, interval = "credible", level = 0.95)
```

```
## No intervals
plot(cal, interval = NULL)

## Intervals only
plot(cal, density = FALSE, level = 0.68, lwd = 5)
plot(cal, density = FALSE, level = 0.95, lwd = 5)

## Change colors
plot(cal[, 1, ], col.interval = "red")
```

`c14_sample` *Sample Calibrated Ages*

Description

Sample Calibrated Ages

Usage

```
c14_sample(object, ...)

## S4 method for signature 'CalibratedAges'
c14_sample(object, n = 100, calendar = get_calendar())
```

Arguments

`object`	A `CalibratedAges` object.
`...`	Currently not used.
`n`	An `integer` specifying the number of random samples.
`calendar`	An `aion::TimeScale` object specifying the target calendar (see `aion::calendar()`). Defaults to `aion::CE()`. If `NULL`, *rata die* are returned.

Value

An `numeric` matrix.

Author(s)

N. Frerebeau

See Also

Other radiocarbon tools: `F14C`, `c14_calibrate()`, `c14_combine()`, `c14_curve()`, `c14_ensemble()`, `c14_plot`, `c14_spd()`, `c14_uncalibrate()`, `rec_plot`

Examples

```
## Calibrate multiple dates
cal <- c14_calibrate(
  values = c(5000, 4500),
  errors = c(45, 35),
  names = c("X", "Y")
)

## Sample
spl <- c14_sample(cal, n = 100)
```

---

c14_spd *Summed Probability Distributions*

Description

Computes summed probability distributions (SPD) of radiocarbon dates.

Usage

```
c14_spd(object, ...)

## S4 method for signature 'CalibratedAges'
c14_spd(object, normalize_date = FALSE, normalize_spd = FALSE)
```

Arguments

object	A CalibratedAges object.
...	Currently not used.
normalize_date	A logical scalar: should the total probability mass of the calibrated dates be normalised (to sum to unity within the time-span of analysis)?
normalize_spd	A logical scalar: should the total probability mass of the SPD be normalised (to sum to unity)?

Details

Summed probability distributions (SPD) are not statistically valid estimators of the calendar age of a potential future sample. They should not be used in any dates-as-data approach to provide a population proxy.

Value

A CalibratedSPD object.

Author(s)

N. Frerebeau

See Also

Other radiocarbon tools: F14C, c14_calibrate(), c14_combine(), c14_curve(), c14_ensemble(), c14_plot, c14_sample(), c14_uncalibrate(), rec_plot

Examples

```
## Radiocarbon data from Bosch et al. 2015
data("ksarakil")

## Calibrate
cal <- c14_calibrate(
  values = ksarakil$date,
  errors = ksarakil$error,
  names = ksarakil$code,
  curves = "marine13",
  reservoir_offsets = 53,
  reservoir_errors = 43,
  from = 50000, to = 0
)
plot(cal, level = 0.68)

## SPD
s <- c14_spd(cal)
plot(s)
```

---

c14_uncalibrate *Uncalibrate a Radiocarbon Date*

Description

Uncalibrate a Radiocarbon Date

Usage

```
c14_uncalibrate(object, ...)

## S4 method for signature 'numeric'
c14_uncalibrate(object, curves = "intcal20")

## S4 method for signature 'CalibratedAges'
c14_uncalibrate(object, n = 10000, rounding = getOption("ananke.round"), ...)
```

Arguments

object	A CalibratedAges object or a numeric vector of calibrated ages (in years BP).
...	Currently not used.
curves	A character vector specifying the calibration curve to be used. Different curves can be specified.

n	An integer specifying the number of random samples.
rounding	A character string specifying the rounding convention. It can be one of "none" (the default, no rounding) or "stuiver". Any unambiguous substring can be given.

Author(s)

N. Frerebeau

See Also

Other radiocarbon tools: F14C, c14_calibrate(), c14_combine(), c14_curve(), c14_ensemble(), c14_plot, c14_sample(), c14_spd(), rec_plot

Examples

```
## Calibrate multiple dates
cal <- c14_calibrate(
  values = c(5000, 4500),
  errors = c(45, 35),
  names = c("X", "Y")
)

## Uncalibrate
c14_uncalibrate(cal, rounding = "stuiver")
```

---

describe *Data Description*

Description

Data Description

Usage

