Package 'imputeREE'

June 22, 2023

Title Impute Missing Rare Earth Element Data in Zircon

Version 0.0.5

Description Set of functions to impute missing rare earth data, calculate La and Pr concentrations and Ce anomalies in zircons based on the Chondrite-Onuma and Chondrite-Lattice of Carrasco-Godoy and Campbell (2023) <doi:10.1007/s00410-023-02025-9> and the Logarithmic regression from Zhong et al. (2019) <doi:10.1007/s00710-019-00682-y>.

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LazyData true

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Depends R (>= 4.0)

URL https://github.com/cicarrascog/imputeREE

BugReports https://github.com/cicarrascog/imputeREE/issues

NeedsCompilation no

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R topics documented:

`add_element_data` *Add ionic radius and chondrite and mantle values, Z and Mass*

Description

This is a helper function to work with Element_norm() and Element_denorm(). Add Ionic Radius to data and chondrite values. For now, only supports 3+ in eight-fold coordination for REE, Zr and Y.Values are from Shannon(1976), McDonough and Sun (1995) and Palme and O'Neill (2014).

Usage

```
add_element_data(dat)
```

Arguments

`dat`	Long data REE format

Value

A data frame

add_ID *Add_ID*

Description

Add an unique ID per observation and checks that is not overwriting an existing column. If the column already exist, it will take no action. This is a wrapper of tibble::rowid_to_column() that checks that not columns is overwritten.

Usage

```
add_ID(dat, ID = "rowid")
```

Arguments

dat	a tibble or a dataframe
ID	Name of column to use for rownames. 'rowid' is used if none is specified. er parameters passed onto the `tibble::rowid_to_column()` function

Value

a data frame

add_IonicRadii *Add Chondrite or Mantle values for normalization.*

Description

This is a helper function to work with Element_norm() and Element_denorm(). Takes long pivoted data to match element name and add normalizing values from the Element_data dataset.

Usage

```
add_IonicRadii(dat, method = ShannonRadiiVIII_Coord_3plus)
```

Arguments

dat	a dataframe or tibble.
method	Ionic Radii from Shannon, 1976

Value

a data frame or tibble

add_NormValues *Add Chondrite or Mantle values for normalization.*

Description

This is a helper function to work with Element_norm() and Element_denorm(). Takes long pivoted data to match element name and add normalizing values from the Element_data dataset.

Usage

```
add_NormValues(dat, chondrite = PalmeOneill2014CI)
```

Arguments

dat	Dataframe or tibble. doc
chondrite	PalmeOneill2014CI, Oneill2014Mantle, McDonough1995CI

Value

a data frame or tibble

Ballard_et_al_Zircon *Zircon Rare earth Element Data from Ballard et al. 2001 and 2002.*

Description

Trace element data from selected zircons from the data of Ballard et al. 2001 and 2002.

Usage

```
Ballard_et_al_Zircon
```

Format

A data frame with 210 rows and 18 variables:

Reference Reference of the data

Deposit Deposit associated with the data

Zr_Y_ppm Y concentrations in ppm

Zr_P_ppm P concentrations in ppm

Zr_La_ppm La concentrations in ppm

Zr_Ce_ppm Ce concentrations in ppm

Zr_Pr_ppm Pr concentrations in ppm

Zr_Nd_ppm Nd concentrations in ppm

Zr_Sm_ppm Sm concentrations in ppm

Zr_Eu_ppm Eu concentrations in ppm

Zr_Gd_ppm Gd concentrations in ppm

Zr_Tb_ppm Tb concentrations in ppm

Zr_Dy_ppm Dy concentrations in ppm

Zr_Ho_ppm Ho concentrations in ppm

Zr_Er_ppm Er concentrations in ppm

Zr_Tm_ppm Tm concentrations in ppm

Zr_Yb_ppm Yb concentrations in ppm

Zr_Lu_ppm Lu concentrations in ppm

Source

Ballard, J. R., Palin, J. M., Williams, I. S., Campbell, I. H., and Faunes, A., 2001, Two ages of porphyry intrusion resolved for the super-giant Chuquicamata copper deposit of northern Chile by ELA-ICP-MS and SHRIMP: Geology, v. 29, p. 383–386. (https://pubs.geoscienceworld.org/gsa/geology/article-abstract/29/5/383/192017/Two-ages-of-porphyry-intrusion-resolved-for-the?redirectedFrom=fulltext)

