Ombrone River (Tuscany, Italy). By courtesy of Caterina Gozzi

GEOCHEM NEWSLETTER

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IN THIS ISSUE

So.Ge.I. – ITALIAN GEOCHEMICAL SOCIETY

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Letter from the President

Orlando Vaselli

Dear Friends and Colleagues,
Happy New Year!!
This is the last issue of our GeochemNewsletter for 2023. This year we have increased the number of members. Currently, we indeed have 150 members and several events have been organized, co-organized or sponsored.
October last year, we had the election of the president and the presidential council by means of ELIGO, an electronic and online voting platform that has been purchased for this special occasion. The results, already sent to all the Society's members, are here summarized:
150 Eligible voters, 74.7 % voted.
Presidential council
Marino Vetuschi Zuccolini: 87 preferences
Barbara Nisi:78 preferences
Enrico Dinelli: 58 preferences
Walter D'Alessandro: 49 preferences
Stefano Caliro: 33 preferences
The Presidential council for the next four years (2024-2027) will be composed by: Marino Vetuschi Zuccolini, Barbara Nisi, Enrico Dinelli, Walter D'Alessandro whilst I have been re-elected for the second and last time as President. Thank you.
I do wish to thank you for the massive participation to the ELIGO day and many thanks to Stefano Caliro who, during the previous 4 years as member of the presidential council, has strongly contributed to the events organized by the Society. I would like to welcome Walter D'Alessandro.
In the last issue of the newsletter, I mentioned that a lot of members would have been involved in the joint (SGI-SIMP-SoGeI-AIV) congress of Potenza. The sessions proposed by the members were very successful and I am also glad for the large participation to the General Assembly that was held during this congress. Unfortunately, by a financial point of view there were some problems and there is a "hole" in the budget and we have been asked to partly fill this "hole". Additionally, after many years, the budget related to the joint congress of Parma (2019) was received and also in this case there is a "hole", though smaller with respect to that of Potenza, in the budget. Basically, about 16 k€ are to be paid to SIMP. We are presently trying a payment of instalments. I will keep you posted.
After the Potenza congress, the annual meeting of BeGeo (*Sustainability and risk: BeGEO scientists on the road to the future*) was held from the 3rd to the 5th of October in Naples and fully organized by PhD students and young researchers. Several young So.Ge.I. researchers organized several sessions. I am very glad to say that most our members are <35 years, suggesting that our society is alive as they bring new ideas and conferences.
Finally, from the 29th of November to the 1st of December the young geological/geochemical community of Pisa has organized the GeothermiX Conference (*How Earth's heat is studied and impacts society*), partly sponsored by the Society. Evelina Dallara, Marco Lazzarotti, Marella Parnas, Ilaria Furfori and Fabio Macelloni prepared a brief summary related to this event. It can be found in the newsletter. I do encourage other PhD communities to organize this short meetings with different and appealing topics. The Society is always highly favorable to support these sort of events.

What about 2024? Some events are already well defined. The first one (in chronological order) is the *Summer School on In situ Measurements and Sampling of Volcanic Gases: Science meets Practice* (June 17-21, 2024) under the umbrella of So.Ge.I. The site is always the Island of Vulcano, the participation is free of charge. Each individual has to cover travel, accommodation and food expenses whereas all the (practical) lectures are free and held by researchers from different (national and international) universities and research centers (INGV and CNR). In the newsletter, you will find the First Circular of the Vulcano School. Many thanks to the Firenze and Palermo (university and INGV) personnel and particularly to Franco Tassi, Sergio Calabrese and Stefania Venturi for spending their time and energy in organizing this event, which every year welcomes 60 to 80 students and young researchers for a lot countries.

