HafAn

a *GCDkit* plugin for
interpretation of
Lu–Hf isotopic data

June 14, 2024

R topics documented:

`hfAddResults` *Append Hf in Zrn isotopic data*

Description

Appends the calculated isotopic parameters stored in the matrix '`Hfinit`' to the other numeric data already in the system, typically trace-element analyses.

Usage

```
hfAddResults()
```

Value

Modifies the numeric data matrix('`WR`') to which it appends the following columns:

Menu item	**Explanation**
176Hf/177Hfi	Initial Hf isotopic ratios
EpsHfi	Initial ϵ(Hf) values

HfTCHUR.1stg	Single-stage CHUR Hf model ages
HfTDM.1stg	Single-stage DM Hf model ages
HfTDM.2stg	Two-stage DM Hf model ages

Plugin

Hf.r

Author(s)

Vojtěch Janoušek, <vojtech.janousek@geology.cz>

References

Spencer CJ, Kirkland CL, Roberts NMW, Evans NJ, Liebmann J (2020) Strategies towards robust interpretations of in situ zircon Lu–Hf isotope analyses. Geosci Front 11:843-853. doi: 10.1016/j.gsf.2019.09.004

See Also

hfIso, addResults, hfSaveResults

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hfAgeEps *Plotting Hf growth lines*

Description

Plots single- or two-stage Hf growth curves in the binary diagram age-ϵ(Hf) values.

Usage

```
hfAgeEps1(which = rownames(Hfinit),
    xmin = 0, xmax = NULL, ymin = NULL, ymax = 20,
    evol.lines1 = FALSE, evol.lines2 = TRUE, violins = FALSE,
    age.hist = FALSE, kde.bandwidth = 30, rugs = TRUE,
    pch = labels[which, "Symbol"], col = labels[which,"Colour"],
    cex = labels[which, "Size"], new = TRUE,
    main = "Single-stage Hf isotopic growth diagram",...)

hfAgeEps2(which = rownames(Hfinit), RCC = R.crust,
    xmin = 0, xmax = NULL, ymin = NULL, ymax = 20,
    evol.lines1 = FALSE, evol.lines2 = TRUE, violins = FALSE,
    age.hist = FALSE, kde.bandwidth = 30, rugs = TRUE,
    pch = labels[which, "Symbol"], col = labels[which,"Colour"],
    cex = labels[which, "Size"], new = TRUE,
    main = "Two-stage Hf isotopic growth diagram",...)
```

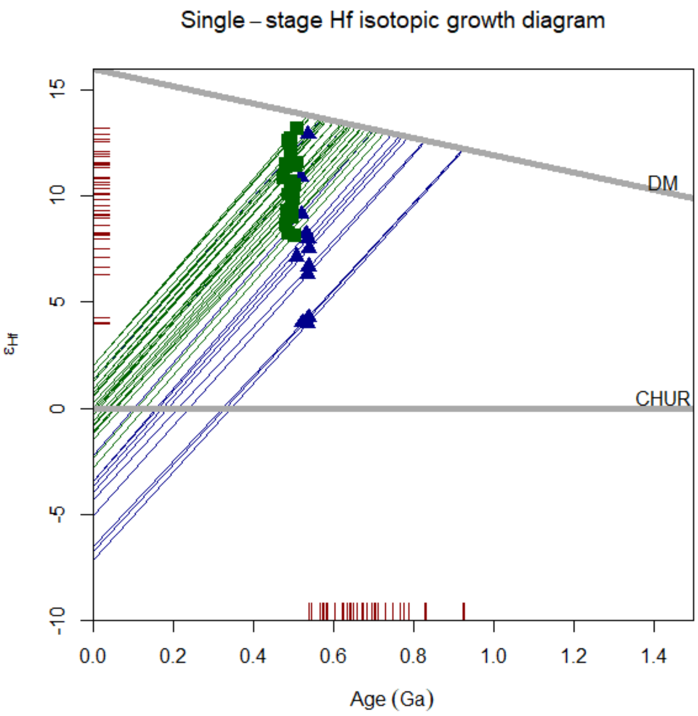
Arguments

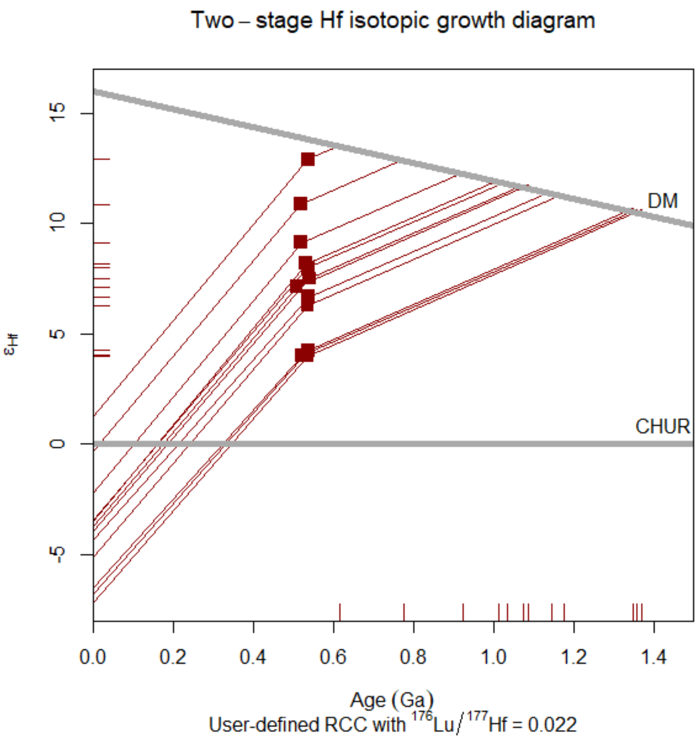
`which`	character or numeric; names or sequence numbers of the samples to be used
`RCC`	numeric; the $^{176}Lu/^{177}Hf$ ratio of the intermediate crustal reservoir for calculation of the two-stage model
`xmin`	numeric; minimum of the age axis in Ga
`xmax`	numeric; maximum of the age axis in Ga
`ymin`	numeric; minimum of the ϵ(Hf) axis
`ymax`	numeric; maximum of the ϵ(Hf) axis
`evol.lines1`	logical; plot the evolution lines from present to the `'age'`?
`evol.lines2`	logical; plot the evolution lines from the `'age'` to the DM?
`violins`	logical; overplot the violin plots for each group?
`age.hist`	logical; overplot the frequency histogram of U–Pb ages?
`kde.bandwidth`	numeric; KDE bandwidth.
`rugs`	logical; show the rugs on both axes?
`pch`	plotting symbols
`col`	plotting colours
`cex`	relative size of the plotting symbols
`new`	logical; should be a new plotting window opened?
`main`	main title for the plot
`...`	optional parameters to the underlying function plotWithLimits