Ballard, J. R., Palin, M. J., and Campbell, I. H., 2002, Relative oxidation states of magmas inferred from Ce(IV)/Ce(III) in zircon: application to porphyry copper deposits of northern Chile: Contributions to Mineralogy and Petrology, v. 144, p. 347–364. (https://link.springer.com/article/10.1007/s00410-002-0402-5)

`calc_all` *Calculate and Impute REE missing data and anomalies.*

Description

This is a wrapper for `data %>% model_REE() %>% impute_REE() %>% add_parameters()`

Usage

```
calc_all(dat, prefix = NULL, suffix = NULL, chondrite = PalmeOneill2014CI)
```

Arguments

`dat`	A data frame with REE data in ppm
`prefix`	A prefix in your columns e.g. ICP_La
`suffix`	A suffix in your columns e.g. La_ppm
`chondrite`	an option from: PalmeOneill2014CI, Oneill2014Mantle, McDonough1995CI

Value

A data frame. Includes imputed REE, model metrics, and calculated variables.

Examples

```
Ballard_et_al_Zircon %>% calc_all(prefix = 'Zr_', suffix = '_ppm')
```

`CleanColnames` *Clean variable names that have prefixes or suffixes*

Description

This is a helper function

Usage

```
CleanColnames(dat, prefix = NULL, suffix = NULL)
```

Arguments

`dat`	a data frame
`prefix`	A character of length 1
`suffix`	A character of length 1

Value

A data frame

`correct_heavy` *Corrects for the model deviations of Er, Yb, Lu and Y*

Description

Calculated value of Yb, Lu and Y slightly deviates from the linear regression. This function apply a correction to compensates those deviations. This function is wrapped inside model_REE()

Usage

```
correct_heavy(
  dat,
  Y_correction_fact = 1/0.72,
  Ho_correction_fact = 1,
  Er_correction_fact = 1/0.974,
  Tm_correction_fact = 1,
  Yb_correction_fact = 1/0.907,
  Lu_correction_fact = 1/0.926
)
```

Arguments

`dat`	A dataframe
`Y_correction_fact`	a number: correction factor for underestimated Y. 1/ 0.72 by default.
`Ho_correction_fact`	a number: correction factor for Ho. 1 by default.
`Er_correction_fact`	a number: correction factor for underestimated Er. 1/0.974 by default.
`Tm_correction_fact`	a number: correction factor for Tm. 1 by default.
`Yb_correction_fact`	a number: correction factor for underestimated Yb. 1/0.907 by default.
`Lu_correction_fact`	a number: correction factor for underestimated Lu. 1/0.926 by default.

Value

a data frame

`correct_middle` *Corrects for the model deviations of Yb, Lu and Y*

Description

Calculated value of Yb, Lu and Y slightly deviates from the linear regression. This function apply a correction to compensates those deviations. This function is wrapped inside model_REE()

Usage

```
correct_middle(
  dat,
  Nd_correction_fact = 1/0.989,
  Sm_correction_fact = 1/1.022,
  Gd_correction_fact = 1/1.033,
  Tb_correction_fact = 1/1.05,
  Dy_correction_fact = 1/1.032,
  Pr_correction_fact = 1/0.918
)
```

Arguments

`dat`	A dataframe
`Nd_correction_fact`	a number: correction factor for underestimated Nd 1/0.0.989
`Sm_correction_fact`	a number: correction factor for overestimated Sm 1/1.022

`Gd_correction_fact`
: a number: correction factor for overestimated Gd 1/1.033

`Tb_correction_fact`
: a number: correction factor for overestimated Tb 1/1.050

`Dy_correction_fact`
: a number: correction factor for overestimated Dy 1/1.032

`Pr_correction_fact`
: a number: correction factor for overestimated Pr 1/0.918

Value

a data frame

`Element_Data` *Element data for calculations*

Description

A dataset containing CI and Mantle values for normalization for selected elements. The data used is from IUPAC, Palme and O'Neill (2014), and McDonough and Sun (1995). Ionic Radii are from Shannon (1976).

