Towards 'Intelligent' hydrogeological conceptual models of volcanic island aquifers

Patrick LACHASSAGNE[1], Alix TOULIER[1,2]
1.HydroSciences Montpellier, Université de Montpellier, CNRS, IRD, IMT, Montpellier, 34000, France
2.Water Resources Research Center, University of Hawai'i at Mānoa, Honolulu, HI, 96848, USA

1. Context

Highly complex hydrogeological systems characterize volcanic island aquifers through various geological structures and substantial spatial variability of their hydrodynamic properties at multiple scales. These aquifers often exhibit double-porosity (fracture/matrix) and compartmentalized groundwater flow patterns. Such specificities frequently hinder the development of reliable **hydrogeological conceptual models** required to understand groundwater recharge dynamics, flow paths, and discharge processes, particularly into the ocean, and to address societal issues such as the sustainable management of their water resources.

2. Scientific objectives


Maui Island (Hawaii)

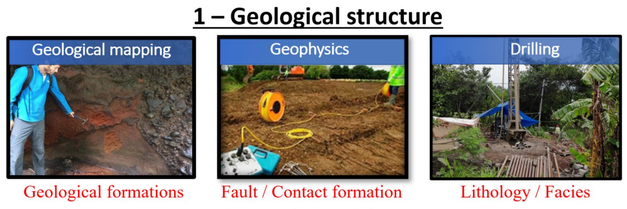
Based on existing hydrogeological datasets (from Indonesia, Mayotte, Réunion Island, Hawaii), this project aims to explore the potential of **Artificial Intelligence (AI) methods** to enhance and improve hydrogeological conceptual models of volcanic aquifers. The objective is to identify preferential recharge areas, potential groundwater storage reservoirs, and submarine groundwater discharge zones by integrating multi-source datasets (climatological, geological, geophysical, hydrological, hydrodynamic, hydrochemical, isotopic, oceanographic, etc.).

3. Approach

Through an exploratory approach combining the valorization of **multidisciplinary field data**, spatial analysis (GIS), **Machine Learning techniques** (Scikit-learn, PIML frameworks), and hydrogeological modeling (Feflow), this project aims to develop **"intelligent" hydrogeological conceptual models (IHCMs)** capable of integrating uncertainty and the intrinsic variability of volcanic systems. Ultimately, this innovative approach could provide a valuable decision-support tool for the sustainable management of water resources in volcanic islands, particularly vulnerable to climate change and increasing water demand.

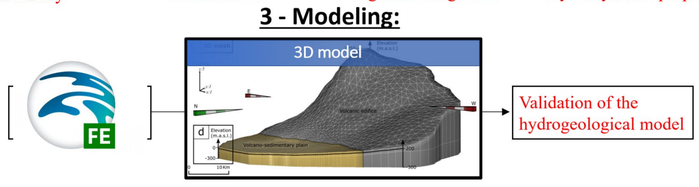
A – Existing data

1 – Geological structure



2 - Hydrogeological functioning:

3 - Modeling:



Leveraging artificial intelligence and field investigations to identify:

-recharge zones,

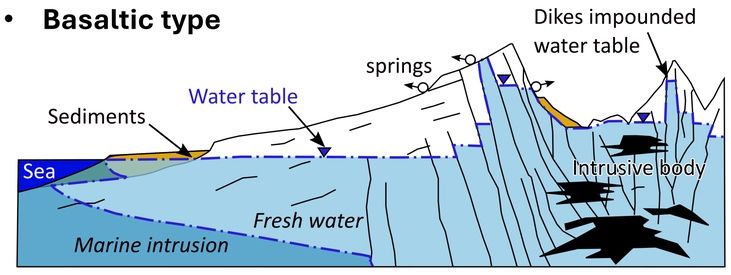
-groundwater flows,

-submarine groundwater discharge zones (SGDs)

B – IA tools

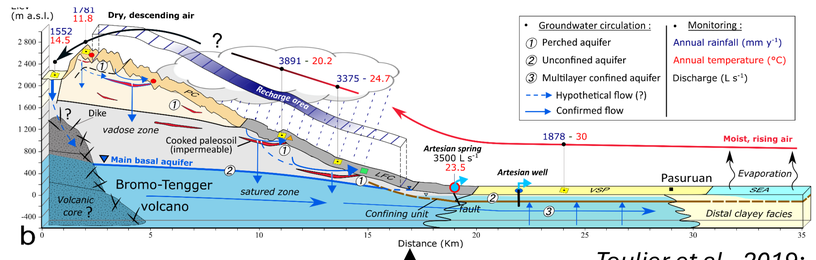
C – "Intelligent" hydrogeological conceptual models (IHCMs)

- **Basaltic type**



Join et al., 2016

- **Andesitic type**



Toulier et al., 2019; Baud et al., 2024

Required profile

- General knowledge in hydrogeology
- Good skills in coding (Matlab, Python) and GIS (ArcGIS)
- Strong interest in Artificial Intelligence (machine learning)
- Scientific and technical English
- Curious, autonomous profile with a taste for teamwork and research

Research Unit

- HydroSciences Montpellier - HYDROPOLIS
- Scientific team HYTAKE

Application

CV + cover letter should be sent by e-mail to P. Lachassagne (patrick.lachassagne@umontpellier.fr) and A. Toulier (atoulier@hawaii.edu)

References

Baud, B., Lachassagne, P., Dumont, M., Toulier, A., Hendrayana, H., Fadillah, A., & Dorfliger, N. (2024). Review: Andesitic aquifers—hydrogeological conceptual models and insights relevant to applied hydrogeology. *Hydrogeology Journal*, 32, 1259–1286. https://doi.org/10.1007/s10040-024-02784-0

Join, J.L., Folio, J.L., Bourhane, A., Comte, J.C., 2016. Groundwater Resources on Active Basaltic Volcanoes: Conceptual Models from La Réunion Island and Grande Comore. Act. volcanoes Southwest Indian Ocean Pit. la Fournaise Karthala 1–428. https://doi.org/10.1007/978-3-642-31395-0_5

Raschka, S., & Mirjalili, V. (2019). *Python Machine Learning: Machine Learning and Deep Learning with Python, scikit-learn, and TensorFlow 2* (3rd ed.). Packt Publishing.

Russell, S. J., & Norvig, P. (2021). *Artificial Intelligence: A Modern Approach* (4th ed.). Pearson.

Toulier, A., Baud, B., de Montety, V., Lachassagne, P., Leonardi, V., Pistre, S., Dautria, J.M., Hendrayana, H., Miftakhul Fajar, M.H., Satrya Muhammad, A., Beon, O., Jourde, H., 2019. Multidisciplinary study with quantitative analysis of isotopic data for the assessment of recharge and functioning of volcanic aquifers: Case of Bromo-Tengger volcano, Indonesia. J. Hydrol. Reg. Stud. 26, 100634. https://doi.org/10.1016/j.ejrh.2019.100634