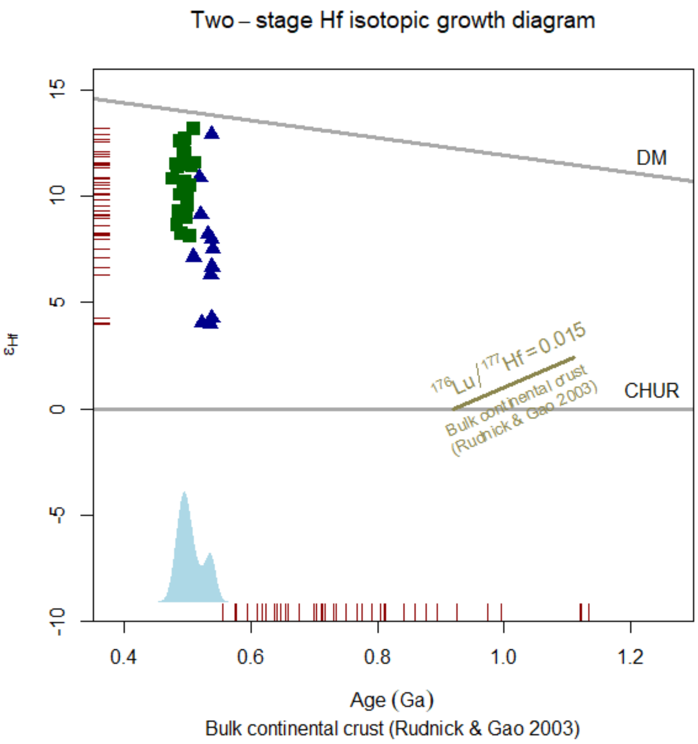
Details

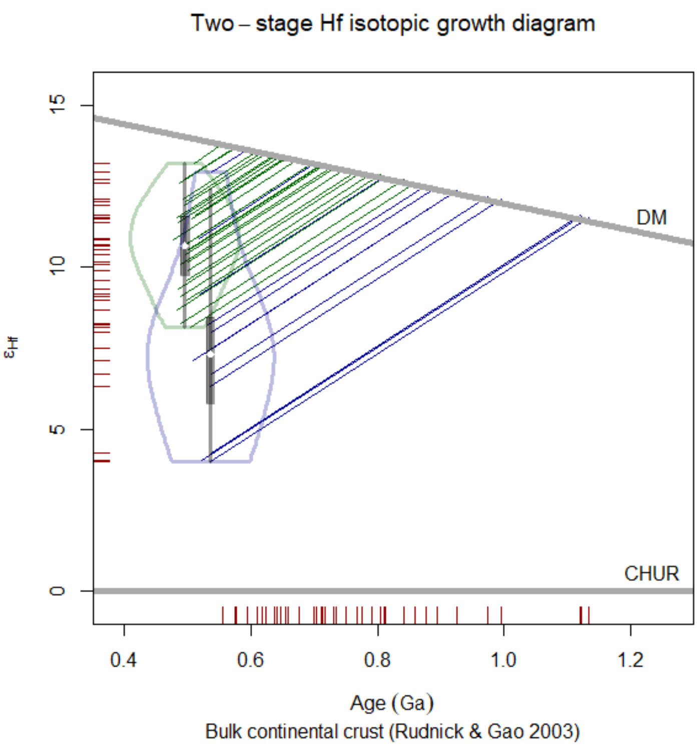
Hafnium growth curves in individual samples can be plotted using either single- or two-stage models *(Kemp & Hawkesworth 2003, 2014)*. Moreover, shown are Hf growth curves for the two main mantle reservoirs, CHUR and Depleted Mantle (DM). The optional small ticks, or rug, on the x axis correspond to depleted-mantle Hf model ages (single- or two-stage, respectively). On the y axis, the extra ticks portray the initial ϵ(Hf) values.

Another option, controlled by the argument `age.hist`, is plotting of the kernel density estimate (KDE) curve for the U–Pb ages along the x axis. The smoothness of this curve can be controlled by the parameter `kde.bandwidth`, with the 'convenient compromise' σ = 30 *(Vermeesch & Garzanti 2015; Andersen et al. 2018)* set as a default value. In general, the higher is this value, the smoother curve results.


Single – stage Hf isotopic growth diagram
DM
CHUR
εHf
Age (Ga)
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4
-10 -5 0 5 10 15


Two – stage Hf isotopic growth diagram
DM
CHUR
εHf
Age (Ga)
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4
-5 0 5 10 15
User-defined RCC with 176Lu/177Hf = 0.022


Two – stage Hf isotopic growth diagram
DM
CHUR
$^{176}Lu/^{177}Hf = 0.015$
Bulk continental crust
(Rudnick & Gao 2003)
ε_{Hf}
Age (Ga)
Bulk continental crust (Rudnick & Gao 2003)


Two – stage Hf isotopic growth diagram
DM
CHUR
ε_{Hf}
Age (Ga)
Bulk continental crust (Rudnick & Gao 2003)

Value

None.

Plugin

Hf.r

Note

This function is Figaro compatible (except violins). For the Hf growth diagram of age vs. initial $^{176}Hf/^{177}Hf$, see hfAgeHfHf2.

Author(s)

Vojtěch Janoušek, <vojtech.janousek@geology.cz>

References

Andersen T, Kristoffersen M, Elburg MA (2018) Visualizing, interpreting and comparing detrital zircon age and Hf isotope data in basin analysis – a graphical approach. Basin Res 30:132–147 doi: 10.1111/bre.12245

Blichert-Toft J, Albaréde F (1997) The Lu–Hf isotope geochemistry of chondrites and the evolution of the mantle–crust system. Earth Planet Sci Lett 148:243-258. doi: 10.1016/S0012821X(97)00040-X

Bouvier A, Vervoort JD, Patchett PJ (2008) The Lu–Hf and Sm–Nd isotopic composition of CHUR: constraints from unequilibrated chondrites and implications for the bulk composition of terrestrial planets. Earth Planet Sci Lett 273:48-57. doi: 10.1016/j.epsl.2008.06.010

Chauvel C, Garçon M, Bureau S, Besnault A, Jahn BM, Ding ZL (2014) Constraints from loess on the Hf–Nd isotopic composition of the upper continental crust. Earth Planet Sci Lett 388:48-58. doi: 10.1016/j.epsl.2013.11.045

Griffin WL, Wang X, Jackson SE, Pearson NJ, O'Reilly SY, Xu X, Zhou X (2002) Zircon chemistry and magma mixing, SE China: in-situ analysis of Hf isotopes, Tonglu and Pingtan igneous complexes. Lithos 61:237-269. doi: 10.1016/S00244937(02)000828

Kemp AIS, Hawkesworth CJ (2003) Granitic perspectives on the generation and secular evolution of the continental crust. In: Holland HD, Turekian KK (eds) Treatise on Geochemistry vol. 3, The Crust (ed. R.L. Rudnick). Elsevier-Pergamon, Oxford, pp 349-410. doi: 10.1016/B0080437516/030279

Kemp AIS, Hawkesworth CJ (2014) Growth and differentiation of the continental crust from isotope studies of accessory minerals. In: Holland HD, Turekian KK (eds) Treatise on Geochemistry (Second Edition). Elsevier, Oxford, pp 379-421. doi: 10.1016/B9780080959757.003120

Lancaster PJ, Storey CD, Hawkesworth CJ, Dhuime B (2011) Understanding the roles of crustal growth and preservation in the detrital zircon record. Earth Planet Sci Lett 305:405-412. doi: 10.1016/j.epsl.2011.03.022

Spencer CJ, Kirkland CL, Roberts NMW, Evans NJ, Liebmann J (2020) Strategies towards robust interpretations of in situ zircon Lu–Hf isotope analyses. Geosci Front 11:843-853. doi: 10.1016/j.gsf.2019.09.004

Vermeesch P, Garzanti E (2015) Making geological sense of 'Big Data' in sedimentary provenance analysis. Chem Geol 409:20–27 doi: 10.1016/j.chemgeo.2015.05.004

See Also

hfAgeHfHf2, hfIso, hfDMage, hfDM2stgAge, hfViolinplot, vioplot

The actual plotting is done by the function plotWithLimits.

Examples

```
sampleDataset("khantaishir_Hf")

# Single-stage DM models
hfAgeEps1(1:39, xmax = 1.5, ymin = -10, ymax = 16, cex = 1.5, evol.lines1 = TRUE)

hfAgeEps1(1:12, xmax = 1.5, ymin = -1, ymax = 16, cex = 1.5, violins = TRUE)

# Two-stage DM models
hfAgeEps2(1:12, RCC = 0.022, # Basaltic (Lancaster et al. 2011)
    evol.lines1 = TRUE, evol.lines2 = TRUE, xmax = 1.5,
    ymin = -8, ymax = 17, pch = 15, col = "darkred", cex = 1.5)

hfAgeEps2(1:39, xmin = 0.35, xmax = 1.3, ymax = 16,
    evol.lines1 = FALSE, evol.lines2 = FALSE, age.hist = TRUE,
    kde.bandwidth = 48, # 'optimal' sigma value (Andersen et al. 2018)
    cex = 1.5, rugs = TRUE)

hfAgeEps2(1:39, xmin = 0.35, xmax = 1.3, ymin = -1, ymax = 16, cex = 0,
    evol.lines1 = FALSE, evol.lines2 = TRUE, violins = TRUE)
```

`hfAgeHfHf2` *Plotting Hf growth lines*

Description

Plots two-stage Hf growth curves in the binary diagram age vs. initial $^{176}Hf/^{177}Hf$.

