Intro to Python and Pandas

DataFrames for Data Science

Sébastien Biass

sebastien.biasse@unige.ch

Earth Sciences

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Background

⚠ We assume that you all followed Guy Simpson's Python crash course

`pandas`: A **package** for data manipulation and analysis handling **structured data**

- **Reading/writing data** from common formats (CSV, Excel, JSON, etc.)
- Handling **missing data**
- **Filtering**, **sorting**, **reshaping** and **grouping** data
- **Aggregating** data (sum, mean, count, etc.)
- **Time series support** (date ranges, frequency conversions)
- **Statistical operations**

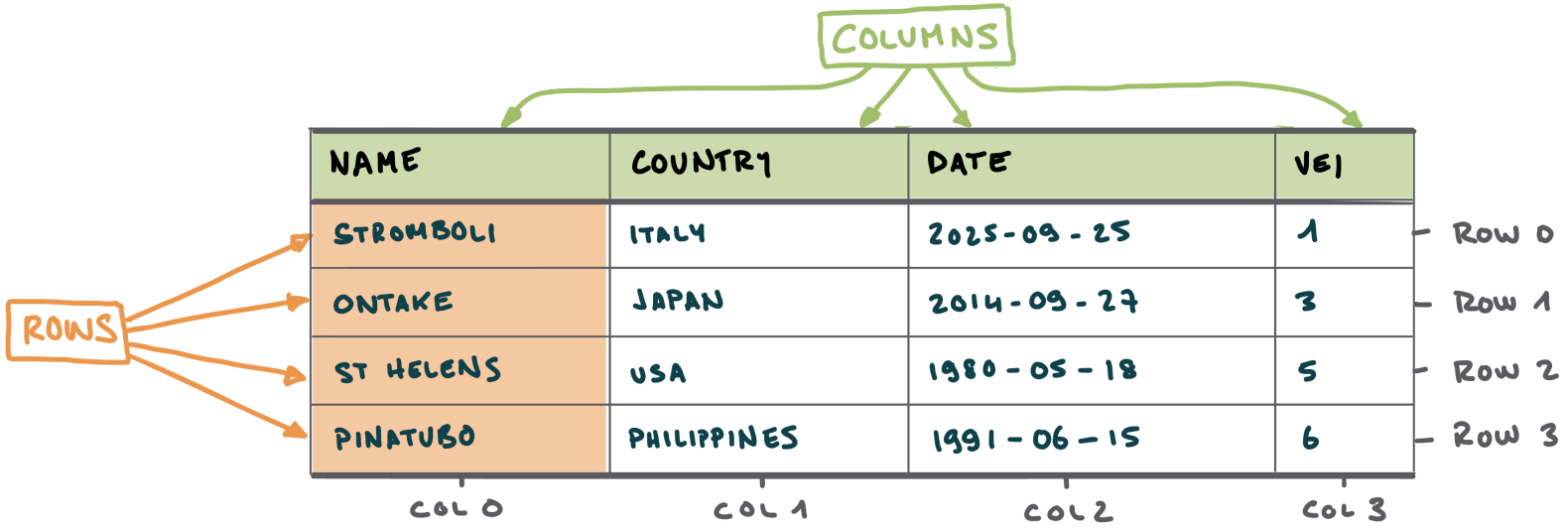
Today's objectives

Understand what is a `pandas` DataFrame and its basic anatomy

- How to load data in a DataFrame
- How to access data → *query by label/position*
- How to filter data → *comparison and logical operators*
- How to rearrange data → *sorting values*
- How to operate on data → *arithmetic and string operations*