```
## S4 method for signature 'CalibratedAges'
describe(x, calendar = get_calendar(), level = 0.954, ...)
```

Arguments

x	A CalibratedAges object.
calendar	An aion::TimeScale object specifying the target calendar (see aion::calendar()).
level	A length-one numeric vector giving the confidence level.
...	Further parameters to be passed to cat().

Value

`describe()` is called for its side-effects. Invisibly returns `x`.

Author(s)

N. Frerebeau

References

Millard, A. R. (2014). Conventions for Reporting Radiocarbon Determinations. *Radiocarbon*, 56(2): 555-559. doi:10.2458/56.17455.

Examples

```
## Calibrate multiple dates
cal <- c14_calibrate(
  values = c(5000, 4500),
  errors = c(45, 35),
  names = c("X", "Y")
)

## Full text description
describe(cal)
```

`F14C` *F14C*

Description

Converts F14C values to 14C ages.

Usage

```
BP14C_to_F14C(values, errors, ...)

F14C_to_BP14C(values, errors, ...)

## S4 method for signature 'numeric,numeric'
BP14C_to_F14C(values, errors, lambda = 8033)

## S4 method for signature 'numeric,numeric'
F14C_to_BP14C(
  values,
  errors,
  lambda = 8033,
  asymmetric = FALSE,
  rounding = getOption("ananke.round")
)
```

Arguments

values	A numeric vector giving the radiocarbon ages or the F14C values.
errors	A numeric vector giving the standard deviations.
...	Currently not used.
lambda	A length-one numeric vector specifying the mean-life of radiocarbon (defaults to 14C half-life value as introduced by Libby 1952).
asymmetric	A logical scalar: should asymmetric 14C errors be returned (van der Plicht & Hogg, 2006)?
rounding	A character string specifying the rounding convention. It can be one of "none" (the default, no rounding) or "stuiver". Any unambiguous substring can be given.

Value

A data.frame.

Author(s)

N. Frerebeau

References

Bronk Ramsey, C. (2008). Radiocarbon Dating: Revolutions in Understanding. *Archaeometry*, 50:249-275. doi:10.1111/j.14754754.2008.00394.x.

Stuiver, M., Polach, H. A. (1977). Discussion Reporting of 14C Data. *Radiocarbon*, 19(3): 355-363. doi:10.1017/S0033822200003672.

van der Plicht, J., Hogg, A. (2006). A Note on Reporting Radiocarbon. *Quaternary Geochronology*, 1(4): 237-240. doi:10.1016/j.quageo.2006.07.001.

See Also

Other radiocarbon tools: c14_calibrate(), c14_combine(), c14_curve(), c14_ensemble(), c14_plot, c14_sample(), c14_spd(), c14_uncalibrate(), rec_plot

Examples

```
## Asymmetric 14C errors (van der Plicht and Hogg 2006)
F14C_to_BP14C(0.0052, 0.0006, asym = TRUE)

## Symmetric 14C errors (Bronk Ramsey 2008)
F14C_to_BP14C(0.0052, 0.0006, asym = FALSE)
```

`interval_credible` *Bayesian Credible Interval*

Description

Bayesian Credible Interval

Usage

```
## S4 method for signature 'CalibratedAges'
interval_credible(x, level = 0.954, n = 100, ...)
```

Arguments

`x`	A `CalibratedAges` object.
`level`	A length-one `numeric` vector giving the confidence level.
`n`	An `integer` specifying the number of random samples.
`...`	Currently not used.

Value

A `CalibratedIntervals` object.

Author(s)

N. Frerebeau

See Also

`arkhe::interval_credible()`

Other statistics: `interval_hdr()`, `mean()`, `median()`, `quantile()`

Examples

```
## Calibrate multiple dates
cal <- c14_calibrate(
  values = c(5000, 4500),
  errors = c(45, 35),
  names = c("X", "Y")
)

## Credible intervals
crd68 <- interval_credible(cal, level = 0.683)
crd95 <- interval_credible(cal, level = 0.954)
crd99 <- interval_credible(cal, level = 0.997)

## Coerce to data.frame
as.data.frame(crd95, calendar = BC())
```

```
## Plot
plot(cal, interval = "credible")
```

`interval_hdr` *Highest Density Regions*

Description

Highest Density Regions

Usage