Usage

```
hfAgeHfHf2(which = rownames(Hfinit), RCC = R.crust,
     xmin = 0, xmax = NULL, ymin = NULL, ymax = DM[,"176Hf/177Hf"],
     evol.lines1 = FALSE, evol.lines2 = TRUE, violins = FALSE,
     age.hist = FALSE, kde.bandwidth = 30, rugs = TRUE,
     pch = labels[which, "Symbol"], col = labels[which,"Colour"],
     cex = labels[which, "Size"], new = TRUE,
     main = "Two-stage Hf isotopic growth diagram",...)
```

Arguments

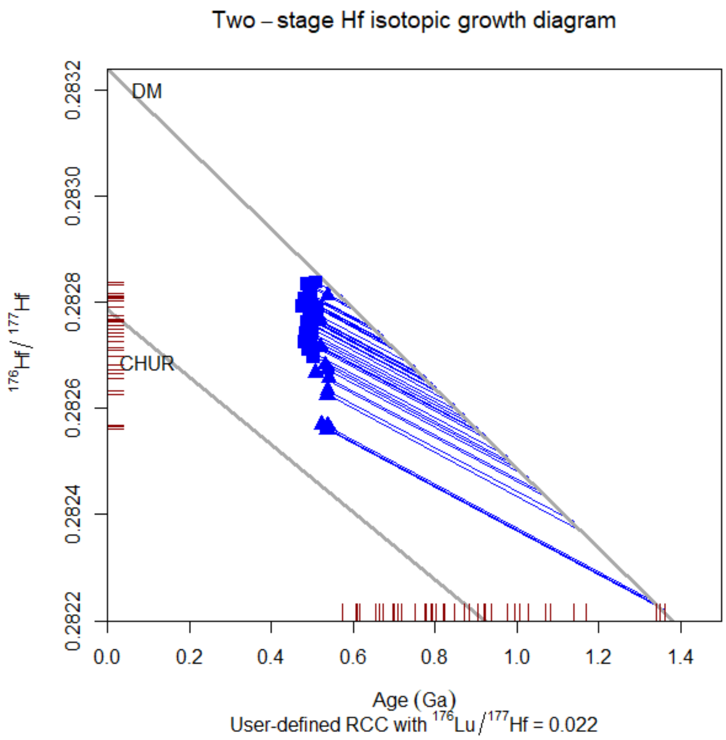
`which`	character or numeric; names or sequence numbers of the samples to be used
`RCC`	numeric; the $^{176}Lu/^{177}Hf$ ratio of the intermediate crustal reservoir for calculation of the two-stage model
`xmin`	numeric; minimum of the age axis in Ga
`xmax`	numeric; maximum of the age axis in Ga
`ymin`	numeric; minimum of the $^{176}Hf/^{177}Hf$ axis
`ymax`	numeric; maximum of the $^{176}Hf/^{177}Hf$ axis
`evol.lines1`	logical; plot the evolution lines from present to the `'age'`?
`evol.lines2`	logical; plot the evolution lines from the `'age'` to the DM?
`violins`	logical; overplot the violin plots for each group?

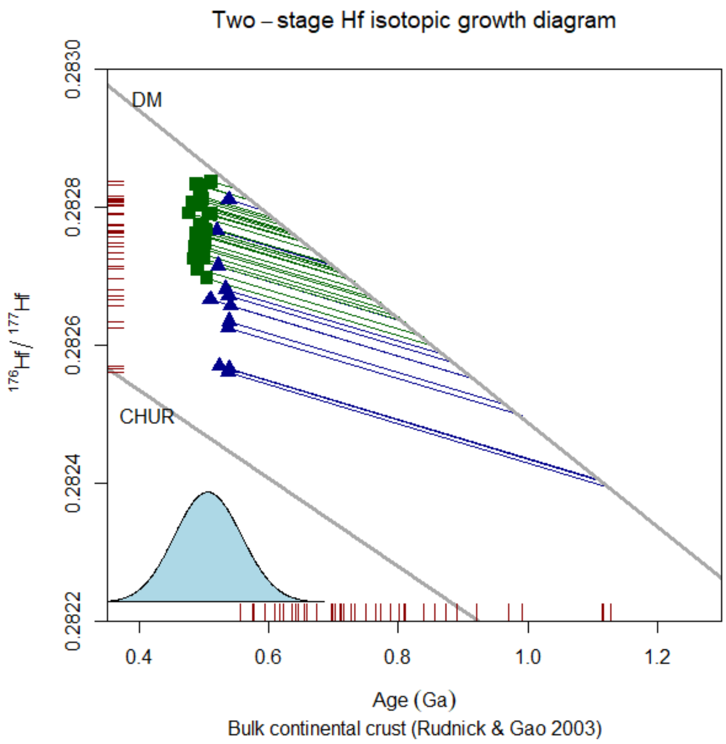
`age.hist`	logical; overplot the frequency histogram of U–Pb ages?
`kde.bandwidth`	numeric; KDE bandwidth.
`rugs`	logical; show the rugs on both axes?
`pch`	plotting symbols
`col`	plotting colours
`cex`	relative size of the plotting symbols
`new`	logical; should be a new plotting window opened?
`main`	main title for the plot
`...`	optional parameters to the underlying function plotWithLimits

Details

In this case, Hf growth curves in individual samples are plotted solely using a two-stage model *(Kemp & Hawkesworth 2003, 2014)*. Moreover, shown are Hf growth curves for the two main mantle reservoirs, CHUR and Depleted Mantle (DM). The optional small ticks, or rug, on the x axis correspond to two-stage Hf model ages. On the y axis, the extra ticks portray the initial $^{176}Hf/^{177}Hf$ ratios.

Another option, controlled by the argument `age.hist`, is plotting of the kernel density estimate (KDE) curve for the U–Pb ages along the x axis. The smoothness of this curve can be controlled by the parameter `kde.bandwidth`, with the 'convenient compromise' σ = 30 *(Vermeesch & Garzanti 2015; Andersen et al. 2018)* set as a default value. In general, the higher is this value, the smoother curve results.





Value

None.

Plugin

Hf.r

Note

This function is Figaro compatible (except violins). For the Hf growth diagram of age vs. ϵ(Hf) values see hfAgeEps.

Author(s)

Vojtěch Janoušek, <vojtech.janousek@geology.cz>

References

Andersen T, Kristoffersen M, Elburg MA (2018) Visualizing, interpreting and comparing detrital zircon age and Hf isotope data in basin analysis – a graphical approach. Basin Res 30:132–147 doi: 10.1111/bre.12245

Blichert-Toft J, Albaréde F (1997) The Lu–Hf isotope geochemistry of chondrites and the evolution of the mantle–crust system. Earth Planet Sci Lett 148:243-258. doi: 10.1016/S0012821X(97)00040-X

Bouvier A, Vervoort JD, Patchett PJ (2008) The Lu–Hf and Sm–Nd isotopic composition of CHUR: constraints from unequilibrated chondrites and implications for the bulk composition of terrestrial planets. Earth Planet Sci Lett 273:48-57. doi: 10.1016/j.epsl.2008.06.010

Chauvel C, Garçon M, Bureau S, Besnault A, Jahn BM, Ding ZL (2014) Constraints from loess on the Hf–Nd isotopic composition of the upper continental crust. Earth Planet Sci Lett 388:48-58. doi: 10.1016/j.epsl.2013.11.045

Griffin WL, Wang X, Jackson SE, Pearson NJ, O'Reilly SY, Xu X, Zhou X (2002) Zircon chemistry and magma mixing, SE China: in-situ analysis of Hf isotopes, Tonglu and Pingtan igneous complexes. Lithos 61:237-269. doi: 10.1016/S00244937(02)000828

Kemp AIS, Hawkesworth CJ (2003) Granitic perspectives on the generation and secular evolution of the continental crust. In: Holland HD, Turekian KK (eds) Treatise on Geochemistry vol. 3, The Crust (ed. R.L. Rudnick). Elsevier-Pergamon, Oxford, pp 349-410. doi: 10.1016/B0080437516/030279

Kemp AIS, Hawkesworth CJ (2014) Growth and differentiation of the continental crust from isotope studies of accessory minerals. In: Holland HD, Turekian KK (eds) Treatise on Geochemistry (Second Edition). Elsevier, Oxford, pp 379-421. doi: 10.1016/B9780080959757.003120

Lancaster PJ, Storey CD, Hawkesworth CJ, Dhuime B (2011) Understanding the roles of crustal growth and preservation in the detrital zircon record. Earth Planet Sci Lett 305:405-412. doi: 10.1016/j.epsl.2011.03.022

Spencer CJ, Kirkland CL, Roberts NMW, Evans NJ, Liebmann J (2020) Strategies towards robust interpretations of in situ zircon Lu–Hf isotope analyses. Geosci Front 11:843-853. doi: 10.1016/j.gsf.2019.09.004

Vermeesch P, Garzanti E (2015) Making geological sense of 'Big Data' in sedimentary provenance analysis. Chem Geol 409:20–27 doi: 10.1016/j.chemgeo.2015.05.004

See Also

hfAgeEps1, hfAgeEps2, hfIso, hfDMage, hfDM2stgAge, hfViolinplot, vioplot

The actual plotting is done by the function plotWithLimits.

