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The Shallow Geothermal Energy Potential of Lagoa Municipality (S. Miguel Island, Azores): A Preliminary Evaluation

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INTRODUCTION

The Autonomous Region of the Azores (Portugal; Figure 1) sits on the Mid-Oceanic Ridge, near the triple junction of the Eurasian, Núbia, and North American plates. The archipelago is composed by nine islands and some islets, including S. Miguel, the largest and the most populous one.

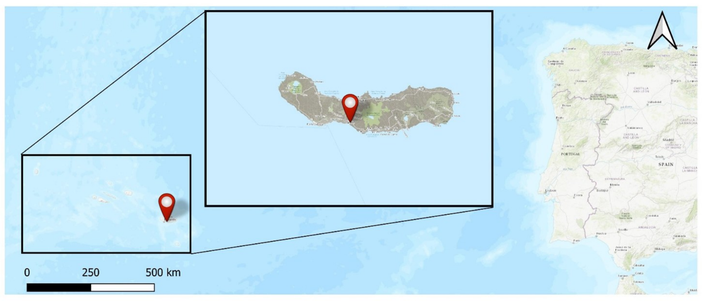


Figure 1. Location of the Azores archipelago and of Lagoa Municipality in S. Miguel Island.

Due to their privileged location, high enthalpy geothermal resources have been used to generate electricity in S. Miguel since 1980 (Nunes et al., 2022).

Shallow geothermal energy systems, by using just the surface terrain normal temperature, such as geothermal heat pumps, on the other hand, have not yet been installed in the island, and these could be a great complement to the energy mix. Geothermal heat pumps could be used to displace electricity consumed by heating and cooling systems in residential and commercial buildings, as well in local greenhouses to extend their production for the increasing tourism demand.

To develop this emerging industry in the Azores, a preliminary assessment of the shallow geothermal potential energy is mandatory. This work presents a first thermal mapping using the Lagoa municipality as a case study.

GEOLOGICAL SETTING

S. Miguel Island consists of volcanic young rocks, most of which are Quaternary in age with a few lava flows of the Pliocene (Moore, 1991). These rocks comprise an essentially bimodal compositional suite consisting of alkali basalt and trachyte (Moore, 1991). The lithological units of Lagoa municipality are illustrated in Figure 2.

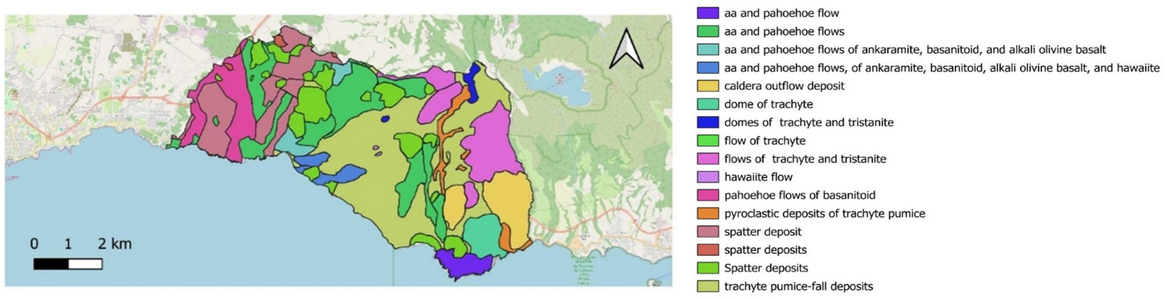


Figure 2. Geological setting of Lagoa municipality.

METHODS

A preliminary assessment and mapping of the shallow geothermal potential was carried out using the G.POT method (Casasso and Sethi, 2016; Figure 3) and GIS tools.

The G.POT method is an empirical relationship designed to calculate the average annual heat load (Q_{BHE}; MWh) that can be sustainably exchanged by a borehole heat exchanger (BHE) with a length of L (m), for a given soil condition. The results of this empirical relationship correspond to the highest value of the average thermal load that can be extracted or injected into the ground. The empirical equation is:

$$Q_{BHE} = \frac{a \times (T_0 - T_{lim}) \times \lambda \times L \times t'_c}{P_{max}(\mu'_s, \mu'_c, t'_c) + 4 \times \pi \times \lambda \times R_b}$$

with,

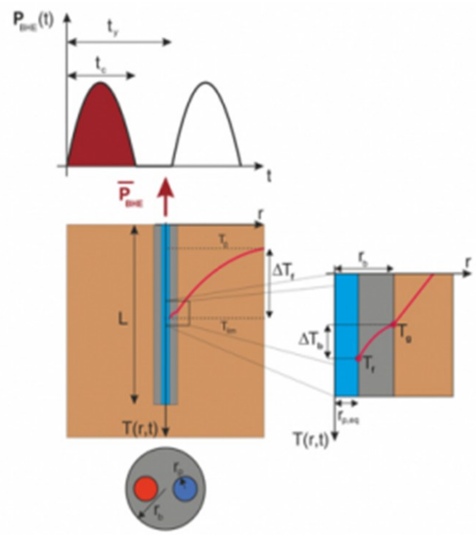


Figure 3. Conceptual scheme of the G.POT method.

$$P_{max}(\mu'_s, \mu'_c, t'_c) = p_1 \times t'_c \times \log(\mu'_s) + (p_2 \times t'_c + p_3) \times \log(\mu'_c) + p_4 \times t'_c + p_5$$

and, $\mu'_s = \frac{r_b^2}{4\alpha t_s}$, $\mu'_c = \frac{r_b^2}{4\alpha t_c}$, and $t'_c = \frac{t_c}{t_y}$

Weather data for 2024 from the Ponta Delgada Airport was used in this analysis, and the climate data suggest that the heating season is about 177 days long and the cooling season is about 105 days long (Figure 4).