```
## S4 method for signature 'CalibratedAges,missing'
interval_hdr(x, level = 0.954, ...)
```

Arguments

`x`	A `CalibratedAges` object.
`level`	A length-one `numeric` vector giving the confidence level.
`...`	Currently not used.

Value

A `CalibratedIntervals` object.

Author(s)

N. Frerebeau

References

Hyndman, R. J. (1996). Computing and graphing highest density regions. *American Statistician*, 50: 120-126. doi:10.2307/2684423.

See Also

`stats::density()`, `arkhe::interval_hdr()`

Other statistics: `interval_credible()`, `mean()`, `median()`, `quantile()`

Examples

```
## Calibrate multiple dates
cal <- c14_calibrate(
  values = c(5000, 4500),
  errors = c(45, 35),
  names = c("X", "Y")
)

## HDR
hdr68 <- interval_hdr(cal, level = 0.683)
hdr95 <- interval_hdr(cal, level = 0.954)
hdr99 <- interval_hdr(cal, level = 0.997)

## Coerce to data.frame
as.data.frame(hdr95, calendar = BC())

## Plot
plot(cal, interval = "hdr")
```

`ksarakil` *Ksâr 'Akil Radiocarbon Dates*

Description

Ksâr 'Akil Radiocarbon Dates

Usage

```
ksarakil
```

Format

A `data.frame` with 16 rows and 5 variables:

code Laboratory code.

date Radiocarbon date (year BP).

error Radiocarbon error (year).

layer Stratigraphic layer.

phase Chronological phase.

Source

Bosch, M. D., Mannino, M. A., Prendergast, A. L., O'Connell, T. C., Demarchi, B., Taylor, S. M., Niven, L., van der Plicht, J. and Hublin, J.-J. (2015). New Chronology for Ksâr 'Akil (Lebanon) Supports Levantine Route of Modern Human Dispersal into Europe. *Proceedings of the National Academy of Sciences* 112(25): 7683-8. doi:10.1073/pnas.1501529112.

labels *Find Labels from Object*

Description

Find a suitable set of labels from an object for use in printing or plotting, for example.

Usage

```
## S4 method for signature 'CalibratedAges'
labels(object, ...)
```

Arguments

object	An object from which to find labels.
...	Currently not used.

Value

A character vector.

Author(s)

N. Frerebeau

See Also

Other mutators: as.data.frame(), as.list(), mutators, subset()

mean *Mean*

Description

Mean

Usage

```
## S4 method for signature 'CalibratedAges'
mean(x, na.rm = FALSE, ..., calendar = get_calendar())

## S4 method for signature 'ProxyRecord'
mean(x, na.rm = FALSE, ...)
```

Arguments

x	A CalibratedAges object.
na.rm	A logical scalar: should NA values be stripped before the computation proceeds?
...	Currently not used.
calendar	An aion::TimeScale object specifying the target calendar (see aion::calendar()). If NULL, *rata die* are returned.

Value

A numeric vector.

Author(s)

N. Frerebeau

See Also

Other statistics: interval_credible(), interval_hdr(), median(), quantile()

Examples

```
## Calibrate multiple dates
cal <- c14_calibrate(
  values = c(5000, 4500),
  errors = c(45, 35),
  names = c("X", "Y")
)

## Statistics
quantile(cal)
median(cal)
mean(cal)

## Plot
plot(cal, calendar = CE())

## Need to set 'calendar'
abline(v = median(cal, calendar = CE()), lty = 2, col = "blue")
abline(v = mean(cal, calendar = CE()), lty = 2, col = "red")
```

---

median *Median*

Description

Median

Usage

```
## S4 method for signature 'CalibratedAges'
median(x, na.rm = FALSE, ..., calendar = get_calendar())
```

Arguments

x	A CalibratedAges object.
na.rm	A logical scalar: should NA values be stripped before the computation proceeds?
...	Currently not used.
calendar	An aion::TimeScale object specifying the target calendar (see aion::calendar()). If NULL, *rata die* are returned.

Value

A numeric vector.

Author(s)

N. Frerebeau

See Also

Other statistics: interval_credible(), interval_hdr(), mean(), quantile()

Examples

```
## Calibrate multiple dates
cal <- c14_calibrate(
  values = c(5000, 4500),
  errors = c(45, 35),
  names = c("X", "Y")
)

## Statistics
quantile(cal)
median(cal)
mean(cal)

## Plot
plot(cal, calendar = CE())

## Need to set 'calendar'
abline(v = median(cal, calendar = CE()), lty = 2, col = "blue")
abline(v = mean(cal, calendar = CE()), lty = 2, col = "red")
```

mutators *Get or Set Parts of an Object*

Description

Getters and setters to extract or replace parts of an object.

Arguments

x	An object from which to get or set element(s).
value	A possible value for the element(s) of x.

Value

An object of the same sort as x with the new values assigned.

Author(s)

N. Frerebeau

See Also

Other mutators: as.data.frame(), as.list(), labels(), subset()

pb_age *Geological Model Age from Lead Isotope Analysis*

Description

Compute geological model age (T) and U/Pb (mu) and Th/U (kappa) ratios from lead isotopic measurements.

Usage

```
pb_age(x, y, z, ...)