From the 1st to the 4th of July, 2024, the second congress of the Italian Society of Geochemistry will be held in Perugia. The organizing and scientific committees are presently active at their best for a successful event. Many thanks to the Perugia colleagues for their efforts.
The two committees have decided to have 4 topics:
1) Experimental and Computational Geochemistry;
2) Environmental Geochemistry;
3) Geochemistry of volcanic, geothermal and seismically active areas;
4) Cosmochemistry and Planetary Sciences.
We do wish to thank the President of INGV (Prof. Carlo Doglioni) for sponsoring this congress. Here below, you can find the 1st circular whilst the second one is supposed to be ready by the end of January.

From the 3rd to the 6th of September, 2024 the Granulite & Granulite Conference, partly sponsored by our Society, will be held in Verbania (northern Italy). Antonio Langone is one of the organizer of this conference. More information can be found at https://granulites2024.sfmc-fr.org/.

Three other events are, hopefully, on their way. The first one is a So.Ge.I. day(s) on *The Geochemistry of Mercury* to be held in Abbadia San Salvatore (Siena). The period has not been defined yet. June and early July are apparently very busy. It can be though to move this event at the end of August or September. As soon as more infos will be gathered, I will keep you posted.
Perhaps, you may recall that in June 2020, there was the idea to organize the 3rd Isotope Ratio MS Day. Unfortunately, the sanitary emergency caused the cancellation of the event. It seems that there are good chances to have this interesting scientific meeting this year. "*Background value and geochemical baseline*", this could be the topic of a 1-day event. Even in this case, site and dates are to be defined.

Differently, it is sure that the Italian Geological Society and the Italian Society of Mineralogy and Petrology are organizing the joint congress entitled *"Geology for sustainable management of our planet"* at the Bari University Campus from the 3rd to the 5th of September 2024. I would like to thank Barbara Nisi since she is the representative of our Society, being one of the members of the scientific committee of the congress. Even for this congress, a few sessions has been proposed by the So.Ge.I. members.

What about the content of this newsletter? Well, we have the eighth episode of "R". Caterina Gozzi is always available to provide interesting insights about this free software environment for statistical computing and graphics. I hope that other young researchers will be able to provide some contributions related to either their scientific activity or relevant field works.

Marino Zuccolini prepared a brief summary related to the online meeting about the PNRR Mission 4, Component 2, Line 3.1 that is meant cover an important topic of the geological sciences that is to become a reference structure for the sharing of geological-environmental data in view of the next challenges related to environmental changes.

Antonella Buccianti reported on the conference titled "*Water & Nature*", organized by Caterina Gozzi and Stefania Venturi and supported by our Society. It was held last November in the Main Hall of the University of Florence. The intimate relationship between water and the health of the ecosystems under the effect of climate changes and the increasing human pressure was the main target of the conference. The Department of Earth Sciences of the University of Florence and the National Biodiversity Future Centre as part of the PNRR project sponsored the event.

Many thanks to Jacopo Cabassi for his valuable contribution in preparing the detailed list of the papers produced by our community, which is continuously increasing. The last but not the least acknowledgement is to Stefania Venturi for handing all the newsletter issues. Eventually, I am very grateful to all those young researchers who contribute to maintain our social media alive.

Follow So.Ge.I. on Social Media

https://twitter.com/SocietaGe

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https://instagram.com/societageochimica_it

https://it.linkedin.com/company/societageochimicaitaliana

PRIMA CIRCOLARE

A.D. 1308 unipg
DIPARTIMENTO DI FISICA E GEOLOGIA
DIPARTIMENTO DI ECCELLENZA MUR 2023/2027

2° CONGRESSO
SOCIETÀ GEOCHIMICA ITALIANA

FROM THEORETICAL TO APPLIED GEOCHEMISTRY

PERUGIA – 1-4 LUGLIO 2024

Dall'1 al 4 Luglio 2024 si terrà a **Perugia** il **2° Congresso della Società Geochimica Italiana**. L'evento sarà ospitato presso il **Complesso Monumentale di San Pietro**.

Il Congresso si articolerà in **sessioni tematiche** dedicate alla geochimica dei fluidi, alla geochimica ambientale, alla geochimica sperimentale e computazionale, alla cosmochimica e alle scienze planetarie. Ciascuna sessione accoglierà **contributi orali e poster**.