Examples

```
sampleDataset("khantaishir_Hf")

hfAgeHfHf2(1:39, RCC = 0.022, # Basaltic (Lancaster et al. 2011)
   evol.lines1 = FALSE, evol.lines2 = TRUE, xmax = 1.5, ymin = 0.2822, col = "blue" , cex = 1.5)

hfAgeHfHf2(1:39, cex = 1.5, xmax = 1.3, ymin = 0.2822, evol.lines1 = TRUE, evol.lines2 = FALSE)

hfAgeHfHf2(1:39, xmin = 0.35, xmax = 1.3, ymin = 0.2822, ymax = 0.2830,
    evol.lines1 = FALSE, evol.lines2 = TRUE, age.hist = TRUE,
    kde.bandwidth = 48, # 'optimal' sigma value (Andersen et al. 2018)
    cex = 1.5, rugs = TRUE)

hfAgeHfHf2(1:39, xmin = 0.35, xmax = 1.3, ymin = 0.2822, cex = 1,
    evol.lines1 = FALSE, evol.lines2 = TRUE, violins = TRUE)
```

`hfHist` *Histogram of U–Pb ages or Hf isotopic parameters*

Description

The function to produce a histogram for the given data values.

Usage

```
hfHist(what = NULL, x = NULL, freq = FALSE,
    bin.number = NULL, bin.width = NULL, col = "lightblue", border = "black",
    kde = TRUE, kde.bandwidth = 30,
    ...)
```

Arguments

`what`	the variable name; see Details
`x`	numeric; a vector of data to be plotted
`freq`	logical; if TRUE, the histogram is a representation of frequencies, otherwise probability densities are plotted
`bin.number`	integer, approximate number of bins per histogram
`bin.width`	integer, width for each of the bins
`col`	colour to fill the bars
`border`	colour of the border around the bars
`kde`	logical; should be the kernel density estimate (KDE) curve shown?
`kde.bandwidth`	numeric; KDE bandwidth.
`...`	further parameters to the function hist

Details

This function produces a standard histogram of univariate data with equi-spaced bins.

The number or width of individual bins can be specified using the arguments `bin.number` and `bin.width`, respectively.

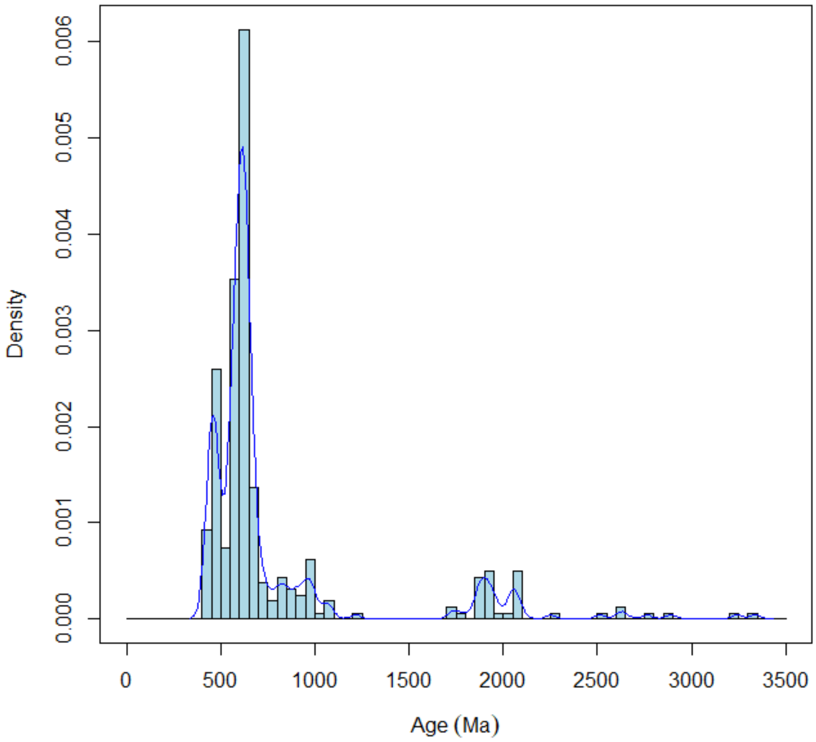
Moreover, optional arguments to the underlying function `hist` can be supplied, directly (`col` or `border`) or via the `...` parameter. In particular, the argument `breaks` provides a rather versatile way of specifying the number/width of individual bins.

If desired (`col = TRUE` and `freq = FALSE`), a curve portraying the kernel density estimate (KDE) is also drawn using the function `density`. The smoothness of this curve can be controlled by the parameter `kde.bandwidth`, with the 'convenient compromise' $\sigma = 30$ *(Vermeesch & Garzanti 2015, Andersen et al. 2018)* set as a default value. In general, the higher is this value, the smoother curve results.

The variables to choose from are:

Menu item	**Explanation**
Age (Ma)	U–Pb ages
176Hf/177Hfi	Initial Hf isotopic ratios
EpsHfi	Initial ϵ(Hf) values
HfTCHUR.1stg	Single-stage CHUR Hf model ages
HfTDM.1stg	Single-stage DM Hf model ages
HfTDM.2stg	Two-stage DM Hf model ages

These can be specified also upon the function call, as the parameter '`what`'. The possibilities are `'Age (Ma)'`, `'176Hf/177Hfi'`, `'EpsHfi'`, `'HfTCHUR.1stg'`, `'HfTDM.1stg'` or `'HfTDM.2stg'`.



Frequency histogram with superimposed KDE curve (`bin.width = 50`*,* `kde.bandwidth = 30`*) for detrital zircons from metavolcanic-sedimentary basement of the Western Carpathians (data of Soejono et al. 2024)*

Value

An object of class 'histogram', a list returned by the function hist.

Author(s)

This is merely just an interface to the standard R functions *hist* and *density*.

Implemented by Vojtěch Janoušek, `<vojtech.janousek@geology.cz>`.

References

Andersen T, Kristoffersen M, Elburg MA (2018) Visualizing, interpreting and comparing detrital zircon age and Hf isotope data in basin analysis – a graphical approach. Basin Res 30:132–147 doi: 10.1111/bre.12245

Soejono I, Collett S, Kohút M, Janoušek V, Schulmann K, Bukovská Z, Novotná N, Zelinková T, Míková J, Hora JM, Veselovský F (2024) Paleogeography of the Gondwana passive margin fragments involved in the Variscan and Alpine collisions: perspectives from metavolcanic-sedimentary basement of the Western Carpathians. Earth Sci Rev 253: 104763 doi: 10.1016/j.earscirev.2024.104763

Vermeesch P, Garzanti E (2015) Making geological sense of 'Big Data' in sedimentary provenance analysis. Chem Geol 409:20–27 doi: 10.1016/j.chemgeo.2015.05.004

See Also

hist, density, hfBoxplot, hfStripplot, hfViolinplot

Examples

```
sampleDataset("tatric_Hf")

hfHist("176Hf/177Hfi", breaks = 10)

hfHist("Age (Ma)", bin.number = 20, col = "khaki")

hfHist("Age (Ma)", bin.width = 100, freq = TRUE, kde = FALSE)

hfHist("Age (Ma)", bin.width = 50, freq = FALSE, kde = TRUE, kde.bandwidth = 50)
```

---

hfIso *Hf isotopes in zircon*

Description

Main function that age-corrects the in-situ zircon Hf isotopic data to a given age; calculates initial ϵ(Hf) values, single-stage CHUR, as well as single- and two-stage depleted-mantle (DM) Nd model ages.

Usage

```
hfIso(age = NULL, GUI = FALSE)

hfInitial(age, x = WR)

hfEpsilon(age, x = WR, digits = 2)

hfCHURage(x = WR, digits = 3)

hfDMage(x = WR, digits = 3)

hfDM2stgAge(x = WR, age = NULL, RCC = R.crust, digits = 3)
```

Arguments

age	age in Ma
GUI	logical; is the function called from GUI?
x	numeric matrix with isotopic data to be recalculated
digits	integer; the precision of the result
RCC	numeric; the $^{176}Lu/^{177}Hf$ ratio of the intermediate crustal reservoir used for calculation of the two-stage Hf model ages

Details

Recalculates the Hf isotopic data and returns the numeric matrix `Hfinit` with the following columns (DM = Depleted Mantle):

Menu item	**Explanation**
176Hf/177Hfi	Initial Hf isotopic ratios
EpsHfi	Initial ϵ(Hf) values
HfTCHUR.1stg	Single-stage CHUR Hf model ages
HfTDM.1stg	Single-stage DM Hf model ages
HfTDM.2stg	Two-stage DM Hf model ages

If the parameter '`age`' is provided upon the call to the main function `hfIso()`, the same value is used for all the samples. On the other hand, if the parameter '`age`' is empty, and no column named '`Age`' is found in the dataset, the user is prompted to enter a value from a dialogue. For the remaining functions, if the argument '`age`' is empty, it is taken from the value assigned upon loading the dataset.