## S4 method for signature 'numeric,numeric,numeric'
pb_age(
  x,
  y,
  z,
  t0 = 3.8,
  x_star = 18.75,
  y_star = 15.63,
  z_star = 38.86,
```

```
  mu = 9.66,
  kappa = 3.9,
  th232 = 0.049475,
  u238 = 0.155125,
  u235 = 0.98485,
  u238_235 = 137.79,
  tolerance = sqrt(.Machine$double.eps),
  stop = 100
)

## S4 method for signature 'list,missing,missing'
pb_age(
  x,
  t0 = 3.8,
  x_star = 18.75,
  y_star = 15.63,
  z_star = 38.86,
  mu = 9.66,
  kappa = 3.9,
  th232 = 0.049475,
  u238 = 0.155125,
  u235 = 0.98485,
  u238_235 = 137.79,
  tolerance = sqrt(.Machine$double.eps),
  stop = 100
)
```

Arguments

x	A numeric vector of 206Pb/204Pb ratios. If y and z are missing, must be a list (or a data.frame) with numeric components (columns) x, y and z.
y	A numeric vector of 207Pb/204Pb ratios. If missing, an attempt is made to interpret x in a suitable way.
z	A numeric vector of 208Pb/204Pb ratios. If missing, an attempt is made to interpret x in a suitable way.
...	Currently not used.
t0	A numeric value giving the time of the second stage of the reference model.
x_star	A numeric value giving the 206Pb/204Pb ratio at $t = 0$.
y_star	A numeric value giving the 207Pb/204Pb ratio at $t = 0$.
z_star	A numeric value giving the 208Pb/204Pb ratio at $t = 0$.
mu	A numeric value giving the 238U/204Pb ratio of the reference model.
kappa	A numeric value giving the 232Th/238U ratio of the reference model.
th232	A numeric value giving the decay constants of 232Th.
u238	A numeric value giving the decay constants of 238U.
u235	A numeric value giving the decay constants of 235U.

u238_235	A numeric value giving the actual 238U/235U ratio.
tolerance	A numeric value specifying the tolerance (stopping criteria for the Newton–Raphson method).
stop	An integer giving the stopping rule (i.e. maximum number of iterations) to avoid infinite loop.

Value

A four columns data.frame:

age Geological model age (in Ma).

mu 238U/204Pb ratio.

kappa 232Th/238U ratio.

residual Newton loop residual.

Note

Reference values from Albarede & Juteau (1984).

Author(s)

N. Frerebeau, F. Albarede (original Matlab code)

References

Albarède, F., Desaulty, A.-M. & Blichert-Toft, J. (2012). A Geological Perspective on the Use of Pb Isotopes in Archaeometry. *Archaeometry*, 54: 853-867. doi:10.1111/j.14754754.2011.00653.x.

Albarède, F. & Juteau, M. (1984). Unscrambling the Lead Model Ages. *Geochimica et Cosmochimica Acta*, 48(1): 207-12. doi:10.1016/00167037(84)903648.

Allègre, C. (2005). *Géologie isotopique*. Belin sup. Paris: Belin.

Examples

```
Pb <- data.frame(
  x = c(18.23247, 18.22936, 18.23102), # Pb206/Pb204
  y = c(15.65199, 15.65216, 15.65097), # Pb207/Pb204
  z = c(38.5167, 38.51516, 38.51601)   # Pb208/Pb204
)

## Default reference values from Albarede & Juteau (1984)
pb_age(
  Pb,
  t0 = 3.8,
  x_star = 18.75, y_star = 15.63, z_star = 38.86,
  mu = 9.66, kappa = 3.90, th232 = 0.049475,
  u238 = 0.155125, u235 = 0.98485, u238_235 = 137.79
)

## Reference values from Albarede et al. (2012)
```

```
pb_age(
  Pb,
  t0 = 4.43,
  x_star = 18.75, y_star = 15.63, z_star = 38.83,
  mu = 9.66, kappa = 3.90, th232 = 0.049475,
  u238 = 0.155125, u235 = 0.98485, u238_235 = 137.79
)
```

`proxy_ensemble` *Layer-Counted Proxy Records Uncertainties*

Description

Represents layer-counted proxy records as sequences of probability distributions on absolute, error-free time axes.

Usage

```
proxy_ensemble(positions, ...)