Conferenze plenarie affronteranno **tematiche multidisciplinari** presentando argomenti di ricerca di confine tra la geochimica e altre discipline scientifiche, quali biogeochimica e planetologia.

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Created: 1 October 2023

In occasione del Congresso saranno inoltre consegnati i **Premi SoGeI 2024** per le **migliori Tesi di Dottorato** in ambito geochimico. Il bando sarà pubblicato entro il 31gennaio 2024 sul sito web della Società Geochimica Italiana.

COMITATO SCIENTIFICO:

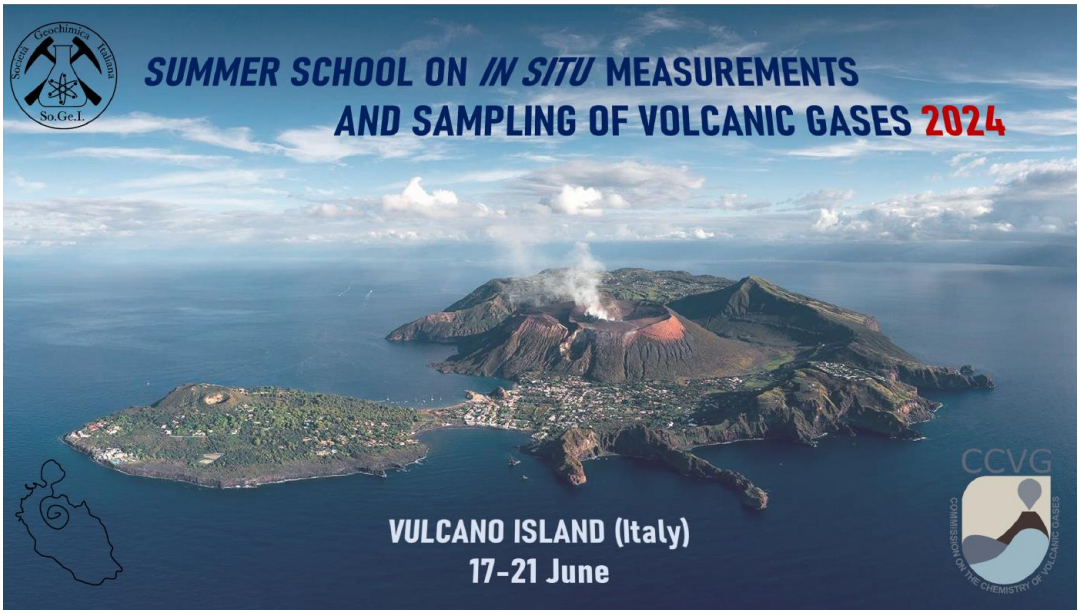
Carlo Cardellini (UNIPG); Enrico Dinelli (UNIBO); Cinzia Federico (INGV); Francesco Frondini (UNIPG); Luigi Marini (STEAM srl); Barbara Nisi (CNR-IGG); Elena Pavoni (UNITS); Giuseppe Saldi (UNIPG); Daniela Varrica (UNIPA); Orlando Vaselli (UNIFI); Martina Zucchi (UNIBA)

COMITATO ORGANIZZATORE:

Alessandra Ariano (UNIPG); Carlo Cardellini (UNIPG); Francesco Frondini (UNIPG); Monia Procesi (INGV); Lisa Ricci (UNIPG); Giuseppe Saldi (UNIPG); Mauro Tieri (UNIPG); Stefania Venturi (UNIFI); Azzurra Zucchini (UNIPG); Marino Vetuschi Zuccolini (UNIGE)

La **sottomissione degli abstract** sarà possibile a partire da **Febbraio 2024**.

Maggiori informazioni saranno fornite nelle prossime comunicazioni e sul sito della Società Geochimica Italiana (www.societageochimica.it)



The ***Summer School on In Situ Measurements and Sampling of Volcanic Gases***, patronized by the Italian Geochemical Society (**So.Ge.I.**) and the IAVCEI Commission on the Chemistry of Volcanic Gases (**CCVG**), will be hosted in **Vulcano Island**, in the Aeolian Archipelago (Sicily, Italy).