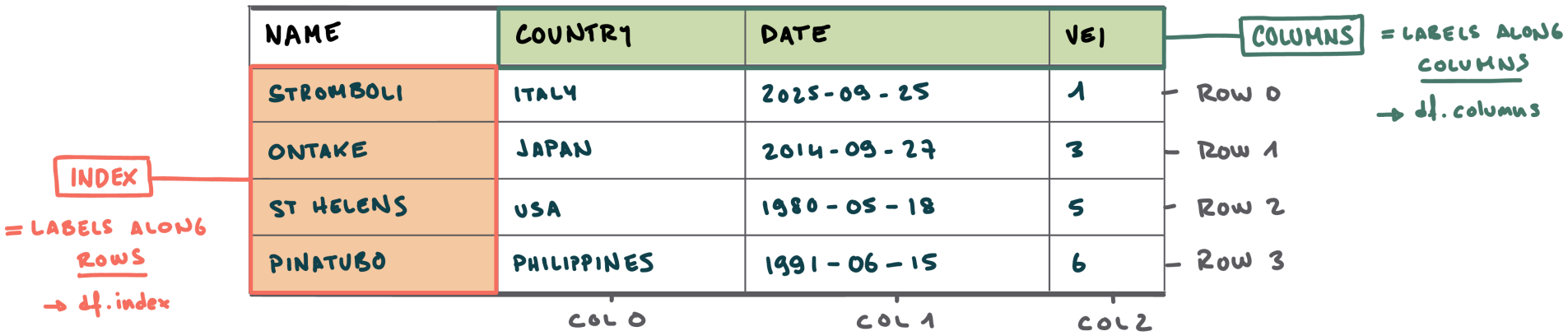
Introduction to pandas

Anatomy of a DataFrame



- Similar to *Excel* → contains *tabular data* composed of rows and columns
- In *Excel*:
  - → **Rows** are accessed using *numbers*
  - → **Columns** are accessed using *letters*

Anatomy of a DataFrame



- Unlike *Excel*, **rows** and **columns** can be labelled
  - → Index refers to the label of the **rows**. In the *index*, **values are usually unique** - meaning that each entry has a different label.
  - → Column refers to the label of - logically - the **columns**