Usage

```
Element_Data
```

Format

A data frame with 77 rows and 11 variables:

Z Atomic Number

Element_name Element Symbol

Atomic_Mass Atomic Mass from IUPAC

Unit Measure Unit of the Concentrations, ppm = parts per million, pct = percentage

PalmeOneill2014CI Chondrite values from Palme and Oneil (2014)

PalmeOneill2014CI_RSD Uncertainty from chondrite values from Palme and O'Neill (2014) as RSD (Relative standard Deviation)

PalmeOneill2014Mantle Primitive Mantle values from Palme and O'Neill (2014)

PalmeOneill2014Mantle_RSD Uncertainty from Primitive Mantle Values from Palme and O'Neill (2014) as RSD (Relative standard Deviation)

McDonough1995CI Chondrite values from McDonough and Sun (1995)

ShannonRadiiVIII_Coord_3plus Shannon (1976) Ionic Radii for elements in Eight-fold coordination and 3+ charge

Z_Zhong numbers assigned by Zhong et al. (2019) for a logarithmic regression to calculate Zircon REE. ...

Source

IUPAC Website (https://iupac.org/)

Palme, H., and O'Neill, H. St. C., 2014, 3.1 - Cosmochemical Estimates of Mantle Composition, in Holland, H. D. and Turekian, K. K. eds., Treatise on Geochemistry (Second Edition): Oxford, Elsevier, p. 1-39.(doi:10.1016/B9780080959757.002011)

McDonough, W. F., and Sun, S. -s., 1995, The composition of the Earth: Chemical Geology, v. 120, p. 223-253.(doi:10.1016/00092541(94)001404)

Shannon, R. D., 1976, Revised effective ionic radii and systematic studies of interatomic distances in halides and chalcogenides: Acta Crystallographica Section A, v. 32, p. 751-767. doi:10.1107/S0567739476001551

Shannon, R. D., 1976, Revised effective ionic radii and systematic studies of interatomic distances in halides and chalcogenides: Acta Crystallographica Section A, v. 32, p. 751-767. doi:10.1107/S0567739476001551

Zhong, S., Seltmann, R., Qu, H., and Song, Y., 2019, Characterization of the zircon Ce anomaly for estimation of oxidation state of magmas: a revised Ce/Ce* method: Mineralogy and Petrology, v. 113, no. 6, p. 755–763. doi:10.1007/s0071001900682y

---

`element_denorm` *Denormalize chrodrite Normalize to ppm*

Description

Denormalize chrodrite Normalize to ppm

Usage

```
element_denorm(dat, method = PalmeOneill2014CI)
```

Arguments

`dat`	A dataframe
`method`	an option from: 'PalmeOneill2014CI', 'Oneill2014Mantle', 'McDonough1995CI'

Value

A dataframe

`Element_norm` *Calculate normalized values for a list of elements*

Description

Element norm normalize values according to published values for the Primitive mantle and chondrites. By defect, it uses the values from Palme and O'Neill (2014). By default, REE + Y list is provided

Usage

```
Element_norm(
  data,
  return = "rect",
  chondrite = PalmeOneill2014CI,
  prefix = NULL,
  suffix = NULL,
  Element_list = REE_plus_Y_Elements
)
```

Arguments

`data`	a data frame
`return`	a character from: "rect" for a wide data return,"raw" for a long data return,"append" to append the results to the input data
`chondrite`	an option from: PalmeOneill2014CI, Oneill2014Mantle, McDonough1995CI
`prefix`	A prefix in your columns e.g. ICP_La
`suffix`	A suffix in your columns e.g. La_ppm
`Element_list`	a character vector: indicating the elements that should be normalized. REE + Y by default

Value

a data frame

`impute_REE` *Impute Rare earth elements*

Description

Imputes missing REE after modelling. Expect the output of 'model_REE()' function. Only missing values are replaced.

Usage

```
impute_REE(data, prefix = NULL, suffix = NULL, rsquared = 0.95)
```

Arguments

data	A dataframe resulting from 'model_ree()'
prefix	A prefix in your columns e.g. ICP_La
suffix	A suffix in your columns e.g. La_ppm
rsquared	A numerical value between 0 and 1. Tolerance to mis-fitting models. set as 0.9 by default.

Details

By default, exclude models with R-squared lower than 0.95. This limit is flexible and method dependent. As guidelines, the Chondrite-Lattice mthod should consider R-squared > 0.95 for at least 3 points. The Chondrite-Onuma method should consider R-squared >0.98 for at least 4 points.