The school is addressed to **Master and PhD students** and **PostDoc researchers**
It gathers researchers and professors with diverse expertise in
fluid geochemistry, microbiology, biogeochemistry, atmospheric chemistry, volcanology and hydrogeochemistry.

The aim of the school is to bring together students and professional scientists from diverse backgrounds, stimulating the development of a **multidisciplinary approach** to the study of complex natural systems.

Field activities will be performed both at **La Fossa Crater**, in the inhabited area of **Vulcano Porto** and in the hydrothermalized area of **Baia di Levante**.

The students will have the opportunity to experience, directly in the field, different techniques of **fumarolic gas and water sampling**, **remote sensing**, **measurements of diffuse soil degassing**, **sampling of submerged gas emissions**, **air quality measurements** and **soil sampling for microbiological analysis**, devoted mainly to (but not limited to) volcanic surveillance and monitoring, environmental quality assessment, and understanding of deep and shallow geobiochemical processes.

No registration fee is required. Students will be responsible for their accomodation and travel expenses.

Registration deadline: 1 March, 2024

To register, write to **franco.tassi@unifi.it** - **stefania.venturi@unifi.it** – **sergio.calabrese@unipa.it**

Members' Activities

GeothermiX

Evelina Dallara

GeothermiX was the first international conference on geothermal energy geothermics organized at the Department of Earth Sciences of the University of Pisa, held from 29th November to 1st December. This event has been entirely organized by Ph.D. students of the aforementioned Department, to deal with geothermal energy from a geological and environmental point of view.

Five different sessions were therefore organized, starting with structural geology, geochemical and geophysical methods, environmental monitoring and modelling, and concluding with didactic and dissemination of georesources. In all the sessions national and international (from the University of Iceland and ETH Zürich) keynotes could held their speeches, and several young researchers had the opportunity to present their ongoing work in geothermal energy. A poster session was organized too, during which several Ph.D. students could explain their research and interact with the other participants.

About 80 people participated in presence and about 50 online. Different nationalities, institutions and universities were represented. Furthermore, since it is important to promote initiatives that foster gender equality in all spheres of the society, we would also like to emphasize that in organizing the event we tried to involve people considering also this aspect. Indeed, a great participation of women has been observed during the three days of the conference.

The third day a field trip to the Larderello geothermal area took place. This activity has been organized in conjunction with Enel Green Power, who guided the group through the Valle Secolo powerplant. The day, and therefore the conference, has been concluded with the lunch at Vapori di Birra, where the geothermal energy is directly used for beer production, and later with the visit to the Le Biancane Natural Park, characterized by fumaroles and steaming ground.

The whole event has been financed first by the University of Pisa, which each year gives the possibility to Ph.D. students to organize this kind of events. Furthermore, this conference couldn't have been possible without the help from So.Ge.I., the Department of Earth Sciences (UNIPI), who also hosted the event, INGV and UGI. The latter has also funded a Ph.D. grant which gave the possibility to 10 Ph.D. students to obtain a partial refund to facilitate them to join the event. Among the partnerships, there are also SIGEA, OGT, BeGeo, AIGAA, ARPAT, Regione Toscana, and the Museo di Storia Naturale di Calci, apart from the media partners.

The Organizing committee:

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Indirizzo del sito:
http://geothermix2023.dst.unipi.it/index.php/en/

Figures (from top to bottom) (i) Organizing Committee. From left to right: Ilaria Furfori, Evelina Dallara, Marella Parnas, Fabio Macelloni, Marco Lazzarotti, and Birhan Kebede. (ii) Poster Session at the Department of Earth Sciences. (iii) During the conference. (iv) Field Trip at Larderello; here at the demonstrative well. (v) Field Trip at the Le Biancane Natural Park.