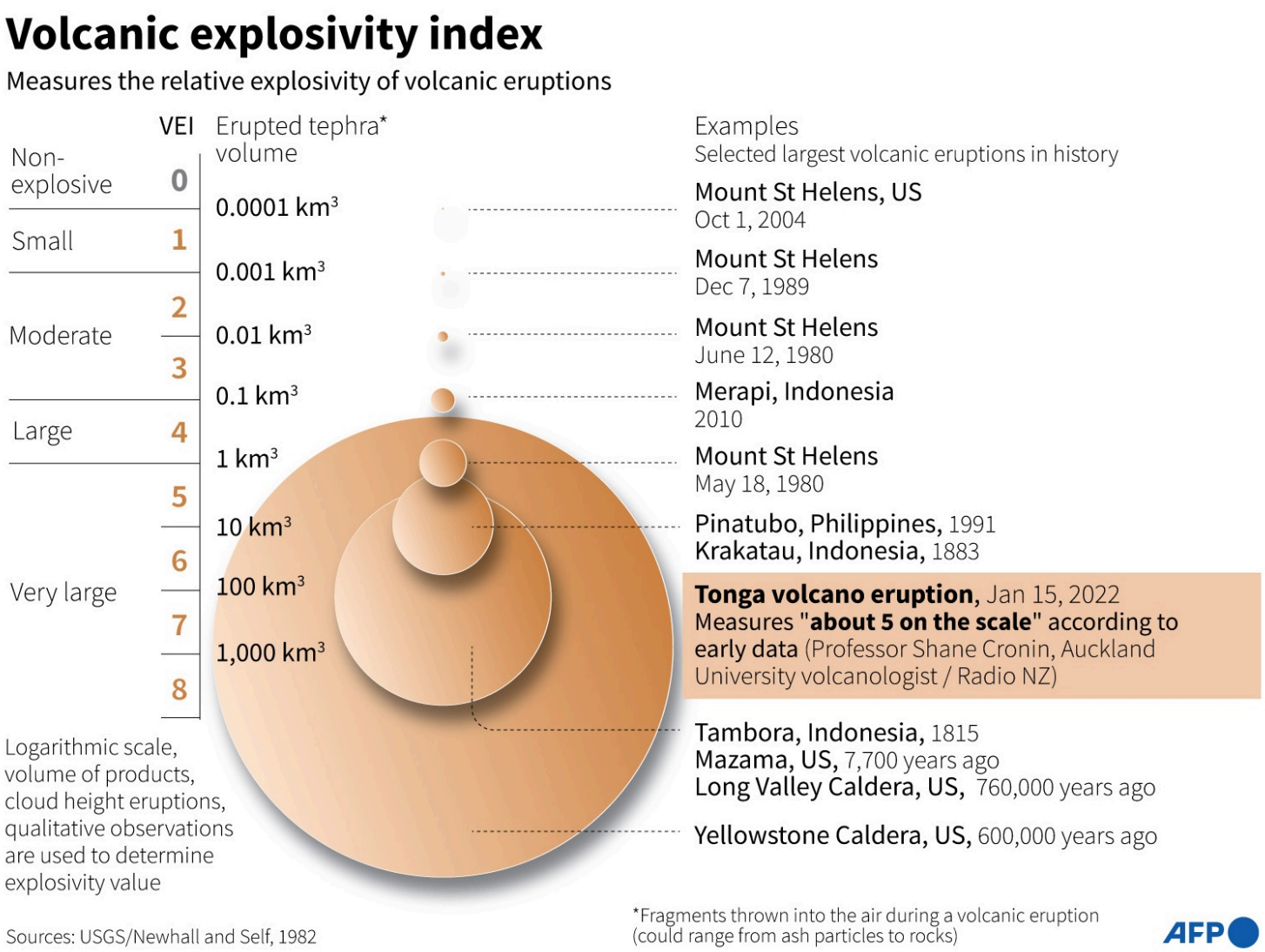
Data structure

The dataset

Synthetic dataset of **selected volcanic eruptions** → first 5 rows:

Name	Country	Date	VEI	Latitude	Longitude
St. Helens	USA	1980-05-18	5	46.1914	-122.196
Pinatubo	Philippines	1991-04-02	6	15.1501	120.347
El Chichón	Mexico	1982-03-28	5	17.3559	-93.2233
Galunggung	Indonesia	1982-04-05	4	-7.2567	108.077
Nevado del Ruiz	Colombia	1985-11-13	3	4.895	-75.322

Volcanic explosivity index (VEI)



Setting up the notebook

- We start by importing the `pandas` library
- We import it under the name `pd` - which is faster to type!

```
# Import the required packages
import pandas as pd
```

Setting up the notebook

- We then load the specified data with the `pd.read_csv()` function
- This returns a DataFrame object in a variable named `df`

```
1 # Import the required packages
2 import pandas as pd
3
4 # Read the data
5 df = pd.read_csv('data/dummy_volcanoes.csv', parse_dates=['Date']) # Load data
```

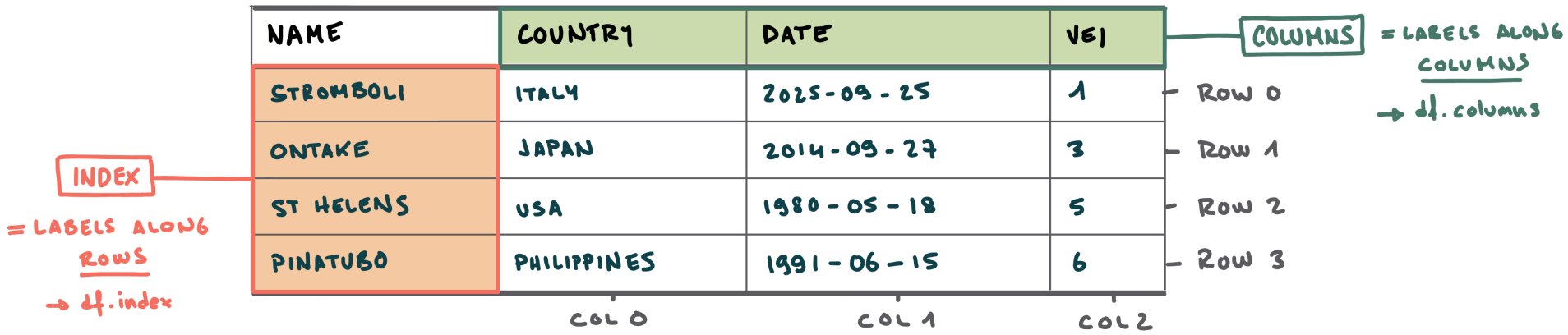
Setting up the notebook

- We print some data for inspection with `df.head()`
- The functions are now directly called from the DataFrame `df` object

```
1 # Import the required packages
2 import pandas as pd
3
4 # Read the data
5 df = pd.read_csv('../class1/data/dummy_volcanoes.csv', parse_dates=['Date']) # Load data
6
7 # Show the first 3 rows
8 df.head(3)
```

	Name	Country	Date	VEI	Latitude	Longitude
0	St. Helens	USA	1980-05-18	5	46.1914	-122.1956
1	Pinatubo	Philippines	1991-04-02	6	15.1501	120.3465
2	El Chichón	Mexico	1982-03-28	5	17.3559	-93.2233