The main parameters for Hf isotopic data recalculations are set from the graphical interface, triggered by the function 'hfOptions'. These include the ^{176}Lu decay constant, $^{176}Lu/^{177}Hf$ and $^{176}Hf/^{177}Hf$ ratios of the CHUR and Depleted Mantle reservoirs, and $^{176}Lu/^{177}Hf$ ratio of the intermediate crustal reservoir used for calculation of the two-stage Hf model ages.

Value

For `hfIso`:

`Hfinit` numeric matrix with the results

For all other functions:

`results` numeric matrix, or vector, with the results

Plugin

Hf.r

Author(s)

Vojtěch Janoušek, `<vojtech.janousek@geology.cz>`

References

Blichert-Toft J, Albaréde F (1997) The Lu–Hf isotope geochemistry of chondrites and the evolution of the mantle–crust system. Earth Planet Sci Lett 148:243-258. doi: 10.1016/S0012821X(97)00040-X

Bouvier A, Vervoort JD, Patchett PJ (2008) The Lu–Hf and Sm–Nd isotopic composition of CHUR: constraints from unequilibrated chondrites and implications for the bulk composition of terrestrial planets. Earth Planet Sci Lett 273:48-57. doi: 10.1016/j.epsl.2008.06.010

Chauvel C, Garçon M, Bureau S, Besnault A, Jahn BM, Ding ZL (2014) Constraints from loess on the Hf-Nd isotopic composition of the upper continental crust. Earth Planet Sci Lett 388:48-58. doi: 10.1016/j.epsl.2013.11.045

Fisher CM, Vervoort JD, Hanchar JM (2014) Guidelines for reporting zircon Hf isotopic data by LA-MC-ICPMS and potential pitfalls in the interpretation of these data. Chem Geol 363:125-133. doi: 10.1016/j.chemgeo.2013.10.019

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Hayakawa T, Shizuma T, Iizuka T (2023) Half-life of the nuclear cosmochronometer ^{176}Lu measured with a windowless 4π solid angle scintillation detector. Communications Physics 6:299. doi: 10.1038/s42005023014067

Kemp AIS, Hawkesworth CJ (2003) Granitic perspectives on the generation and secular evolution of the continental crust. In: Holland HD, Turekian KK (eds) Treatise on Geochemistry vol. 3, The Crust (ed. R.L. Rudnick). Elsevier-Pergamon, Oxford, pp 349-410. doi: 10.1016/B0080437516/030279

Kemp AIS, Hawkesworth CJ (2014) Growth and differentiation of the continental crust from isotope studies of accessory minerals. In: Holland HD, Turekian KK (eds) Treatise on Geochemistry (Second Edition). Elsevier, Oxford, pp 379-421. doi: 10.1016/B9780080959757.003120

Lancaster PJ, Storey CD, Hawkesworth CJ, Dhuime B (2011) Understanding the roles of crustal growth and preservation in the detrital zircon record. Earth Planet Sci Lett 305:405-412. doi: 10.1016/j.epsl.2011.03.022

Scherer E, Münker C, Mezger K (2001) Calibration of the lutetium–hafnium clock. Science 293:683-687. doi: 10.1126/science.1061372

Söderlund U, Patchett PJ, Vervoort JD, Isachsen CE (2004) The ^{176}Lu decay constant determined by Lu–Hf and U–Pb isotope systematics of Precambrian mafic intrusions. Earth Planet Sci Lett 219:311-324. doi: 10.1016/S0012821X(04)000123

Spencer CJ, Kirkland CL, Roberts NMW, Evans NJ, Liebmann J (2020) Strategies towards robust interpretations of in situ zircon Lu–Hf isotope analyses. Geosci Front 11:843-853. doi: 10.1016/j.gsf.2019.09.004

Tatsumoto M, Unruh DM, Patchett PJ (1981) U–Pb and Lu–Hf systematics of Antarctic meteorites. Mem Natl Inst Polar Res (Jpn), spec issue 20: 237-249

Vervoort JD, Kemp AIS (2016) Clarifying the zircon Hf isotope record of crust–mantle evolution. Chem Geol 425:65-75. doi: 10.1016/j.chemgeo.2016.01.023

Vervoort JD, Kemp AIS, Fisher CM (2018) Hf isotope constraints on evolution of the depleted mantle and growth of continental crust. AGU Fall Meeting Abstracts.

See Also

hfOptions, hfAgeEps, hfAgeEps2, hfStripplot, hfBoxplot, hfViolinplot, hfAddResults, hfSaveResults

Examples

```
sampleDataset("khantaishir_Hf")

# Recalculation using the age information from the file;
# this is done automatically upon loading a new data set;
# column named 'Age' is present in the datafile
hfIso()

# Using the same age for all samples
hfIso(500)

hfInitial(346)
```

```
out <- cbind(hfEpsilon(0), hfEpsilon(346))
colnames(out) <- c(0, 346)
print(out)

# Model ages
hfCHURage()

hfDMage()

hfDM2stgAge()

# default RCC (crustal 176Lu/177Hf) value is taken from the system (variable 'R.crust')
hfDM2stgAge(age = 300)

# basaltic RCC (Lancaster et al. 2011) is assumed here
hfDM2stgAge(RCC = 0.022)
```

`hfLegend` *Display Hf legend*

Description

Displays a graphical legend explaining the current assignment of plotting symbols and colours used by the *HafAn* plugin.

Usage

```
hfLegend(pos = "topright", new.plot = TRUE, main = NULL, ...)
```

Arguments

`pos`	position of the legend.
`new.plot`	logical: shall be opened a new plotting window for the legend?
`main`	character; (optional) name of the legend window
`...`	any additional parameters for the function `legend`.

Details

The current assignment of plotting symbols and colours is based on 'groups' which need to be defined beforehand. See Examples.

Value

None.

Plugin

Hf.r

Author(s)

Vojtěch Janoušek, <vojtech.janousek@geology.cz>

See Also

legend, figLegend, showLegend assignSymbGroup, groupsByLabel

Examples

```
sampleDataset("khantaishir_Hf")
groupsByLabel("sample")

hfAgeEps2(1:39, xmin = 0.35, xmax = 1.3, ymax = 16,
    evol.lines1 = FALSE, evol.lines2 = FALSE, age.hist = TRUE,
    cex = 1.5, rugs = TRUE)

hfLegend("topleft")
```

`hfOptions` *Editor of Hf isotopic parameters*

Description

Graphical user interface (GUI) allowing selection of the main parameters for the Hf isotopic data recalculations.

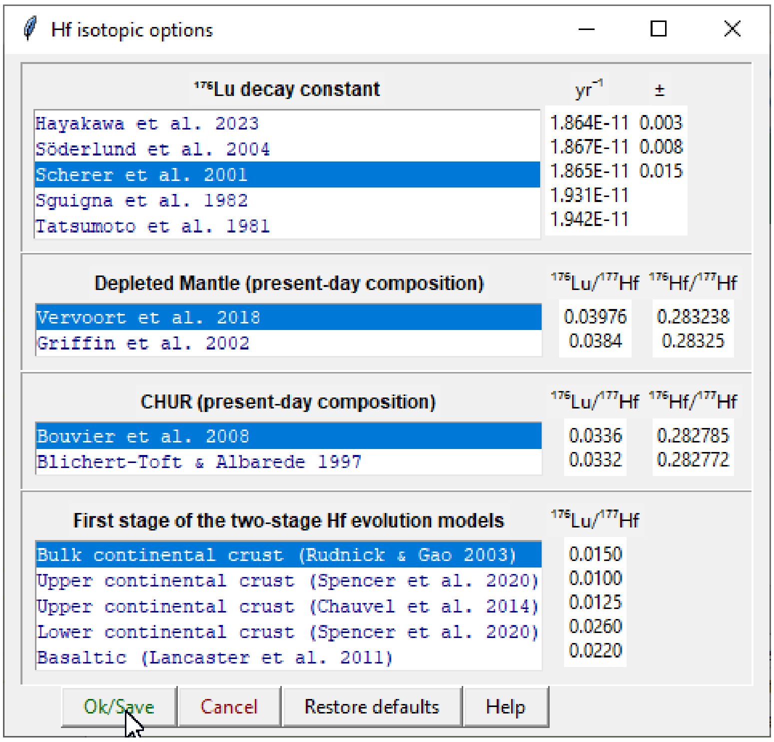
Usage

```
hfOptions()
```

Details

This GUI editor, written in the Tcl/Tk language, allows choosing the main Hf isotopic data recalculation options, i.e. the ^{176}Lu decay constant, $^{176}Lu/^{177}Hf$ and $^{176}Hf/^{177}Hf$ ratios of the CHUR and Depleted Mantle reservoirs, and $^{176}Lu/^{177}Hf$ ratio of the intermediate crustal reservoir used for calculation of the two-stage Hf model ages.