Members' Activities

GeoSciencesIR

Marino Vetuschi Zuccolini

The project (PNRR Mission 4, Component 2, Line 3.1) sees ISPRA as a leader involving 2 Research Entities and 13 Universities and the meeting saw the participation of 35 Stakeholders between public and private of the 52 called by the Panel. The main purpose of the Project is to cover an important topic of the geological sciences that is to become a reference structure for the sharing of geological-environmental data in view of the next challenges related to environmental mutations. The speakers stressed the need to develop the Project and to keep it active at least for the next 10 years in order to provide continuity to the dissemination of digitized data for the research community and the professional world, according to FAIR and INSPIRE standards. The operational development of the Project foresees 8 specific WP focused according to the Speakers to acquire sensitive information in different areas of Geoscience such as: WP2 - Geological & Geothematic Mapping and Modelling: development of algorithms, Web Services, Modelling of Submerged Areas, Seabeds and Active Faults WP3 - Landslides & Sinkholes:IFFI and Sinkholes analysis and update, innovative in situ techniques for landslides and sinkholes; WP4 - Risk Monitoring and Management: Risk Monitoring, Active and capable faults, Nowcasting Meteo, e-learning WP5 - Georesources and Land Monitoring: Sustainability of Mining, Consumption-Coperurae and Land Use (SINRM and Gem) WP6-7-8: Harmonisation of data models (Semantics, GEOSCIML, INSPIRE, OPENAPI, GML and Geopackage), Cloud Infrastructure to increase interoperability between Researchers, Installation of a Technology Architecture for Geological Data Validation and E-learning. The second meeting dedicated to stakeholders will be held on February 27 in Rome at the headquarters of the CNR, in Via Aldo Moro.

For those who want to get more information, please visit the website of the Project https://geosciences-ir.it.

Moreover, for those who are interested at the link of YouTube-ISPRA (https://youtu.be/GBO6JERpsX8) a video related to the round table held in Florence during the GeoSciences IR @ ETE 2023 can be visualized.

Members' Activities

Water & Nature

Antonella Buccianti

On November 16, 2023, a conference on *"Water & Nature"* was held in the main hall of the University of Florence introduced by the delegate of the Rector Prof. Maria Paola Monaco and the Director of the Department of Earth Sciences, Prof. Luca Bindi.

The aim of the conference was to discuss the deep link that joins water and the health of the ecosystems under the effect of dimate changes and an increasing human pressure. The conference was organized by the Department of Earth Sciences of the University of Florence and the National Biodiversity Future Centre as part of the PNRR project.

In many cases complex systems- like ecosystems- lose stability passing through tipping points at which they respond abruptly to small changes under the effect of external drivers, as for example, dimate changes. The ability of identifying such tipping points is hindered by our limited understanding of the underlying complexity for most of these systems. In addition, almost none of these systems exists in isolation, but all are part of a network of interacting and interdependent elements. Moreover, crossing a tipping point in one part of the system may lead to a cascade of transitions in another with an increasing risk under present rates of global environmental deterioration. In the conference Dr. Vasilsi Dakos working at the CNRS, Institut des Sciences de l'Evolution de Montpellier (F) and Visiting Professor of the DS, has presented a talk about how to evaluate resilience, tipping points and early warning signals preparing ourselves for surprise under global changes. The coordinator of the National Commission for Environmental Evaluation of the Italian Ministry for Environment and Energy Security, Dr. Avv. Paola Brambilla, discussed the legal dimension of wetland protection focusing the attention on the necessity to develop an adequate legislation.

On the other hand, Dr. Lorenzo Ciccarese from ISPRA has presented an interesting talk about the hydric emergency under dimate changes and dedine of Nature, focusing the attention of the interconnections among the different parts of an ecosystem and the relapses on human society.

After the first three general talks the conference is continued with the presentation of some preliminary results obtained under the National Biodiversity Future Centre project financed by the PNRR. Results concerned the investigation of biodiversity and dimate changes on the coastal lagoons of central Italy (WWF Oasis, Prof. Adele Bertini and Dr. Federica Badino) and the study of river catchments considered as a fundamental element of the surficial environment, with the case study of the Ombrone (Gr) river (Dr. Stefania Venturi, Dr. Caterina Gozzi, Dr. Francesca Giannetti).