Value

A dataframe

Examples

```
Ballard_et_al_Zircon %>%
dplyr::slice(1:100) %>%
model_REE(prefix = 'Zr', suffix = 'ppm') %>%
impute_REE(prefix = 'Zr', suffix = 'ppm')
```

---

modelChondrite_lattice

Model REE contents using the Chondrite-Lattice method of R*hrefhttps://link.springer.com/article/10.1007/s00410-023-02025-9Carrasco-Godoy and Campbell (2023)*

Description

This function apply the Chondrite-Lattice method which is a linear regression between the misfit parameter from the lattice strain equation and the logarithm of their chondrite normalized values. At least 2 points are required to use this method. This method is based on the work of Blundy and Wood (1994) but using chondrite normalized values as noted by Carrasco-Godoy and Campbell (2023). Refer to Carrasco-Godoy and Campbell (2023) for details.

Usage

```
modelChondrite_lattice(
  dat,
  exclude = c("La", "Pr", "Ce", "Eu", "Y"),
  Calibrate = T,
  prefix = NULL,
  suffix = NULL,
  r0 = 0.87,
  chondrite = PalmeOneill2014CI,
  Pr_correction_fact = 1/0.918,
  Y_correction_fact = 1/0.72,
  Dy_correction_fact = 1/1.032,
  Ho_correction_fact = 1,
  Er_correction_fact = 1/0.974,
  Tm_correction_fact = 1,
  Yb_correction_fact = 1/0.8785,
  Lu_correction_fact = 1/0.8943,
  Nd_correction_fact = 1/0.989,
  Sm_correction_fact = 1/1.022,
  Gd_correction_fact = 1/1.033,
  Tb_correction_fact = 1/1.05
)
```

Arguments

dat	A data frame with REE data in ppm
exclude	a string: vector including elements that should be omitted from modelling. La, Ce and Eu are the default. Ce and Eu should be always included
Calibrate	Logical (T or F). If True, the model is calibrated using the correction factors. By default it is the reciprocal of the median REE from the work of Carrasco-Godoy and Campbell is used.
prefix	A prefix in your columns e.g. ICP_La
suffix	A suffix in your columns e.g. La_ppm
r0	A number: ionic radii of the lattice site r0. By default is 0.87 A, the median value obtained by Carrasco-Godoy and Campbell.
chondrite	an option from: PalmeOneill2014CI, Oneill2014Mantle, McDonough1995CI
Pr_correction_fact	a number: correction factor for overestimated Pr 1/0.918
Y_correction_fact	a number: correction factor for underestimated Y. 1/ 0.72 by default.
Dy_correction_fact	a number: correction factor for overestimated Dy 1/1.032
Ho_correction_fact	a number: correction factor for Ho. 1 by default.
Er_correction_fact	a number: correction factor for underestimated Er. 1/0.97 by default.

`Tm_correction_fact`
: a number: correction factor for Tm. 1 by default.

`Yb_correction_fact`
: a number: correction factor for underestimated Yb. 1/0.8785 by default.

`Lu_correction_fact`
: a number: correction factor for underestimated Lu. 1/0.8943 by default.

`Nd_correction_fact`
: a number: correction factor for underestimated Nd 1/0.0.989

`Sm_correction_fact`
: a number: correction factor for overestimated Sm 1/1.022

`Gd_correction_fact`
: a number: correction factor for overestimated Gd 1/1.033

`Tb_correction_fact`
: a number: correction factor for overestimated Tb 1/1.050

Value

a dataframe

See Also

Other model REE: `modelChondrite_Onuma()`, `modelZhong()`, `model_REE()`

Examples

```
Ballard_et_al_Zircon %>%  modelChondrite_lattice(prefix = 'Zr', suffix = 'ppm')
```

---

modelChondrite_Onuma *Model REE contents using the Chondrite-Onuma method of* R*hrefhttps://link.springer.com/article/10.1007/s00410-023-02025-9Carrasco-Godoy and Campbell (2023)*

Description

This function apply the Chondrite-Onuma method which is a quadratic regression between the ionic radius of the REE and the logarithm of their chondrite normalized values. At least 3 non-linear points are required to use this method. This method is based on the work of Onuma et al. (1968) but using chondrite normalized values as noted by Carrasco-Godoy and Campbell (2023). Refer to Carrasco-Godoy and Campbell (2023) for details.