All the possible recalculation options are stored in a simple text file 'constants_hfIso.xxx', whereby the currently selected options are marked by an asterisk.



Value

Assigns the following global variables:

`lambda`	numeric matrix; the ^{176}Lu decay constant
`CHUR`	numeric matrix; $^{176}Lu/^{177}Hf$ and $^{176}Hf/^{177}Hf$ ratios of the CHUR
`DM`	numeric matrix; $^{176}Lu/^{177}Hf$ and $^{176}Hf/^{177}Hf$ ratios of the Depleted Mantle (DM)
`R.crust`	numeric vector; $^{176}Lu/^{177}Hf$ ratio of the intermediate crustal reservoir used for calculation of the two-stage Hf model ages

Plugin

Hf.r

Note

For time being, this editor allows only choosing, but not adding/editing the parameters. Such changes have to be made directly in the configuration file '`constants_hfIso.xxx`'.

Author(s)

Vojtěch Janoušek, <`vojtech.janousek@geology.cz`>

References

Blichert-Toft J, Albaréde F (1997) The Lu–Hf isotope geochemistry of chondrites and the evolution of the mantle–crust system. Earth Planet Sci Lett 148:243-258. doi: 10.1016/S0012821X(97)00040-X

Bouvier A, Vervoort JD, Patchett PJ (2008) The Lu–Hf and Sm–Nd isotopic composition of CHUR: constraints from unequilibrated chondrites and implications for the bulk composition of terrestrial planets. Earth Planet Sci Lett 273:48-57. doi: 10.1016/j.epsl.2008.06.010

Chauvel C, Garçon M, Bureau S, Besnault A, Jahn BM, Ding ZL (2014) Constraints from loess on the Hf-Nd isotopic composition of the upper continental crust. Earth Planet Sci Lett 388:48-58. doi: 10.1016/j.epsl.2013.11.045

Fisher CM, Vervoort JD, Hanchar JM (2014) Guidelines for reporting zircon Hf isotopic data by LA-MC-ICPMS and potential pitfalls in the interpretation of these data. Chem Geol 363:125-133. doi: 10.1016/j.chemgeo.2013.10.019

Griffin WL, Wang X, Jackson SE, Pearson NJ, O'Reilly SY, Xu X, Zhou X (2002) Zircon chemistry and magma mixing, SE China: in-situ analysis of Hf isotopes, Tonglu and Pingtan igneous complexes. Lithos 61:237-269. doi: 10.1016/S00244937(02)000828

Hayakawa T, Shizuma T, Iizuka T (2023) Half-life of the nuclear cosmochronometer ^{176}Lu measured with a windowless 4π solid angle scintillation detector. Communications Physics 6:299. doi: 10.1038/s42005023014067

Kemp AIS, Hawkesworth CJ (2003) Granitic perspectives on the generation and secular evolution of the continental crust. In: Holland HD, Turekian KK (eds) Treatise on Geochemistry vol. 3, The Crust (ed. R.L. Rudnick). Elsevier-Pergamon, Oxford, pp 349-410. doi: 10.1016/B0080437516/030279

Kemp AIS, Hawkesworth CJ (2014) Growth and differentiation of the continental crust from isotope studies of accessory minerals. In: Holland HD, Turekian KK (eds) Treatise on Geochemistry (Second Edition). Elsevier, Oxford, pp 379-421. doi: 10.1016/B9780080959757.003120

Lancaster PJ, Storey CD, Hawkesworth CJ, Dhuime B (2011) Understanding the roles of crustal growth and preservation in the detrital zircon record. Earth Planet Sci Lett 305:405-412. doi: 10.1016/j.epsl.2011.03.022

Scherer E, Münker C, Mezger K (2001) Calibration of the lutetium–hafnium clock. Science 293:683-687. doi: 10.1126/science.1061372

Sguigna AP, Larabee AJ, Waddington JC (1982) The half-life of ^{176}Lu by a lambda-lambda coincidence measurement. Can J Phys 60: 361–364 doi: 10.1139/p82049

Söderlund U, Patchett PJ, Vervoort JD, Isachsen CE (2004) The ^{176}Lu decay constant determined by Lu–Hf and U–Pb isotope systematics of Precambrian mafic intrusions. Earth Planet Sci Lett 219:311-324. doi: 10.1016/S0012821X(04)000123

Spencer CJ, Kirkland CL, Roberts NMW, Evans NJ, Liebmann J (2020) Strategies towards robust interpretations of in situ zircon Lu–Hf isotope analyses. Geosci Front 11:843-853. doi: 10.1016/j.gsf.2019.09.004

Tatsumoto M, Unruh DM, Patchett PJ (1981) U–Pb and Lu–Hf systematics of Antarctic meteorites. Mem Natl Inst Polar Res (Jpn), spec issue 20: 237-249

Vervoort JD, Kemp AIS (2016) Clarifying the zircon Hf isotope record of crust–mantle evolution. Chem Geol 425:65-75. doi: 10.1016/j.chemgeo.2016.01.023

Vervoort JD, Kemp AIS, Fisher CM (2018) Hf isotope constraints on evolution of the depleted mantle and growth of continental crust. AGU Fall Meeting Abstracts.

See Also

hfIso

`hfSaveResults` *Saving Hf in Zrn isotopic data*

Description

Saves the calculated isotopic parameters stored in the matrix '`Hfinit`' to a file.

Usage

```
hfSaveResults(digits = 6)
```

Arguments

`digits`	precision of the results to be saved.

Details

Saves the data frame `Hfinit` with the following columns:

Menu item	**Explanation**
176Hf/177Hfi	Initial Hf isotopic ratios
EpsHfi	Initial ϵ(Hf) values
HfTCHUR.1stg	Single-stage CHUR Hf model ages
HfTDM.1stg	Single-stage DM Hf model ages
HfTDM.2stg	Two-stage DM Hf model ages

At the moment, the possible file formats include plain text (*.TXT), Web page (*.HTML) or MS Excel (*.XLS).

Value

None.

Plugin

Hf.r

Author(s)

Vojtěch Janoušek, `<vojtech.janousek@geology.cz>`

References

Spencer CJ, Kirkland CL, Roberts NMW, Evans NJ, Liebmann J (2020) Strategies towards robust interpretations of in situ zircon Lu–Hf isotope analyses. Geosci Front 11:843-853. doi: 10.1016/j.gsf.2019.09.004

See Also

hfIso, saveResults, HTMLTableMain, excelExport

hfAddResults

hfStats — *Statistical plots of U–Pb ages or Hf isotopic parameters*

Description

Plots a boxplot or stripplot for a given isotopic parameter, respecting groups.

