The Journal of Open Source Software

PyVOLCANS: A Python package to flexibly explore similarities and differences between volcanic systems

Pablo Tierz*[1], Vyron Christodoulou†[1], John A. Stevenson[1], and Susan C. Loughlin[1]

1 British Geological Survey, The Lyell Centre, Edinburgh, UK.

DOI: 10.21105/joss.03436

Software

- Review
- Repository
- Archive

Editor: Pending Editor

Submitted: 30 June 2021
Published: 30 June 2021

Summary

There are over 1,400 volcanoes on Earth that have either erupted or shown signs of volcanic activity (e.g. fumaroles or hot springs) in, approximately, the last 12,000 years. Of these, around 40-50 are erupting at any given time (Global Volcanism Program, 2013; Siebert et al., 2010). Volcanoes provide a range of economic benefits, such as fertile soils, geothermal energy or valuable mineralisations, create a strong sense of belonging among local populations, and fascinate visitors. However, volcanic systems can also generate hazardous phenomena, which may threaten local inhabitants, tourists and infrastructure at distances of up to tens or hundreds of kilometres.

In order to understand and quantify volcanic hazard, volcano scientists are faced with many questions. How often do eruptions occur? How big are they? What style of eruption is possible (e.g. mainly explosive or effusive)? From where on the volcano is eruptive activity sourced? What areas around the volcanic system may be impacted? Will there be any early warning signals?

Quantitative data to address these questions are scarce (Loughlin et al., 2015). While a handful of volcanoes (e.g. Etna, Italy; Kīlauea, USA; Merapi, Indonesia) have been extensively studied, hundreds of volcanic systems around the world remain poorly-understood. One possible mitigation to the issue of data scarcity in volcanology and volcanic hazard assessment is the use of *analogue volcanoes* (Newhall et al., 2017; Newhall & Hoblitt, 2002). These are volcanoes with similar characteristics to a data-scarce volcano of interest. Data and insights from the well-studied volcano(es) can be used to provide estimates for important variables, such as the number of eruptions during specific time windows or the size of those eruptions. Such methods have been used for many years but we have created the first tool to enable a structured and harmonised approach worldwide.

Statement of need

`PyVOLCANS` (Python VOLCano ANalogues Search) is an open-source tool that addresses the need for an objective, data-driven method for selection of analogue volcanoes. It is based on the results of VOLCANS (Tierz et al., 2019), a first-of-its-kind method to quantify the analogy (or similarity) between volcanic systems, based on a structured combination of five volcanological criteria: tectonic setting, rock geochemistry, volcano morphology, eruption size, and eruption style. `PyVOLCANS` provides a command-line interface to make the results from the VOLCANS study easily accessible to a wide audience. `PyVOLCANS` is a versatile tool

*Corresponding author
†Now at The Data Lab, The Bayes Centre, Edinburgh, UK

for volcano scientists, with potential applications ranging from investigating commonalities between volcanic systems (Cashman & Biggs, 2014) to supporting probabilistic volcanic hazard assessment at local, regional and global scales. It can also be used as a tool for teaching and scientific outreach.

Users can easily derive data-driven sets of *top* analogue volcanoes (i.e. those with highest analogy) to any volcanic system listed in the reference database for recent global volcanism: the Volcanoes of the World Database, hosted by the Global Volcanism Program of the Smithsonian Institution (Global Volcanism Program, 2013). Users can also choose the number of *top* analogue volcanoes to investigate and can customise the importance (i.e. weight) that is given to each of the five aforementioned volcanological criteria. Additionally, users can select a number of *a priori* analogue volcanoes (i.e. volcanoes deemed as analogues by other means, such as expert knowledge) and assess their values of analogy with the target volcano to see how well they match on different criteria and if other volcanoes could be a better choice (Figure 1).

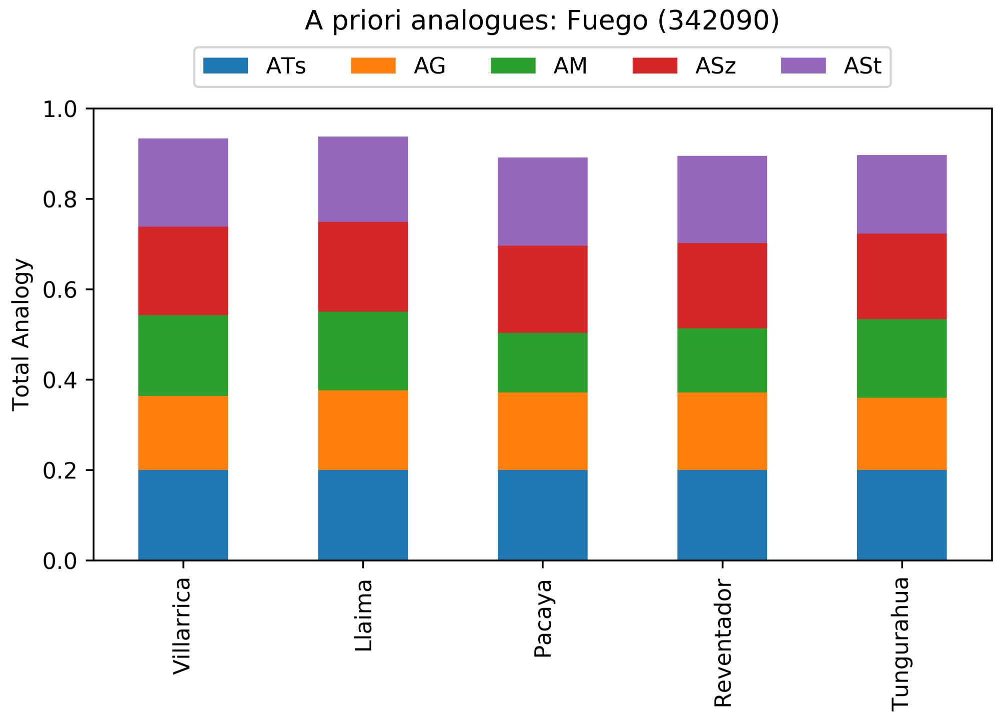

Figure 1: Values of single-criterion (colours) and total analogy (bar heights) between an example target volcano, Fuego (Guatemala)*, and five *a priori* analogues (please see Tierz et al., 2019, for more details). ATs: Analogy in Tectonic setting; AG: Analogy in rock Geochemistry; AM: Analogy in volcano Morphology; ASz: Analogy in eruption Size; ASt: Analogy in eruption Style. *Number between brackets denotes the unique volcano identifier used by the GVP database.