Finally, Dr. Carlo Scoccianti for the WWF Oasis Committee of the Florentine area, has presented the result of thirty years of design and management of the humid area located between Firenze and Prato, considering the role played by the flooding areas in the developing of new habitats.

The conference was attended by people in the main hall and transmitted live on the official channel of the university of Florence and has represented an in-depth discussion moment of the role of water between extreme flooding events alternated to severe drought periods. The event was sponsored by the Italian Geochemical Society (SoGeI).

R-Corner

Caterina Gozzi

Download and install R and R Studio

R is completely free software that can be used on Linux, Windows and Mac operating systems. Visit https://www.r-project.org and follow the instructions to download the version of R compatible with your system.

R Studio provides an integrated environment for R with numerous features to improve the user experience and make using R easier. After installing R, you can download and install R Studio for free from http://www.rstudio.com/.

Heatmaps in R

Heatmaps are graphical representations of data, where the individual values contained in a matrix are represented using colors. One of their main advantages is that they allow us to simultaneously visualize clusters of samples and variables (e.g., chemical elements). First, hierarchical clustering is performed on both the rows and the columns of the data matrix. The columns/rows of the data matrix are then re-ordered according to the hierarchical clustering result, putting similar observations close to each other.

Creating heatmaps in R can be achieved using various packages. These include the commonly used `heatmap` function from base R, the `geom_tile` function from the ggplot2 package, or alternatively `pheatmap()` from pheatmap R package for more flexibility and customization.

Among the possible functions, here we describe how to draw heat maps using the `heatmap.2()` function from the R package **gplots** (Warnes et al., 2022). We recommend this function as it produces high-quality matrices with side dendrograms and a color key to easy interpret the results, while allowing for a good degree of customization. Its use, combined with the color scales provided by the package viridis (Garnier et al., 2023), enables to display the matrix using different color palettes. In *Figure 1,* we provide a code example that you can customize based on your specific data and visualization preferences. The first step is to install and activate the R packages gplots and **viridis** (see, https://CRAN.R-project.org/package=gplots, https://CRAN.R-project.org/package=viridis). Subsequently, you can apply the `heatmap.2()` function on your data. It is important to note that `heatmap.2()`, similarly to other functions to create heatmaps, takes a matrix as input. If you have a data frame, you should convert it to a matrix with `as.matrix()`, to be noted is that only numeric variables are allowed in it.

```
library(gplots)
library(viridis)
heatmap.2(as.matrix(data),
          margins = c(6,6),
          density.info = "none",
          trace = "none",
          Rowv = TRUE,
          dendrogram = "both",
          colsep=1:nrow(data),
          rowsep=1:nrow(data),
          sepcolor = "black",
          col =
viridis::viridis_pal(option =
"turbo"))
```