Usage

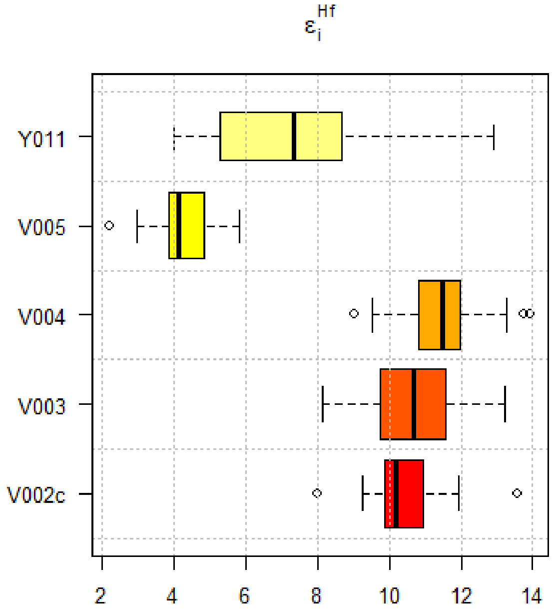
```
hfBoxplot(what = NULL, varwidth = TRUE, cex.axis = 1, col = "lightblue",
    horizontal = TRUE, xaxs = "i", ...)

hfStripplot(what = NULL)
```

Arguments

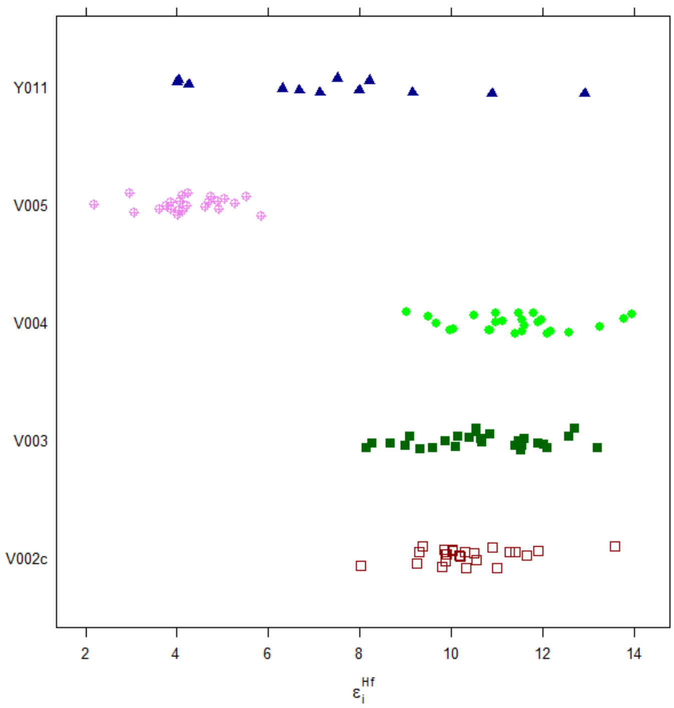
`what`	the variable name; see Details
`varwidth`	logical, should be the boxes drawn with widths proportional to the square-roots of the number of observations in each of the groups?
`cex.axis`	numeric; the relative size of the axis annotation relative to the current setting of `cex`
`col`	plotting colours
`horizontal`	logical; should be the boxplots horizontal?
`xaxs`	character; the style of axis interval calculation to be used for the x-axis. Possible values are "r", "i", "e", "s", "d". See `par`
`...`	Additional parameters to the function `boxplot`

Details

The boxplot (or box-and-whisker plot) has been designed by *Tukey (1977)* to portray faithfully a statistical distribution of univariate data. The box represents, for each of the groups, the two quartiles, the line inside is a median, the whiskers span the whole range without outliers. The outliers themselves are shown by small circles.



Stripplot *(Esty & Banfield 2003)* shows 1D scatter plots for each of the groups, with some artificial noise (jitter) added to make the individual points better visible. Stripplots are a good alternative to boxplots when sample sizes are small.



The variables to choose from are:

Menu item	Explanation
Age (Ma)	U–Pb ages
176Hf/177Hfi	Initial Hf isotopic ratios
EpsHfi	Initial ϵ(Hf) values
HfTCHUR.1stg	Single-stage CHUR Hf model ages
HfTDM.1stg	Single-stage DM Hf model ages
HfTDM.2stg	Two-stage DM Hf model ages

These can be specified also upon the function call, as the parameter 'what'. The possibilities are 'Age (Ma)', '176Hf/177Hfi', 'EpsHfi', 'HfTCHUR.1stg', 'HfTDM.1stg' or 'HfTDM.2stg'.

Value

For boxplot, a list object with data produced by the function 'boxplot'.

Plugin

Hf.r

Author(s)

Vojtěch Janoušek, <vojtech.janousek@geology.cz>

References

Esty WW, Banfield JD (2003) The box-percentile plot. J Stat Softw 8: 1–14. doi: 10.1016/j.gsf.2019.09.004

Spencer CJ, Kirkland CL, Roberts NMW, Evans NJ, Liebmann J (2020) Strategies towards robust interpretations of in situ zircon Lu–Hf isotope analyses. Geosci Front 11:843-853. doi: 10.1016/j.gsf.2019.09.004

Tukey JW (1977) Exploratory Data Analysis. Pearson, Reading, MA, pp 1–712

See Also

boxplot, stripplot, hfViolinplot, hfHist

Examples

```
sampleDataset("khantaishir_Hf")
groupsByLabel("sample")

hfBoxplot("Age (Ma)")

hfBoxplot("EpsHfi")

hfBoxplot("HfTDM.2stg", col = heat.colors(5))

hfStripplot("EpsHfi")

hfStripplot("HfTDM.2stg")
```

`hfViolinplot` *Violin plots of Hf isotopic ratios/model ages*

Description

Produces a violin plot for a given isotopic parameter, respecting groups.

Usage

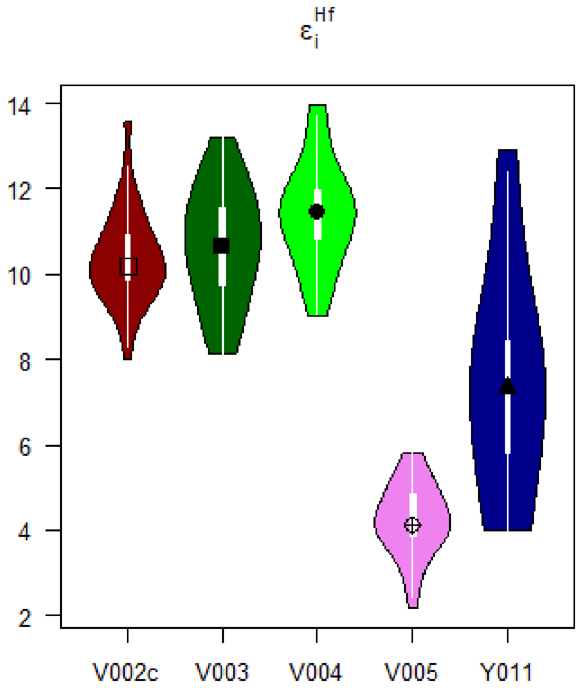
```
hfViolinplot(what = NULL, col = NULL, border = "black", rectCol = "white",
    lineCol = "white", pchMed = NULL, colMed = "black", cex = 1.5,
    xlab = "", ylab = "", ...)
```

Arguments

`what`	the variable name; see Details
`col`	colour(s) to fill the violins
`border`	outline colour(s) for the violins
`rectCol`	fill colour(s) for the box(es)
`lineCol`	colour of the box outline and whiskers
`pchMed`	plotting symbol(s) used for the median point(s)
`colMed`	colour(s) for the median point
`xlab`	character; label for the x axis
`ylab`	character; label for the y axis
`cex`	numeric; relative size of the text
`...`	additional parameters for the `vioplot` function

Details

The violin plots *(Hintze & Nelson 1998)* have been proposed as yet another alternative to boxplots illustrating the distribution of univariate statistical data. In effect they combine boxplot with two density traces placed symmetrically around it. The box extends between the two quartiles; median is denoted by a point. The whiskers show the whole range without outliers. However, unlike in the boxplots, outliers are not shown as individual points.



The variables to choose from are:

Menu item	**Explanation**
Age (Ma)	U–Pb ages
176Hf/177Hfi	Initial Hf isotopic ratios
EpsHfi	Initial ϵ(Hf) values
HfTCHUR.1stg	Single-stage CHUR Hf model ages
HfTDM.1stg	Single-stage DM Hf model ages
HfTDM.2stg	Two-stage DM Hf model ages

These can be specified also upon the function call, as the parameter 'what'. The possibilities are `'Age (Ma)'`, `'176Hf/177Hfi'`, `'EpsHfi'`, `'HfTCHUR.1stg'`, `'HfTDM.1stg'` or `'HfTDM.2stg'`.

Value

A list object with statistical summary (upper and lower limits, median, two quartiles) of the data as produced by the function 'vioplot'.

Plugin

Hf.r

Author(s)

This is merely just an interface to the function *vioplot* from the namesake package designed by D. Adler, S.T. Kelly, T. Elliott and J. Adamson.

Implemented by Vojtěch Janoušek, <vojtech.janousek@geology.cz>

References

Adler D, Kelly ST, Elliott T, Adamson J (2022) vioplot: violin plot. R package version 0.4.0. Accessed on February 16, 2024, at https://github.com/TomKellyGenetics/vioplot

Hintze JL, Nelson RD (1998) Violin plots: a box plot–density trace synergism. Am Stat 52:181-184. doi: 10.2307/2685478

See Also

vioplot, hfBoxplot, hfStripplot, hfHist

Examples

```
sampleDataset("khantaishir_Hf")
groupsByLabel("sample")

hfViolinplot("EpsHfi")

hfViolinplot("HfTDM.1stg", col = "lightblue")
```

---

khantaishir_Hf — *Hafnium isotopic dataset from the Khantaishir Magmatic Complex (Mongolia)*

Description

A dataset of in-situ (LA ICP-MS) Lu–Hf isotopic analyses and U–Pb ages for zircons from the Cambrian Khantaishir Magmatic Complex (Lake Zone, south-central Mongolia) *(Janoušek et al. 2018)*.

