Ph.D. position
Starting: 2024/2025

A complex system model of volcanic plumbing systems: Integration of physical models and network structures

Location : Prague, Czech Republic and Lyon, France (at least 12 months in each location.)
Timing :Starting as soon as possible (Expected: Winter 2024, Spring 2025)
Salary: 18 months at the standard French Ph.D. salary and 18 months at a typical Czech Republic Ph.D. salary (France: approx. 1800€ net. Possibility to increase the salary by giving classes. Czech Republic: starting at 24 750 CZK)
Supervision : co-supervised by: Catherine Annen (volcanologist, Institute of Geophysics of the Czech Academy of Sciences) and Rémy Cazabet (Computer Scientist, LIRIS Laboratory and IXXI, University Lyon 1, France)
Contact: `remy.cazabet@univ-lyon1.fr`, `annen@ig.cas.cz`

1. Ph.D. Subject

The objective of this PhD project is to use a multiscale complex system[1] approach to investigate the behavior of magmatic systems that underlay volcanoes. The relationship between the intensity (emitted volume) and frequency of volcanic eruptions follows a power law[2]. The largest eruptions (e.g. Yellowstone, 630,000 BP) are rare but have a global impact, can modify the climate, and potentially wipe out our civilization[3] while small eruptions can still strongly affect local communities (e.g. Soufrière Hills, Montserrat, 1995) and/or have important economic impacts at the continental scale (e.g. Eyjafjallajökull, Iceland, 2010).

The magma that feeds volcanoes is extracted from partially molten rocks and travel through a series of fractures and magma chambers on its way to the surface ([4], Fig. 1). A large part of the magma does not actually reach the Earth's surface but solidifies en route. The ability of the magma to accumulate in magma chambers and to ascend through fractures and conduits without solidifying strongly depends on the magma flow, while the opening of fractures depends on pressures and country rock strength. While various aspects of volcanic magmatism are well-known, a global understanding of the volcanic system as a whole is still lacking.

The objective of the Ph.D. is to build a global, multiscale model (fig. 2) of a magmatic plumbic system, modeling individual components of the system (magma chambers, dykes) in a way compatible with current scientific knowledge, while also respecting the organization of the system in term of space, temporality, and topology (network structure). The objective of this model is to investigate how the topology of the system (distribution of components in space, Network topology[5]) affects the flow of magma and ultimately the intensity and frequency of volcanic eruptions. The approach will involve two scales:

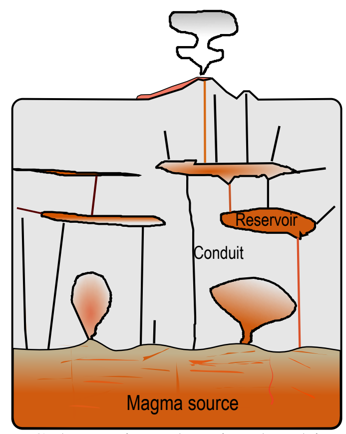

Figure 1. Schematic volcanic plumbing system

1. Abstraction/Macro-scale: The volcanic plumbing system is modelled as a graph. The nodes are magma reservoirs and the links are the magma conduits. The graph is spatial as the position of reservoirs in space affects the system and the graph is dynamic as reservoirs are filling and emptying as magma is transferred through the conduits.
2. Physical/Micro-scale: Each node is modelled with a physical model based on current observations and knowledge.

The PhD work plan is broadly:

- 1st semester: Literature review of magmatic systems and network science.
- 2nd semester: Development of the global model with integration of physical models from the literature.
- 3rd semester: Model validation using case studies. Exploration of parameter space.

- 4th and 5th semester: Applications to volcanic plumbing systems. Test of current conceptual models. Determination of the conditions that reproduce observations.
- 6th semester: Writing of the thesis.

The PhD project is transdisciplinary and international. It involves complex system sciences and Earth Sciences and will be supervised by a computer scientist (Dr Rémy Cazabet) and a volcanologist (Dr Catherine Annen). It is co-financed by the University Claude Bernard Lyon 1 and the Institute of Geophysics of the Czech Academy of Sciences. The student will share their time between Lyon (France) and Prague (Czech Republic).

The supervisors have experience working together, and the project is expected to grow, as other funding is secured. A preliminary study on a toy model has already been conducted[6].

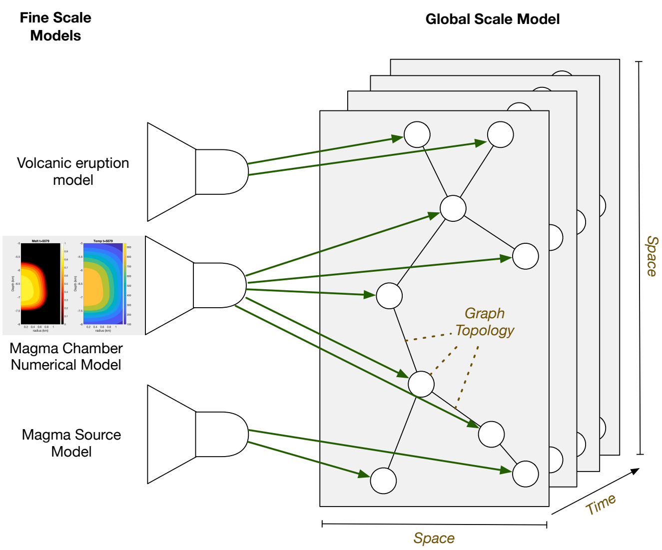

Figure 2. Multiscale approach. Physical models determine the behavior of nodes (micro scale) of a spatio-temporal network (macro scale).

For additional information and for applications, please contact Rémy Cazabet (`remy.cazabet@univ-lyon1.fr`) or Catherine Annen (`annen@ig.cas.cz`)

References

[1] James Ladyman, James Lambert, and Karoline Wiesner. What is a complex system? *European Journal for Philosophy of Science*, 3:33–67, 2013.

[2] Paolo Papale. Global time-size distribution of volcanic eruptions on earth. *Scientific reports*, 8(1):6838, 2018.

[3] Stephen Self. The effects and consequences of very large explosive volcanic eruptions. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 364(1845):2073–2097, 2006.

[4] Steffi Burchardt, Catherine J Annen, Janine L Kavanagh, and Suraya Hilmi Hazim. Developments in the study of volcanic and igneous plumbing systems: outstanding problems and new opportunities. *Bulletin of Volcanology*, 84(6):59, 2022.

[5] Albert-László Barabási. Network science. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 371(1987):20120375, 2013.

[6] Rémy Cazabet, Catherine Annen, Jean-François Moyen, and Roberto Weinberg. A toy model for approaching volcanic plumbing systems as complex systems. In *3rd French Regional Conference on Complex Systems (FRCCS 2023)*, 2023.