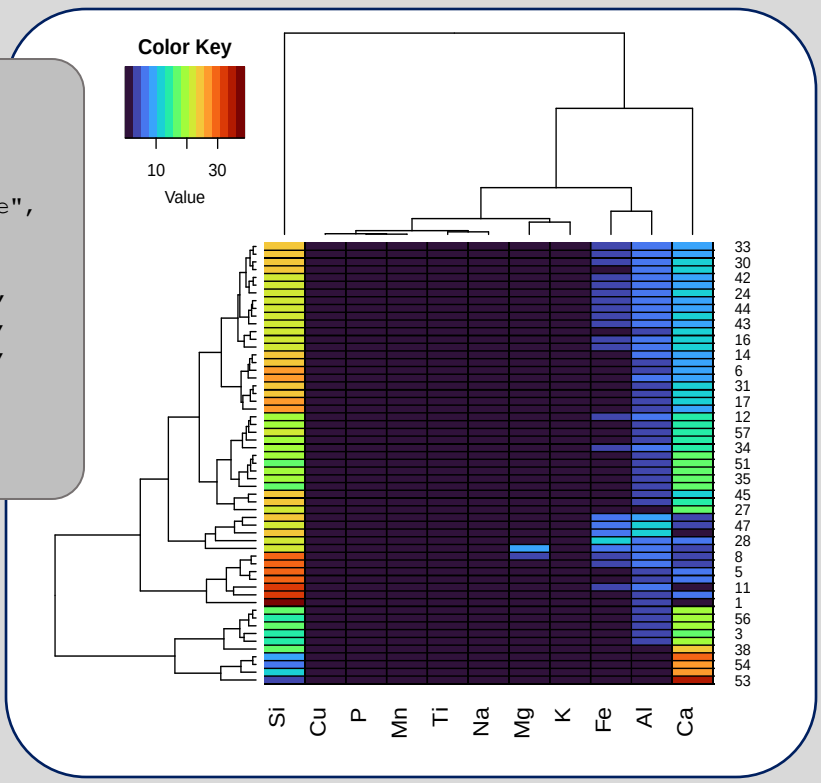

Fig. 1 Code example for building heatmaps with gplots package and related output matrix to the right. Input data: major elements concentrations (in % wt) measured in the Tiber River Basin.

If we notice that some of the labels are truncated, we can adjust the viewing area by using the `margins` argument (as shown in example code: c(6,6)). This two numbers vector will add space below and to the right of the heatmap. We can play with these numbers until we reach a satisfactory visualization.
The function also automatically adds density/trace lines, which can be useful but may complicate the visualization. They can be removed by setting "none" to `density.info` and `trace` arguments (*Fig.1*).
Other options include the possibility to remove the clustering from the rows, only keeping the column clustering and dendrogram with Rowv = FALSE, by default Rowv is TRUE. The `dendrogram` argument indicates whether to draw "none", "row", "column" or "both" dendrograms (default is "both").
The arguments called `colsep` and `rowsep`, allow to add vertical and horizontal separating lines, whose color can be defined with `sepcolor`.
The creation of a custom color range can be done using the col argument and the package **`viridis`**. A character string indicates the color map option to use. Eight options are available: "magma", "inferno", "plasma", "viridis', "cividis', "rocket", "mako", "turbo".
Figure 1 on the right illustrates the resulting matrix. Input data of stream sediment compositions in the Tiber River Basin (central Italy) are here considered as application example. As you can see, this heatmap is not very insightful, since all the variation is absorbed by Si and Ca variables. In such cases, one can also normalize the data using the `scale` argument, indicating if the values should be centered and scaled in either the row direction or the column direction, or none (default is "none").
A valid alternative could be the use of a correlation matrix calculated with the function `cor()` as input instead of the data matrix, as shown in *Figure 2*.

```
library(gplots)
library(viridis)
cormat<-signif(cor(data),2)
heatmap.2(as.matrix(cormat),
          margins = c(6,6),
          density.info = "none",
          trace = "none",
          Rowv = TRUE,
          dendrogram = "both",
          colsep=1:nrow(cormat),
          rowsep=1:nrow(cormat),
          sepcolor = "black",
          col =
viridis::viridis_pal(option =
"turbo"))
```