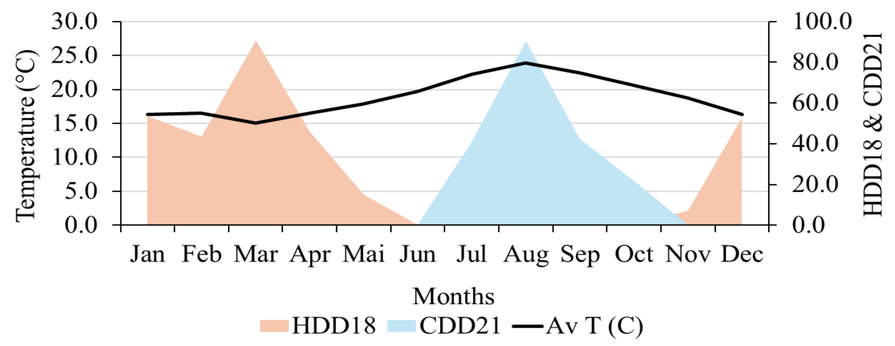


Figure 4. Monthly average temperatures for 2024 and heating and cooling degree-days.

RESULTS AND DISCUSSION

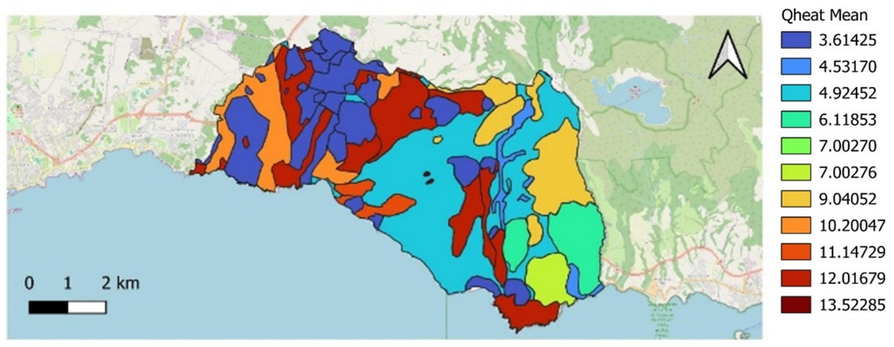


Figure 5. Mapping of the average annual thermal energy that can be extracted from the ground by a 50 m deep borehole heat exchanger during the heating season.

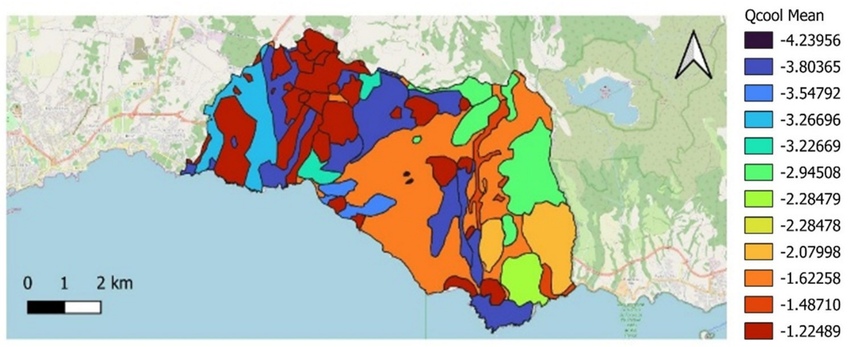


Figure 6.Mapping of the average annual thermal energy that can be injected in the ground by a 50 m deep borehole heat exchanger during the cooling season.

This preliminary analysis illustrates the shallow geothermal energy potential of the Lagoa municipality based on surface lithological outcrops (Figure 5 and 6). The results outline that lithologies with greater thermal conductivity have greater shallow geothermal energy potential. However, more in-depth research in terms of sampling and thermal conductivity analysis is needed to improve these estimates and build a more accurate map, namely by making in situ sampling by drill coring and assess the lithological and thermal properties variability at depth.

Here, a uniform lithology was assumed over a length of 50 m, which is far from precise for some of the geological deposits but gives a preliminary understanding of the shallow geothermal potential of this municipality and the next steps needed to improve assessments. In addition, the choice of a 50 m deep BHE was based on the reasoning that drilling is expensive on the island and systems with shallower BHEs would be the best option.

The results suggest that, on average, a 50 m deep BHE could be capable to meet the heating and domestic hot water needs of a 200 m^2 residential dwelling, assuming a reference value for the heating demand of 23.05 kWh/m^2/year (DRE, 2024) and a reference value for the domestic hot water demand of 14.41 kWh/m^2/year (DRE, 2024).

CONCLUSION

This preliminary study outlines the significant shallow geothermal energy potential of Lagoa municipality, and of S. Miguel Island, and further research is worthwhile to improve estimates and help de-risking the geothermal heat pump industry in the Azores Archipelago. Deeper and more detailed evaluation of thermal geological parameters are the next needed steps to further improve the assessment accuracy.

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