Setting the index



Setting the index

- ...for now, the index (→ **the first column)** is and *integer*
- This might be acceptable in datasets where the *label* is not important

```
1 # Show the first 3 rows
2 df.head(3)
```

	Name	Country	Date	VEI	Latitude	Longitude
0	St. Helens	USA	1980-05-18	5	46.1914	-122.1956
1	Pinatubo	Philippines	1991-04-02	6	15.1501	120.3465
2	El Chichón	Mexico	1982-03-28	5	17.3559	-93.2233

Setting the index

- Here we want to access the data using the **name of the volcano**
- We **set the index** using `set_index()`

```
# Set the index to the 'Name' column
df = df.set_index('Name')

# Show the first 3 rows
df.head(3)
```

Name	Country	Date	VEI	Latitude	Longitude
St. Helens	USA	1980-05-18	5	46.1914	-122.1956
Pinatubo	Philippines	1991-04-02	6	15.1501	120.3465
El Chichón	Mexico	1982-03-28	5	17.3559	-93.2233

Exploring data

- Here are some **basic functions** to review the structure of the dataset:

Function	Description
`df.head()`	Prints the *first* 5 rows of the DataFrame.
`df.tail()`	Prints the *last* 5 rows of the DataFrame.
`df.info()`	Displays some info about the DataFrame, including the number of rows (*entries*) and columns.
`df.shape`	Returns a list containing the number of rows and columns of the DataFrame.
`df.index`	Returns a list containing the index along the *rows* of the DataFrame.
`df.columns`	Returns a list containing the index along the *columns* of the DataFrame.

Sorting data

- Sorting numerical, datetime or strings using `.sort_values`
- Importance of documentation to understand arguments

```
1 df.sort_values('VEI').head() # Sort volcanoes by VEI in ascending number
```

Name	Country	Date	VEI	Latitude	Longitude
Nyiragongo	DR Congo	2021-05-22	1	-1.5200	29.2500
Merapi	Indonesia	2023-12-03	2	-7.5407	110.4457
Ontake	Japan	2014-09-27	2	35.5149	137.4781
Kīlauea	USA	2018-05-03	2	19.4194	-155.2811
Etna	Italy	2021-03-16	2	37.7510	15.0044

Sorting data

- Sorting numerical, datetime or strings using `.sort_values`
- Importance of documentation to understand arguments

```
df.sort_values('VEI').head() # Sort volcanoes by VEI in ascending number
df.sort_values('Date', ascending=False).head() # Sort volcanoes by eruption dates from recent
```

Name	Country	Date	VEI	Latitude	Longitude
Merapi	Indonesia	2023-12-03	2	-7.5407	110.4457
Cleveland	USA	2023-05-23	3	52.8250	-169.9444
Sinabung	Indonesia	2023-02-13	3	3.1719	98.3925
Nyiragongo	DR Congo	2021-05-22	1	-1.5200	29.2500
La Soufrière	Saint Vincent	2021-04-09	4	13.2833	-61.3875

Sorting data

- Sorting numerical, datetime or strings using `.sort_values`
- Importance of documentation to understand arguments

```
df.sort_values('VEI').head() # Sort volcanoes by VEI in ascending number
df.sort_values('Date', ascending=False).head() # Sort volcanoes by eruption dates from recent
df.sort_values('Country').head() # Also works on strings to sort alphabetically
```

Name	Country	Date	VEI	Latitude	Longitude
Calbuco	Chile	2015-04-22	4	-41.2972	-72.6097
Nevado del Ruiz	Colombia	1985-11-13	3	4.8950	-75.3220
Nyiragongo	DR Congo	2021-05-22	1	-1.5200	29.2500
Eyjafjallajökull	Iceland	2010-04-14	4	63.6333	-19.6111
Galunggung	Indonesia	1982-04-05	4	-7.2567	108.0771