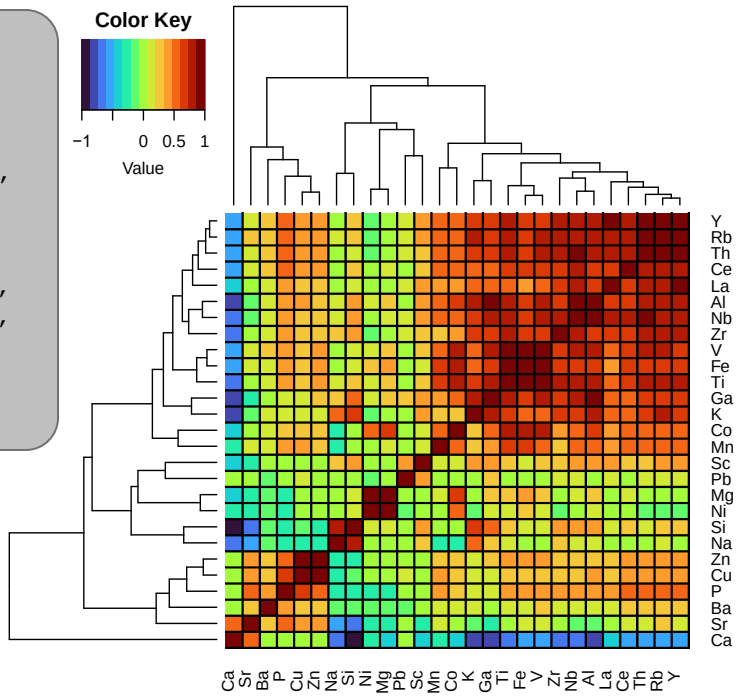

Fig. 2 Code example for building heatmaps with gplots package and related output matrix to the right. Input data: correlation matrix of major and trace elements concentrations (in % wt) measured in the Tiber River Basin.

In this case, the resulting matrix will display clustered variables on both row and column. Moderate positive and negative correlations (red and blue colors, respectively) can be easily visualized thanks to the color key legend, whereas variables association are highlighted by the dendrograms.
For additional functions we recommend to refer to the following R Documentation about `heatmap.2` function https://www.rdocumentation.org/packages/gplots/versions/3.1.3/topics/heatmap.2.

References

gplots: Various R programming tools for plotting data. Warnes GR., Bolker B., Bonebakker L., Gentleman R., Huber W., Liaw, A. ... (2022). R package version 3.1.3, 2022.
Garnier, S., Ross, N., Rudis, R., Camargo, P.A., Sciaini, M., Scherer, C. (2023). Viridis (Lite) - Colorblind-Friendly Color Maps for R. doi:10.5281/zenodo.4679423, viridis package version 0.6.4, https://sjmgarnier.github.io/viridis/.

Events and Opportunities

Schools and Thematic Days

- Vulcano Summer School on *in situ* measurements and sampling of volcanic gases 2024
  Vulcano Island (Italy), 17-21 June 2024
  1st circular

Conferences and Congresses

- 2nd Congress of the Italian Geochemical Society (So.Ge.I.)
  From theoretical to applied geochemistry
  Perugia (Italy), 1-4 July 2024
  1st circular

- Granulite & Granulite Conference
  Verbania (Italy), 3-6 September 2024
  Website

- SGI-SIMP Joint Congress
  Geology for sustainable management of our planet
  Bari (Italy), 3-5 September 2024
  Website

Members' Publications

List of Members' Publications (IF≥2)

referred to the period Aug 22, 2023 – Dec 31, 2023

Abedini, A., Khosravi, M. & **Mongelli, G.** (2023). Critical metals distribution in the late Triassic–early Jurassic Nasr-Abad bauxite deposit, Irano–Himalayan karst bauxite belt, NW Iran. *Geochemistry*. https://doi.org/10.1016/j.chemer.2023.126039

Agusto, M., Lamberti, M. C., **Tassi, F.**, Carbajal, F., Llano, J., Nogués, V., Núñez, N., Sánchez, H., Rizzo, A., García, S., Yiries, J., Vélez, M. L., Massenzio, A., Velasquez, G., Bucarey, C., Gómez, M., Euillades, P. & Ramos, V. (2023). Eleven-Year Survey of the Magmatic-Hydrothermal Fluids From Peteroa Volcano: Identifying Precursory Signals of the 2018–2019 Eruption. *Geochemistry, Geophysics, Geosystems*, *24*(11). https://doi.org/10.1029/2023GC011064

Aiuppa, A. & Moussallam, Y. (2023). Hydrogen and hydrogen sulphide in volcanic gases: abundance, processes, and atmospheric fluxes. *Comptes Rendus - Geoscience*, *356*, 1–24. https://doi.org/10.5802/crgeos.235

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