## S4 method for signature 'numeric'
proxy_ensemble(
  positions,
  proxy_values,
  proxy_errors,
  proxy_step,
  time_values,
  time_errors,
  calendar,
  from = NULL,
  to = NULL,
  by = NULL,
  n = 30,
  progress = getOption("ananke.progress"),
  verbose = getOption("ananke.verbose")
)
```

Arguments

`positions`	A positive `numeric` vector giving the positions (e.g. depths) at which proxy values and calendar ages were measured. In the case of layers of non-zero thickness, this should be the middle value of the slice. It must be in decreasing order (i.e. in chronological order).
`...`	Currently not used.
`proxy_values`	A `numeric` vector giving the proxy values.
`proxy_errors`	A `numeric` vector giving the proxy uncertainties.

proxy_step	A length-one numeric vector specifying the step size (in units of proxy_values) at which proxy records densities are to be estimated.
time_values	A numeric vector giving the calendar ages (in years).
time_errors	A numeric vector giving the calendar age uncertainties (in years).
calendar	An aion::TimeScale object specifying the calendar of time (see aion::calendar()).
from	A length-one numeric vector specifying the starting value of the temporal sequence at which densities are to be estimated (in years).
to	A length-one numeric vector specifying the end value of the temporal sequence at which densities are to be estimated (in cal BP years).
by	A length-one numeric vector specifying the increment of the temporal sequence at which densities are to be estimated (in years).
n	An integer specifying the number of item to choose randomly.
progress	A logical scalar: should a progress bar be displayed?
verbose	A logical scalar: should extra information be reported?

Value

A ProxyRecord object.

Note

This function is currently *experimental*.

Author(s)

N. Frerebeau

References

Boers, N., Goswami, B. & Ghil, M. (2017). A Complete Representation of Uncertainties in Layer-Counted Paleoclimatic Archives. *Climate of the Past*, 13(9): 1169-1180. doi:10.5194/cp131169-2017.

See Also

Other proxy tools: proxy_plot

Examples

```
## Get NGRIP records
data("ngrip2010", package = "folio")
ngrip2010 <- subset(ngrip2010, !is.na(MCE))
ngrip2010 <- ngrip2010[nrow(ngrip2010):1, ] # Sort in chronological order

## Replicate fig. 3d from Boers et al. (2017)
## /!\ This may take a while... /!\
ngrip_record <- proxy_ensemble(
  positions = ngrip2010$depth,
```

```
  proxy_values = ngrip2010$delta,
  proxy_errors = 0.01,
  proxy_step = 0.01,
  time_values = ngrip2010$age,
  time_errors = ngrip2010$MCE,
  calendar = b2k(), # /!\
  by = 20,
  n = 30
)

plot(ngrip_record)
```

---

proxy_plot *Plot Layer-Counted Proxy Records Uncertainties*

Description

Plot Layer-Counted Proxy Records Uncertainties

Usage

```
## S4 method for signature 'ProxyRecord,missing'
plot(
  x,
  calendar = get_calendar(),
  iqr = TRUE,
  xlab = NULL,
  ylab = NULL,
  col = grDevices::hcl.colors(12, "YlOrRd", rev = TRUE),
  col.mean = "black",
  col.iqr = col.mean,
  lty.mean = 1,
  lty.iqr = 3,
  lwd.mean = 2,
  lwd.iqr = lwd.mean,
  ...
)
```

Arguments

x	A ProxyRecord object.
calendar	An aion::TimeScale object specifying the target calendar (see aion::calendar()). If NULL, *rata die* are returned.
iqr	A logical scalar: should the mean and IQR be displayed?
xlab, ylab	A character string giving a label for the x and y axis.
col	A list of colors such as that generated by grDevices::hcl.colors().

`col.mean`, `col.iqr`
: A specification for the line colors. Only used if `iqr` is `TRUE`.

`lty.mean`, `lty.iqr`
: A specification for the line types. Only used if `iqr` is `TRUE`.

`lwd.mean`, `lwd.iqr`
: A specification for the line widths. Only used if `iqr` is `TRUE`.

`...`
: Further parameters to be passed to `graphics::image()`.

Value

`plot()` is called it for its side-effects: it results in a graphic being displayed. Invisibly returns `x`.

Author(s)

N. Frerebeau

See Also

Other proxy tools: `proxy_ensemble()`

Examples