Sorting data

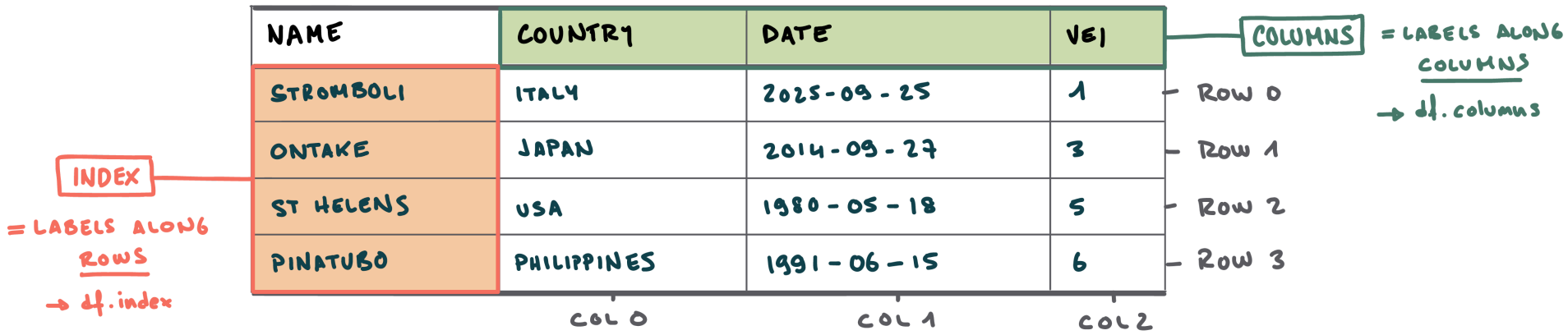
- Sorting numerical, datetime or strings using `.sort_values`
- Importance of documentation to understand arguments

```
df.sort_values('VEI').head() # Sort volcanoes by VEI in ascending number
df.sort_values('Date', ascending=False).head() # Sort volcanoes by eruption dates from recent
df.sort_values('Country').head() # Also works on strings to sort alphabetically
df.sort_values(['Latitude', 'Longitude']).head() # Sorting using multiple columns
```

	Country	Date	VEI	Latitude	Longitude
Name					
Calbuco	Chile	2015-04-22	4	-41.2972	-72.6097
Agung	Indonesia	2017-11-21	3	-8.3422	115.5083
Merapi	Indonesia	2023-12-03	2	-7.5407	110.4457
Galunggung	Indonesia	1982-04-05	4	-7.2567	108.0771
Tavurvur	Papua New Guinea	2014-08-29	3	-4.3494	152.2847