The results from the VOLCANS study have already been used in recent research: e.g. exploring the volcanological factors that influence the development of particular volcano morphologies (White, 2020); constraining potential hazardous phenomena and hazard scenarios at a given target volcano, based on its analogue volcanoes (Simmons, 2020); quantifying probability distributions of eruption sizes and probabilities of occurrence of diverse hazardous phenomena (Tierz et al., 2020); or even exploring volcano analogies at regional scales, by generating sets of analogue volcanoes for tens of volcanic systems (Crummy et al., 2021). The last two example applications have played a key role in developing quantitative hazard analyses for

Ethiopian volcanoes, within the RiftVolc project.

We hope that the release of `PyVOLCANS` will encourage studies based on data-driven selection of analogue volcanoes and that such analyses will continue to grow in number and diversity of their scientific purposes.

Acknowledgements

The research leading to these results has been mainly supported by the UK National Capability Funding (Innovation Flexible Fund programme). We would like to warmly thank Eliza Calder for all her work during the development of the VOLCANS method, and Sarah Ogburn for being one of the first people who *convinced* us that we should develop an open-access application of VOLCANS, sooner rather than later. Declan Valters is thanked for support with Python programming, and Fabio Dioguardi for his internal review. Moreover, we would like to sincerely thank a number of colleagues with whom we shared very insightful conversations about analogue volcanoes and/or `PyVOLCANS`: Chris Newhall, Isla Simmons, Adriano Pimentel, Julia Crummy, Gezahegn Yirgu, Charlotte Vye-Brown, Lara Smale, Karen Fontijn, Ben Clarke, Susanna Jenkins, Elly Tennant, Pierre Barbillon, Elaine Spiller, Philippa White, Teresa Ubide, Sebastián García, Victoria Olivera, Jeremy Pesicek, Vanesa Burgos Delgado, Eitnat Lev, Jonty Rougier, Willy Aspinall, Paolo Papale, Monse Cascante and Thomas Giachetti.

References

Cashman, K., & Biggs, J. (2014). Common processes at unique volcanoes–a volcanological conundrum. *Frontiers in Earth Science*, *2*, 28. https://doi.org/10.3389/feart.2014.00028

Crummy, J., Vye-Brown, C., Marchant, B., Leeming, K., & Loughlin, S. (2021). *Estimation of the frequency and magnitude of potential future eruptions from Ethiopian volcanoes through expert elicitation* (Vol. OR/21/013, p. 43). British Geological Survey Internal Report.

Global Volcanism Program. (2013). *Volcanoes of the World, v. 4.10.0 (14 May 2021)*. Venzke, E (ed.). Smithsonian Institution. Downloaded 09 Jun 2021. https://doi.org/10.5479/si.GVP.VOTW4-2013.

Loughlin, S. C., Sparks, S., Brown, S. K., Vye-Brown, C., & Jenkins, S. F. (2015). *Global volcanic hazards and risk*. Cambridge University Press. https://doi.org/10.1017/CBO9781316276273

Newhall, C., Costa, F., Ratdomopurbo, A., Venezky, D., Widiwijayanti, C., Win, N. T. Z., Tan, K., & Fajiculay, E. (2017). WOVOdat–an online, growing library of worldwide volcanic unrest. *Journal of Volcanology and Geothermal Research*, *345*, 184–199. https://doi.org/10.1016/j.jvolgeores.2017.08.003

Newhall, C., & Hoblitt, R. (2002). Constructing event trees for volcanic crises. *Bulletin of Volcanology*, *64*(1), 3–20. https://doi.org/10.1007/s004450100173

Siebert, L., Simkin, T., & Kimberly, P. (2010). *Volcanoes of the World*. Univ of California Press. https://www.ucpress.edu/book/9780520268777/volcanoes-of-the-world

Simmons, I. (2020). *The Quetrupillán Volcanic Complex, Chile: Holocene volcanism, magmatic plumbing system, and future hazards* [PhD thesis]. University of Edinburgh.

Tierz, P., Clarke, B., Calder, E. S., Dessalegn, F., Lewi, E., Yirgu, G., Fontijn, K., Crummy, J. M., Bekele, Y., & Loughlin, S. (2020). Event trees and epistemic uncertainty in long-term volcanic hazard assessment of rift volcanoes: The example of Aluto (Central Ethiopia). *Geochemistry, Geophysics, Geosystems*, *21*(10), e2020GC009219. https://doi.org/10.1029/2020GC009219

Tierz, P., Loughlin, S. C., & Calder, E. S. (2019). VOLCANS: An objective, structured and reproducible method for identifying sets of analogue volcanoes. *Bulletin of Volcanology*, *81*(12), 76. https://doi.org/10.1007/s00445-019-1336-3

White, P. (2020). *An insight into the distinctiveness of 'tall, steep and pointy' volcanoes in Guatemala and Kamchatka* [Master's thesis]. University of Edinburgh.