Ph.D. Project Proposal

Unraveling the geothermal potential of Colombia: The benefits of Machine Learning in the modelling of geothermal systems by Play Fairway Analysis

Keywords

Play Fairway Analysis (PFA), Machine Learning, Numerical Modeling, Geothermal Favorability, Geothermal Energy, Energy Transition

Summary

Geothermal energy is one of the renewable and sustainable energy resources needed to support the global energy transition worldwide. Geothermal resources, like other subsurface resources, cannot be directly observed but must be inferred through indirect observations, creating significant interpretation challenges. Adapted from the Oil&Gas industry, the Play Fairway Analysis (PFA) is a particular exploration methodology, mainly developed for the Great Basin geothermal systems since the 2010s. The concept is a systematic exploration to find regional trends in geology relevant to a particular "play", that is a geological system of interest, and map them. The purpose of this map is then 1) to show the main "fairway", that is the area where a specific play is likely to be successful, and 2) to indicate if and what additional exploration work is needed, and at which scale. This methodology proved to be successful in lowering the exploration risk at all steps of the pre-drilling stage. However, this methodology faces now several limitations. Firstly, the most conventional geothermal systems have already been discovered, leaving the remaining geothermal resources that are blind in nature. Secondly, this approach relies heavily on the amount of data available, which can be low as the geothermal prospects coincide rarely with well-explored areas (i.e. O&G fields). Thirdly, the resolution of the field data is often very variable and rarely continuous. Lastly, the vast amount of techniques available to acquire field data needs manual interpretation of complex geological, geophysical, and geochemical markers. To overcome these limitations, we propose the use of machine learning techniques to augment PFA. The research will implement data-driven PFA techniques, map algebra, spatial statistics, satellite image processing, and both supervised and unsupervised machine learning methods to generate comprehensive models of heat, fluid, and permeability plays. This interdisciplinary approach combines multipurpose data from various geosciences beyond the traditional geology-geophysics-geochemistry framework, enabling better uncertainty analysis and risk reduction in interpretations. The results will contribute significantly to identify and characterize the geothermal resources in different environments of Colombia, such as hydrothermal and sedimentary systems, with potential applications in the exploration and utilization of its geothermal resources.

Context and Scientific Justification

The exploration of geothermal resources to determine the energy potential of a territory is becoming an essential element of national energy plans in different parts of the world. As a renewable and self-sustaining baseload energy, geothermal energy is one of the most cost-effective options in the long term, both for large-scale power generation and for the energy efficiency of low and medium enthalpy resources (direct uses). The conceptual modeling based on the 3G (Geology-Geophysics-Geochemistry), forms the pillar of the representation of the elements of a potential geothermal system. However, as geothermal energy is framed as a geoscience integrating disciplines focused on studying the Earth, several alternatives have emerged to improve and adjust the location of possible scenarios for the exploration of the resource, generally affected by the pressure-temperature relationship. This is the case of Colombia, where the Oil&Gas industry is the main industry and therefore both the data and the methodologies depend directly on this industry. Nowadays, the energy transition plays an important role in changing the dependence on fossil fuels for renewable and sustainable energies such as geothermal energy in Colombia, where there is an estimated geothermal generation potential of 1170.2 MWe (Alfaro et al., 2021). At the same time, in geosciences, it is vital to achieve a reduction in uncertainty as well as the validation of the results obtained. Added to the application of Machine Learning, which attempts to give the user a "safe" development and implementation environment in terms of the explainability and confidence of the results, a research atmosphere is created that incubates questions focused on the applicability of the information obtained:

- Can machine learning models together with conventional methodologies be fed with qualitative and conceptual information?
- Can it be guaranteed that the results obtained have a reliable level of reliability not only for the end user but for all stakeholders in the process?

- Can machine learning not only provide the final results with a high degree of certainty but also provide intermediate results that impact not only the methodology but are reliable multipurpose results that intervene in the improvement of the model inputs?

The main challenge is also in the inclusion of subjective interpretations that are derived from few data, with high variability and uncertainty. This is why a workflow marked by searching, organizing, structuring, cataloging data, numerical modeling and Machine Learning, offers an innovative and real alternative to the problems of identifying and characterizing energy resources such as geothermal energy present in the subsoil. Solving the above challenges is the main motivation of this research proposal. With this it is possible to propose as a methodology derived from another field of subsurface prospecting, plus multipurpose data that offers greater prospects for its application in geothermal exploration. The impacts for both, the AI community and the geoscientific community will be very high, since the use of data and methods derived from these two axes will allow, in the academic and industrial fields, to satisfactorily reduce the uncertainty of models and results achieved, counting on precision and accuracy tools for decision making.

Research Objectives

The general objective of this research is to develop a methodology involving Machine Learning, Numerical Modeling and Play Fairway Analysis (PFA) for the geothermal favorability zones in different types of geothermal systems of Colombia. The following specific objectives are also included:

- Generate and evaluate fluid, permeability, and heat models through ML and PFA
- Determine pilot zones with exploration favorability according to different types of geothermal systems (hydrothermal and sedimentary systems)
- Characterize the geothermal potential through ML and numerical modeling in selected geothermal favorability zones

Research Environment

The PhD student will be integrated and with access to subject domain experts, such as geologists and geophysicists at ISTeP (Institut des Sciences de la Terre de Paris). ISTeP is the Geoscience Laboratory of Sorbonne Université, focused on cutting-edge fundamental research. ISTeP has four research teams (Petrology and Geodynamics; Earth-to-Sea: Structures and Archives; Tectonics; PRISME) and is keen to transfer its expertise to meet societal concerns and the challenges of the environmental and energy transition through 3 Transversal Projects: Natural hazards: gravitational, seismic, volcanic and morpho-hydro-climatic; Transition: decarbonated H2 and geothermal energy resources, CO_2 sequestration, strategic minerals, new and heritage materials; geological history of the Mediterranean Realm). ISTeP has developed numerous national and international collaborations, both academic and industrial, and plays a key role in the training of Earth Sciences students. Its members are heavily involved in the administration and management of research and training at local, national and international levels.

Research Team at ISTeP, Sorbone Université

Frederique ROLANDONE: Main Director (Heat Flow modeling, geothermal gradient, thermal conductivity, geodetic)
Damien DO COUTO: Co-advisor (geothermal modeling, sedimentary process and tectonic, geophysics)
Alain RABAUTE: Co-advisor (numerical methods in geophysics, GIS, Machine Learning)
Jeffrey POORT: Co-advisor (Heat Flow modeling, geothermal gradient, thermal conductivity)

References

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