Querying data

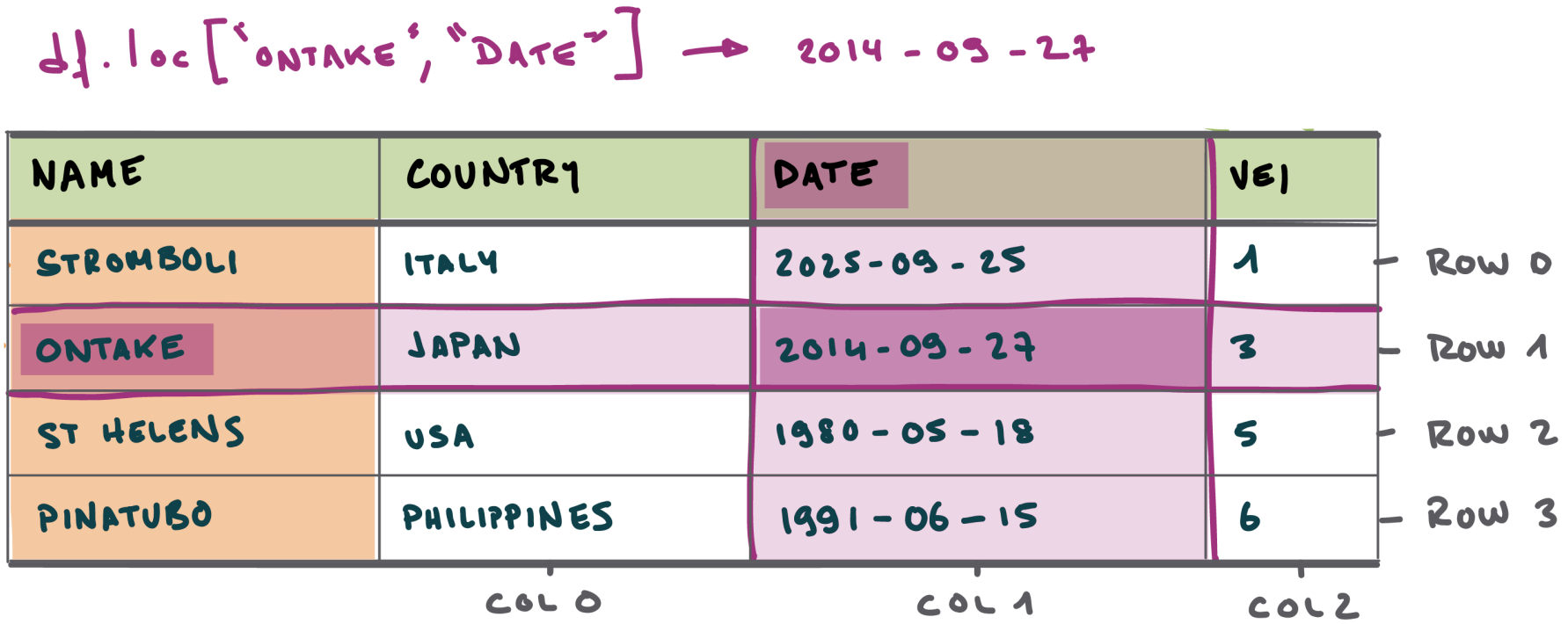
Accessing data in a DataFrame



Accessing data in a DataFrame

Option 1: label-based indexing

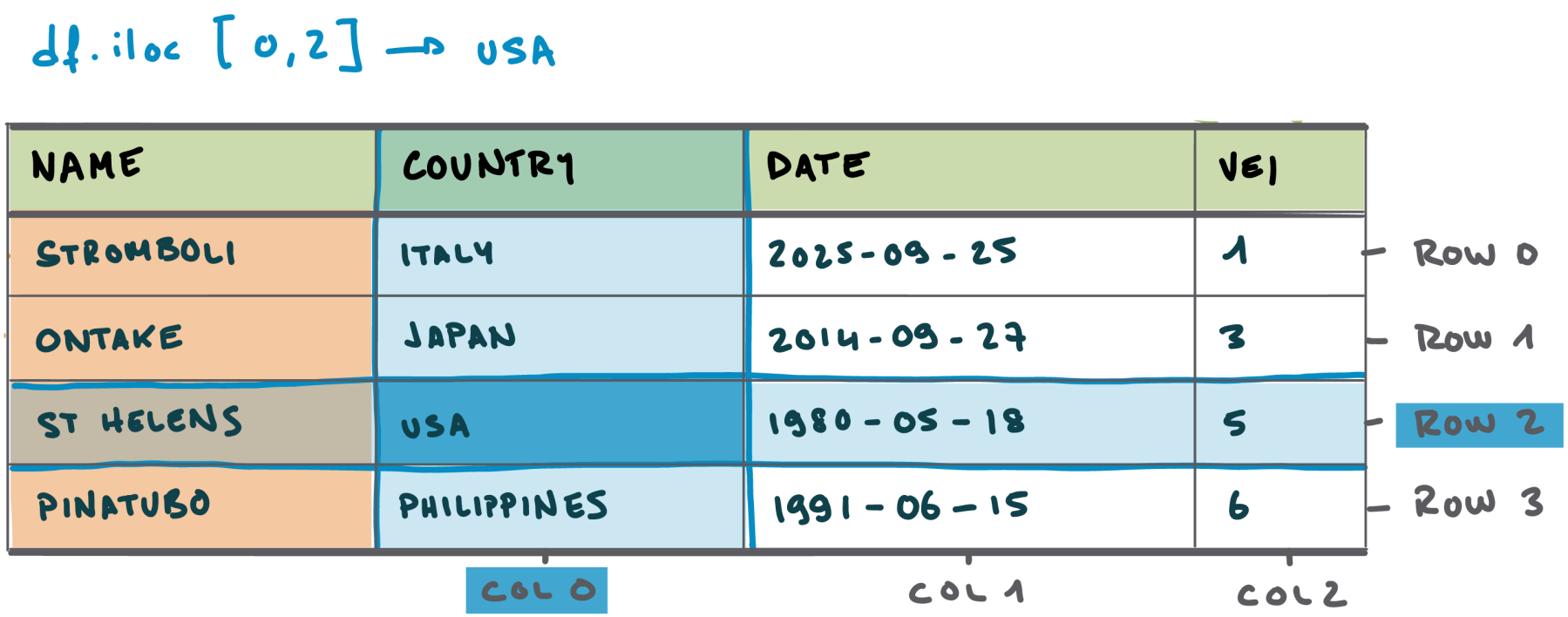
- Use the labels of **index** and **columns** to retrieve data
- Function to use: `df.loc`



Accessing data in a DataFrame

Option 2: position-based indexing

- Use the positions of **index** and **columns** to retrieve data
- Function to use: `df.iloc`