Usage

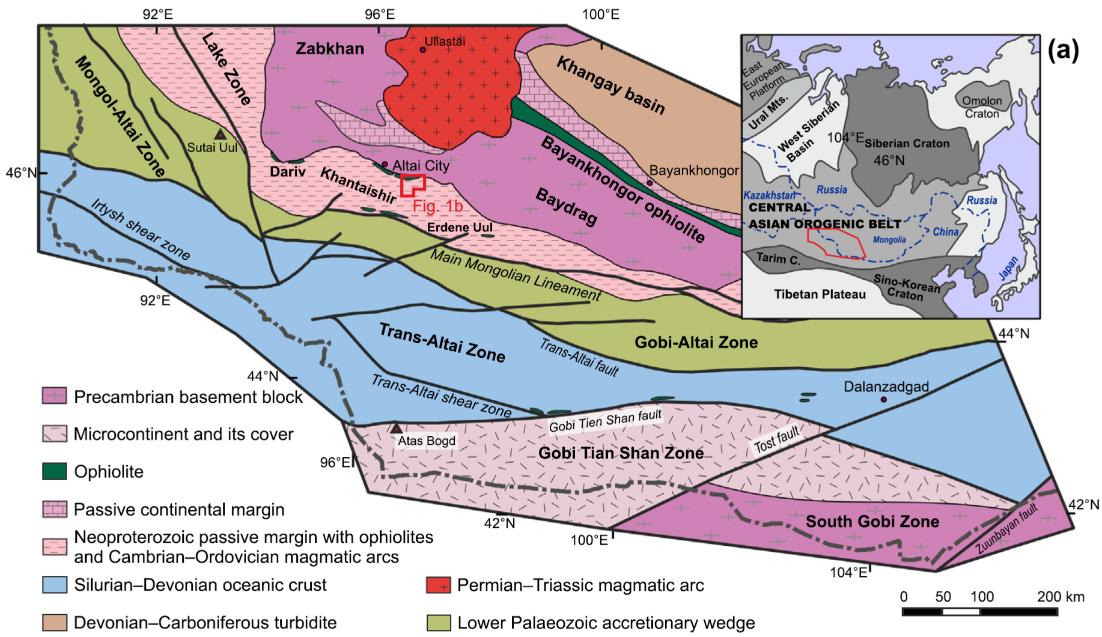
```
sampleDataset("khantaishir_Hf")
```

Format

A data frame containing 111 zircon analyses (Lu–Hf isotopic ratios and U–Pb ages) from 5 samples of mafic–intermediate plutonic rocks.

Details

The Cambrian Khantaishir Magmatic Complex (Lake Zone, Mongolia) exposes a section of a magmatic arc system consisting of deep crustal, (ultra-)mafic cumulates (coarse-grained amphibole gabbros and hornblendites) to shallower crustal levels dominated by amphibole–biotite tonalites. These Hf in zircon isotopic data, together with whole-rock Sr–Nd isotopic compositions, point mostly to juvenile sources, with little, if any, mature crustal contribution *(Janoušek et al. 2018)*.



Plugin

Hf.r

Source

Vojtěch Janoušek, <vojtech.janousek@geology.cz>

References

Janoušek V, Jiang YD, Buriánek D, Schulmann K, Hanžl P, Soejono I, Kröner A, Altanbaatar B, Erban V, Lexa O, Ganchuluun T, Košler J (2018) Cambrian–Ordovician magmatism of the Ikh-Mongol Arc System exemplified by the Khantaishir Magmatic Complex (Lake Zone, south–central Mongolia). Gondwana Res 54:122-149. doi: 10.1016/j.gr.2017.10.003

Examples

```
sampleDataset("khantaishir_Hf")
groupsByLabel("sample")

head(Hfinit)

hfAgeEps2(1:39, xmax = 1.5, ymin = -8, ymax = 16, evol.lines1 = TRUE)

hfViolinplot("EpsHfi")
```

tatric_Hf *Hafnium isotopic dataset for the detrital zircons from the Tatric Unit (Slovakia)*

Description

A dataset of in-situ (LA ICP-MS) Lu–Hf isotopic analyses and U–Pb ages for detrital zircons from the Tatric Unit (Western Carpathians, Slovakia) *(Soejono et al. 2024)*.

Usage

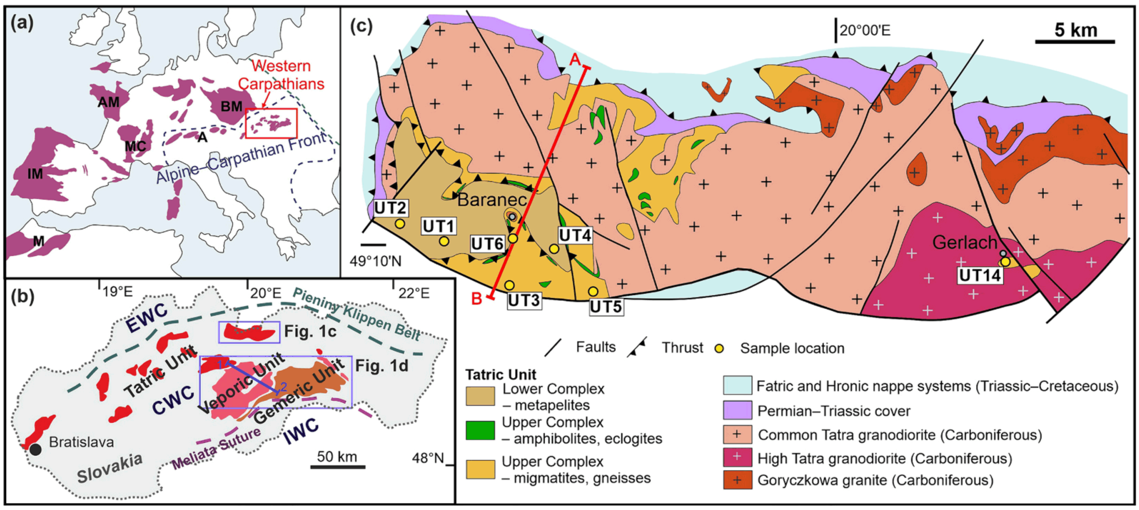
```
sampleDataset("tatric_Hf")
```

Format

A data frame containing 179 detrital zircon analyses (Lu–Hf isotopic ratios and U–Pb ages) from 5 samples of metasedimentary rocks of the Tatric Unit.

Details

This is a subset of detrital zircon dataset from a comprehensive compilation of *Soejono et al. (2024)*. Included here are only data from two metasandstones (UT3, UT6), two paragneisses (UT1, UT14) and a single micaschist (UT5) from the Lower and Upper complexes of the Tatric Unit (for sample locations, see Fig 1c below adopted from the original work).



Plugin

Hf.r

Source

Igor Soejono, <igor.soejono@geology.cz>

Vojtěch Janoušek, <vojtech.janousek@geology.cz>

References

Andersen T, Kristoffersen M, Elburg MA (2018) Visualizing, interpreting and comparing detrital zircon age and Hf isotope data in basin analysis – a graphical approach. Basin Res 30:132–147 doi: 10.1111/bre.12245

Soejono I, Collett S, Kohút M, Janoušek V, Schulmann K, Bukovská Z, Novotná N, Zelinková T, Míková J, Hora JM, Veselovský F (2024) Paleogeography of the Gondwana passive margin fragments involved in the Variscan and Alpine collisions: perspectives from metavolcanic-sedimentary basement of the Western Carpathians. Earth Sci Rev 253:104763 doi: 10.1016/j.earscirev.2024.104763

Examples

```
sampleDataset("tatric_Hf")
groupsByLabel("Sample")

head(Hfinit)
hfHist("Age (Ma)", bin.width = 50, freq = FALSE, kde = TRUE, kde.bandwidth = 50)

hfAgeEps2(xmin = 0.35, xmax = 3.5, evol.lines1 = FALSE, evol.lines2 = FALSE,
    age.hist = TRUE,
    kde.bandwidth = 48, # 'optimal' sigma value (Andersen et al. 2018)
    rugs = FALSE)

hfViolinplot("EpsHfi")
```

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