Usage

```
modelChondrite_Onuma(
  dat,
  exclude = c("La", "Pr", "Ce", "Eu", "Y"),
  Calibrate = T,
  chondrite = PalmeOneill2014CI,
```

```
  prefix = NULL,
  suffix = NULL,
  Pr_correction_fact = 1/1,
  Nd_correction_fact = 1/1.026486418,
  Sm_correction_fact = 1/0.971111041,
  Gd_correction_fact = 1/0.95928241,
  Tb_correction_fact = 1/1.000985745,
  Dy_correction_fact = 1/1.030049321,
  Ho_correction_fact = 1/1.018711009,
  Er_correction_fact = 1/0.996610693,
  Tm_correction_fact = 1/1.053205463,
  Yb_correction_fact = 1/0.982656111,
  Lu_correction_fact = 1/0.952608321,
  Y_correction_fact = 1/0.665380561
)
```

Arguments

`dat`	A data frame with REE data in ppm
`exclude`	a string: vector including elements that should be omitted from modelling. La, Ce and Eu are the default. Ce and Eu should be always included
`Calibrate`	Logical (T or F). If True, the model is calibrated using the correction factors. By default it is the reciprocal of the median REE from the work of Carrasco-Godoy and Campbell is used.
`chondrite`	an option from: PalmeOneill2014CI, Oneill2014Mantle, McDonough1995CI
`prefix`	A prefix in your columns e.g. ICP_La
`suffix`	A suffix in your columns e.g. La_ppm
`Pr_correction_fact`	a number: correction factor for overestimated Pr 1/0.918
`Nd_correction_fact`	a number: correction factor for underestimated Nd 1/0.0.989
`Sm_correction_fact`	a number: correction factor for overestimated Sm 1/1.022
`Gd_correction_fact`	a number: correction factor for overestimated Gd 1/1.033
`Tb_correction_fact`	a number: correction factor for overestimated Tb 1/1.050
`Dy_correction_fact`	a number: correction factor for overestimated Dy 1/1.032
`Ho_correction_fact`	a number: correction factor for Ho. 1 by default.
`Er_correction_fact`	a number: correction factor for underestimated Er. 1/0.97 by default.
`Tm_correction_fact`	a number: correction factor for Tm. 1 by default.

`Yb_correction_fact`
: a number: correction factor for underestimated Yb. 1/0.8785 by default.

`Lu_correction_fact`
: a number: correction factor for underestimated Lu. 1/0.8943 by default.

`Y_correction_fact`
: a number: correction factor for underestimated Y. 1/ 0.72 by default.

Value

a dataframe

See Also

Other model REE: `modelChondrite_lattice()`, `modelZhong()`, `model_REE()`

Examples

```
Ballard_et_al_Zircon %>%  modelChondrite_Onuma(prefix = 'Zr', suffix = 'ppm')
```

---

modelZhong *Model REE contents using the method of* R*hrefhttps://link.springer.com/article/10.1007/s00710-019-00682-yZhong et al. (2019)*

Description

This function apply the logarithmic regression using the method of Zhong et al. (2019). This method considers the relationship between the logarithm of the REE atomic number vs their chondrite normalized values. For more information refer to the Zhong et al. (2019) and Carrasco-Godoy and Campbell (2023) for a discussion of its limitations to calculate La or Ce*.

Usage

```
modelZhong(
  dat,
  exclude = c("La", "Pr", "Ce", "Eu", "Y"),
  Calibrate = F,
  chondrite = PalmeOneill2014CI,
  prefix = NULL,
  suffix = NULL
)
```

Arguments

dat	A data frame with REE data in ppm
exclude	a string: vector including elements that should be omitted from modelling. La, Ce and Eu are the default. Ce and Eu should be always included
Calibrate	Logical (T or F). If True, the model is calibrated using the correction factors. By default it is the reciprocal of the median REE from the work of Carrasco-Godoy and Campbell is used.
chondrite	an option from: PalmeOneill2014CI, Oneill2014Mantle, McDonough1995CI
prefix	A prefix in your columns e.g. ICP_La
suffix	A suffix in your columns e.g. La_ppm

Value

a dataframe

See Also

Other model REE: `modelChondrite_Onuma()`, `modelChondrite_lattice()`, `model_REE()`

Examples

```
Ballard_et_al_Zircon %>%  modelZhong(prefix = 'Zr', suffix = 'ppm')
```