Label-based indexing: Rows

- **Query a row** with `.loc` → Use **square brackets** `[ ]`
  - → Query the *row* for which the *index label* is `Calbuco`
  - → Returns all *columns*

```
1 df.loc['Calbuco']
```

```
Country                      Chile
Date           2015-04-22 00:00:00
VEI                              4
Latitude                   -41.2972
Longitude                  -72.6097
Name: Calbuco, dtype: object
```

→ Returns a pd.Series

```
1 df.loc[['Calbuco']]
```

Name	Country	Date	VEI	Latitude	Long
Calbuco	Chile	2015-04-22	4	-41.2972	-72.6

→ Returns a pd.DataFrame

Label-based indexing: Rows

- Query **multiple rows** with `.loc`
  - → Query the *rows* for which the *index labels* are `Calbuco` or `Taal`
  - → Returns all *columns*

```
1 df.loc[['Calbuco', 'Taal']]
```

Name	Country	Date	VEI	Latitude	Longitude
Calbuco	Chile	2015-04-22	4	-41.2972	-72.6097
Taal	Philippines	2020-01-12	4	14.0020	120.9934

Label-based indexing: Columns

- Query **columns**
  - → Query the *columns* for which the *column labels* are `Country` or `VEI`
  - → Returns all *rows*

- **Option 1**: with `.loc`:

```
1 df.loc[:, ['Country', 'VEI']].head(3)
```

	Country	VEI
Name		
St. Helens	USA	5
Pinatubo	Philippines	6
El Chichón	Mexico	5

- **Option 2**: without `.loc`:

```
1 df[['Country', 'VEI']].head(3)
```

	Country	VEI
Name		
St. Helens	USA	5
Pinatubo	Philippines	6
El Chichón	Mexico	5

Label-based indexing: Rows and Columns

- Again, choice on whether to use `.loc` to query columns

- **Option 1**: Columns are specified inside `.loc`:

```
1 df.loc[['Calbuco', 'Taal'], ['Country', 'V
```

	Country	VEI
Name		
Calbuco	Chile	4
Taal	Philippines	4

- **Option 2**: Columns are specified outside `.loc`:

```
1 df.loc[['Calbuco', 'Taal']][['Country', 'V
```

	Country	VEI
Name		
Calbuco	Chile	4
Taal	Philippines	4

Position-based indexing: Rows

- **Query a row** with `.iloc`
  - → Returns all *columns*

- **One row** (first row):

```
1 df.iloc[[0]]
```

Name	Country	Date	VEI	Latitude	Longit
St. Helens	USA	1980-05-18	5	46.1914	-122.1

- **Range of rows**: (rows 3-4):

```
1 df.iloc[2:4]
```

Name	Country	Date	VEI	Latitude
El Chichón	Mexico	1982-03-28	5	17.3559
Galunggung	Indonesia	1982-04-05	4	-7.2567

Position-based indexing: Rows

- Query rows from the end:
- Example:
  - → Get the **last 5 rows** of the DataFrame:

```
1 df.iloc[-5:]
```

Name	Country	Date	VEI	Latitude	Longitude
La Soufrière	Saint Vincent	2021-04-09	4	13.2833	-61.3875
Calbuco	Chile	2015-04-22	4	-41.2972	-72.6097
St. Augustine	USA	2006-03-27	3	57.8819	-155.5611
Eyjafjallajökull	Iceland	2010-04-14	4	63.6333	-19.6111
Cleveland	USA	2023-05-23	3	52.8250	-169.9444

Position-based and label-based queries

- Mix position-based and label-based indexing:
  - → **Rows** → *labels*
  - → **Columns** → *positions*

```
1 df.iloc[0:5][['Country', 'VEI']]
```

	Country	VEI
Name		
St. Helens	USA	5
Pinatubo	Philippines	6
El Chichón	Mexico	5
Galunggung	Indonesia	4
Nevado del Ruiz	Colombia	3

Filtering data

Boolean indexing

- **Filtering** data with boolean indexing
  - → Returns either `True` or `False` depending on whether the **condition** is satisfied

- Example:

```
1 a = 1
2 b = 2
```

- **Comparison operators**:

Operator	Meaning	Example	Result
`==`	Equal to	`a == b`	`False`
`!=`	Not equal to	`a != b`	`True`
`>`	Greater than	`a > b`	`False`
`<`	Less than	`a < b`	`True`
`>=`	Greater than or equal	`a >= b`	`False`
`<=`	Less than or equal	`a <= b`	`True`