```
## Get NGRIP records
data("ngrip2010", package = "folio")
ngrip2010 <- subset(ngrip2010, !is.na(MCE))
ngrip2010 <- ngrip2010[nrow(ngrip2010):1, ] # Sort in chronological order

## Replicate fig. 3d from Boers et al. (2017)
## /!\ This may take a while... /!\
ngrip_record <- proxy_ensemble(
  positions = ngrip2010$depth,
  proxy_values = ngrip2010$delta,
  proxy_errors = 0.01,
  proxy_step = 0.01,
  time_values = ngrip2010$age,
  time_errors = ngrip2010$MCE,
  calendar = b2k(), # /!\
  by = 20,
  n = 30
)

plot(ngrip_record)
```

quantile *Quantiles of a Density Estimate*

Description

Quantiles of a Density Estimate

Usage

```
## S4 method for signature 'CalibratedAges'
quantile(
  x,
  probs = seq(0, 1, 0.25),
  na.rm = FALSE,
  ...,
  calendar = get_calendar()
)

## S4 method for signature 'ProxyRecord'
quantile(x, probs = seq(0, 1, 0.25), na.rm = FALSE, ...)
```

Arguments

x	A CalibratedAges object.
probs	A numeric vector of probabilities with values in $[0, 1]$.
na.rm	A logical scalar: should NA values be stripped before the computation proceeds?
...	Currently not used.
calendar	An aion::TimeScale object specifying the target calendar (see aion::calendar()). If NULL, *rata die* are returned.

Value

A numeric matrix containing the quantiles.

Author(s)

N. Frerebeau

See Also

Other statistics: interval_credible(), interval_hdr(), mean(), median()

Examples

```
## Calibrate multiple dates
cal <- c14_calibrate(
  values = c(5000, 4500),
  errors = c(45, 35),
  names = c("X", "Y")
)

## Statistics
quantile(cal)
median(cal)
mean(cal)

## Plot
plot(cal, calendar = CE())

## Need to set 'calendar'
abline(v = median(cal, calendar = CE()), lty = 2, col = "blue")
abline(v = mean(cal, calendar = CE()), lty = 2, col = "red")
```

`rec_plot` *Plot a Radiocarbon Event Count Ensemble*

Description

Plot a Radiocarbon Event Count Ensemble

Usage

```
## S4 method for signature 'RECE,missing'
plot(x, calendar = get_calendar(), ...)
```

Arguments

`x`	An `RECE` object.
`calendar`	An `aion::TimeScale` object specifying the target calendar (see `aion::calendar()`). If `NULL`, *rata die* are returned.
`...`	Further parameters to be passed to `graphics::image()`.

Value

`image()` is called it for its side-effects: it results in a graphic being displayed (invisibly returns `x`).

Author(s)

N. Frerebeau

References

Carleton, W. C. (2021). Evaluating Bayesian Radiocarbon-dated Event Count (REC) Models for the Study of Long-term Human and Environmental Processes. *Journal of Quaternary Science*, 36(1): 110-23. doi:10.1002/jqs.3256.

See Also

Other radiocarbon tools: `F14C`, `c14_calibrate()`, `c14_combine()`, `c14_curve()`, `c14_ensemble()`, `c14_plot`, `c14_sample()`, `c14_spd()`, `c14_uncalibrate()`

`subset` *Extract or Replace Parts of an Object*

Description

Operators acting on objects to extract or replace parts.

Usage

```
## S4 method for signature 'CalibratedAges'
x[i, j, k, drop = FALSE]
```

Arguments

`x`	An object from which to extract element(s) or in which to replace element(s).
`i, j, k`	Indices specifying elements to extract or replace.
`drop`	A `logical` scalar: should the result be coerced to the lowest possible dimension? This only works for extracting elements, not for the replacement.

Value

A subsetted object.

Author(s)

N. Frerebeau

See Also

Other mutators: `as.data.frame()`, `as.list()`, `labels()`, `mutators`

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