---

model_REE *Model REE + Y contents using different methods.*

Description

This function models REE + Y using different methods. The Chondrite-Lattice method use a linear regression between the REE (+Y) chondrite-normalized and the missfit term from the lattice strain equation `(ri/3 + r0/6)(ri-r0)^2`. The Chondrite-Onuma method use the quadratic relationship between the ionic radii and chondrite normalized REE values. The method of Zhong et al. (2019) use a logaritmic relationship between the atomic number of the REE and the chondrite normalized REE. For details in the lattice strain theory, see Blundy and Wood 1994. For more details in the imputation methods see Carrasco-Godoy and Campbell (2023), and Zhong et al. (2019)

Usage

```
model_REE(
  dat,
  method = 1,
  long_format = F,
  exclude = c("La", "Pr", "Ce", "Eu", "Y"),
  r0 = 0.84,
  chondrite = PalmeOneill2014CI,
  estimate_r0 = FALSE,
```

```
  r0_step = 0.01,
  r0_min = 0.01,
  r0_max = 0.15,
  prefix = NULL,
  suffix = NULL,
  Calibrate = T,
  Pr_correction_fact = 1/0.918,
  Y_correction_fact = 1/0.72,
  Dy_correction_fact = 1/1.032,
  Ho_correction_fact = 1,
  Er_correction_fact = 1/0.974,
  Tm_correction_fact = 1,
  Yb_correction_fact = 1/0.8785,
  Lu_correction_fact = 1/0.8943,
  Nd_correction_fact = 1/0.989,
  Sm_correction_fact = 1/1.022,
  Gd_correction_fact = 1/1.033,
  Tb_correction_fact = 1/1.05
)
```

Arguments

`dat`	A data frame with REE data in ppm
`method`	a number. a choice of `1` for Chondrite Lattice or `2` for Zhong et al. (2019) or `3` for Chondrite-Onuma method.
`long_format`	If T, rectangular long data is returned.
`exclude`	a string: vector including elements that should be omitted from modelling. La, Ce and Eu are the default. Ce and Eu should be always included
`r0`	A number: ionic radii of the lattice site r0. By default is 0.87 A, the median value obtained by Carrasco-Godoy and Campbell.
`chondrite`	an option from: PalmeOneill2014CI, Oneill2014Mantle, McDonough1995CI
`estimate_r0`	If T, r0 is estimated using a method similar to the one from Loader et al. 2022.
`r0_step`	If r0 is estimated, this define the step for iteration. smaller step heavily increases the computing time.
`r0_min`	Minimun value from which the iteration starts. Calculated from r0.
`r0_max`	Maximun value at which iteration ends. Calculated from r0.
`prefix`	A prefix in your columns e.g. ICP_La
`suffix`	A suffix in your columns e.g. La_ppm
`Calibrate`	Logical (T or F). If True, the model is calibrated using the correction factors. By default it is the reciprocal of the median REE from the work of Carrasco-Godoy and Campbell is used.
`Pr_correction_fact`	a number: correction factor for overestimated Pr 1/0.918
`Y_correction_fact`	a number: correction factor for underestimated Y. 1/ 0.72 by default.

`Dy_correction_fact`
: a number: correction factor for overestimated Dy 1/1.032

`Ho_correction_fact`
: a number: correction factor for Ho. 1 by default.

`Er_correction_fact`
: a number: correction factor for underestimated Er. 1/0.97 by default.

`Tm_correction_fact`
: a number: correction factor for Tm. 1 by default.

`Yb_correction_fact`
: a number: correction factor for underestimated Yb. 1/0.8785 by default.

`Lu_correction_fact`
: a number: correction factor for underestimated Lu. 1/0.8943 by default.

`Nd_correction_fact`
: a number: correction factor for underestimated Nd 1/0.0.989

`Sm_correction_fact`
: a number: correction factor for overestimated Sm 1/1.022

`Gd_correction_fact`
: a number: correction factor for overestimated Gd 1/1.033

`Tb_correction_fact`
: a number: correction factor for overestimated Tb 1/1.050

Value

a dataframe

See Also

Other model REE: `modelChondrite_Onuma()`, `modelChondrite_lattice()`, `modelZhong()`

Examples

```
Ballard_et_al_Zircon %>%  model_REE(prefix = 'Zr', suffix = 'ppm')
```

REE_Elements *Rare earth element list*

Description

A string vector containing the elemental symbols for REE.

Usage

```
REE_Elements
```

Format

Rare earth element list

`REE_plus_Y_Elements` *Rare earth element list*

Description

A string vector containing the elemental symbols for REE and Y.

Usage

```
REE_plus_Y_Elements
```

Format

Rare earth element + Y list

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