Boolean indexing: Example

- Query all volcanoes where `VEI == 4`

```
1 df['VEI'] == 4
```

```
Name
St. Helens          False
Pinatubo            False
El Chichón          False
Galunggung           True
Nevado del Ruiz     False
Merapi              False
Ontake              False
Soufrière Hills     False
Etna                False
Nyiragongo          False
Kīlauea             False
Agung               False
Tavurvur            False
Sinabung            False
Taal                 True
La Soufrière         True
Calbuco              True
```

Boolean indexing: Example

- Query all volcanoes where `VEI == 4`

```
1 df.loc[df['VEI'] == 4]
```

Name	Country	Date	VEI	Latitude	Longitude
Galunggung	Indonesia	1982-04-05	4	-7.2567	108.0771
Taal	Philippines	2020-01-12	4	14.0020	120.9934
La Soufrière	Saint Vincent	2021-04-09	4	13.2833	-61.3875
Calbuco	Chile	2015-04-22	4	-41.2972	-72.6097
Eyjafjallajökull	Iceland	2010-04-14	4	63.6333	-19.6111

Boolean indexing: Strings

- **Filtering** also works with strings
  - → Use **string comparison** operations

- **Example**:

```
1 df.loc[df['Country'] == 'Indonesia']
```

Name	Country	Date	VEI	Latitude	Longitude
Galunggung	Indonesia	1982-04-05	4	-7.2567	108.0771
Merapi	Indonesia	2023-12-03	2	-7.5407	110.4457
Agung	Indonesia	2017-11-21	3	-8.3422	115.5083
Sinabung	Indonesia	2023-02-13	3	3.1719	98.3925

Boolean indexing: Strings

- **Filtering** also works with strings
  - → Use **string comparison** operations

- **String comparison operators**:

Operation	Example	Description
contains	`df['Name'].str.contains('Soufrière')`	Checks if each string contains a substring
startswith	`df['Name'].str.startswith('E')`	Checks if each string starts with a substring
endswith	`df['Name'].str.endswith('o')`	Checks if each string ends with a substring

Operations

Data management operations

- Common data management functions for pandas columns:

Operation	Example	Description
Round	`df['VEI'].round(1)`	Rounds values to the specified number of decimals
Floor	`df['VEI'].apply(np.floor)`	Rounds values down to the nearest integer
Ceil	`df['VEI'].apply(np.ceil)`	Rounds values up to the nearest integer
Absolute value	`df['VEI'].abs()`	Returns the absolute value of each element
Fill missing	`df['VEI'].fillna(0)`	Replaces missing values with a specified value

- Round the `'Latitude'` to two decimals → make sure you store the output!

```
1 df['Latitude'] = df['Latitude'].round(2)
```

Arithmetic operations

- Arithmetic operations on parts of the DataFrame (→ *columns*) using native Python arithmetic operators

Operation	Symbol	Example	Description
Addition	`+`	`df['VEI'] + 1`	Adds a value to each element
Subtraction	`-`	`df['VEI'] - 1`	Subtracts a value from each element
Multiplication	`*`	`df['VEI'] * 2`	Multiplies each element by a value
Division	`/`	`df['VEI'] / 2`	Divides each element by a value
Exponentiation	`**`	`df['VEI'] ** 2`	Raises each element to a power
Modulo	`%`	`df['VEI'] % 2`	Remainder after division for each element

- Divide `VEI` by 2 and store results a new column (→ `VEI_haved`)

```
1 df['VEI_halved'] = df['VEI'] / 2
```

Expanded arithmetic operations

- The range of arithmetic operations can be expanded using `numpy`

Operation	Symbol	Example	Description
Exponentiation	`np.power`	`np.power(df['VEI'], 2)`	Element-wise exponentiation
Square root	`np.sqrt`	`np.sqrt(df['VEI'])`	Element-wise square root
Logarithm (base e)	`np.log`	`np.log(df['VEI'])`	Element-wise natural logarithm
Logarithm (base 10)	`np.log10`	`np.log10(df['VEI'])`	Element-wise base-10 logarithm
Exponential	`np.exp`	`np.exp(df['VEI'])`	Element-wise exponential (e^x)

- Divide `VEI` by 2 and store results a new column (→ `VEI_haved`)

```
1 df['VEI_square'] = np.power(df['VEI'], 2)
```