Procedure to determine geothermal viability

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Overview

- Determine a routine of geophysical surveys and analysis to evaluate the geothermal viability of a site.
- Data required: Refraction seismic, surface wave seismic, resistivity data, hydraulic head readings, core, and well logs.
- Joint inversion utilising the seismic and resistivity data sets to generate an earth model.
- Hydrothermal modeling based on the earth model. Calibrated by hydraulic head, core, and well log data sets.

Introduction

- More than 600,000 ground source heat pumps in the U.S. with approximately 60,000 new systems being built each year
- The technology uses the residual heat of the near surface rocks and soil to either heat or cool air or water being circulated through pipes in the near surface (Fig. 1.).
- Geothermal energy is thought to be able to provide up to 49% of residential energy consumption and cut the carbon emissions of buildings by up to 50%.
- It is the aim of this research to fully investigate the optimization of such systems with regard to placement within certain rock/soil types; the goal being to design a site evaluation routine to take into the field.

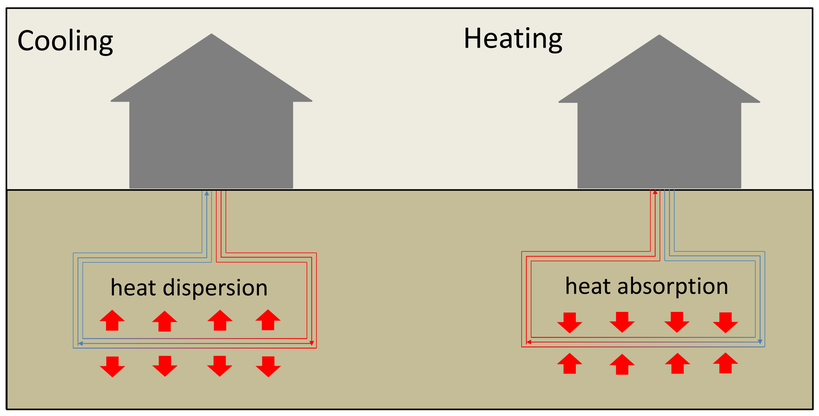

FIG.1. Schematic showing the heating (right) and cooling (left) setup for a geothermal heat pump system.

Workflow

- To best understand the flow of heat in the near subsurface it is important to be able to construct a reliable earth model.
- Joint inversion followed by rock physics analysis makes it possible to identify rock/soil types based on their mineralogy content, which in turn, will determine the thermal properties of the subsurface.
- This procedure will also determine the lateral continuity of these subsurface formations, which will be pertinent information during the design of fluid flow models.
- One objective of this research is to determine which geophysical methods best constrain subsurface thermal properties.

1) Surface seismic data – surface wave and refracted wave data.

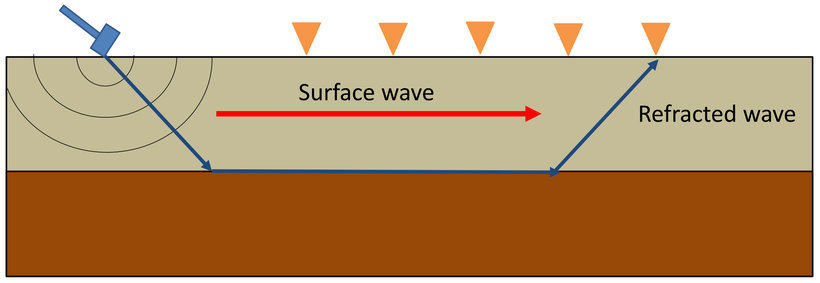

FIG.2. Schematic of a surface seismic survey showing the surface wave and refracted wave.

2) Electrical resistivity tomography data (ERT).

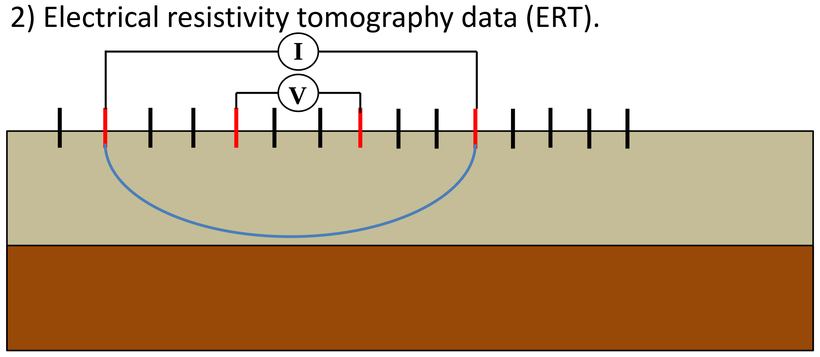

FIG.3. Schematic of a electrical resistivity tomography survey. Groups of four electrodes are activated at difference times to measure different electrode spacings along the survey line.

3) Hydraulic head data.

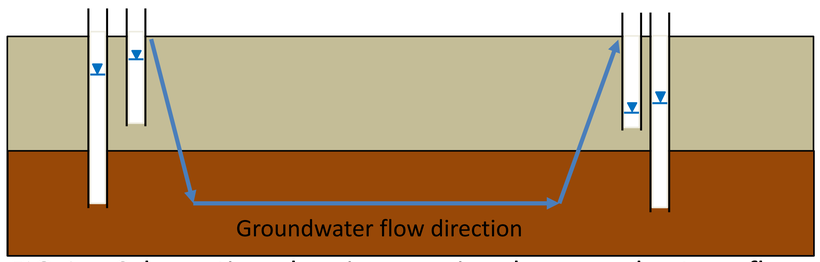

FIG.4. Schematic showing regional groundwater flow direction based on hydraulic head readings from four wells.

4) Core and well logs – The data from these two sources will provide the necessary calibration parameters for the inversion and hydrothermal modeling.

5) Data sets combined into a joined inversion scheme linked through porosity calculations.

- Porosity from seismic data

$$\phi_s = \frac{\rho_s - \sqrt{\rho_s^2 - \frac{4(\rho_s - \rho_f)K_f}{V_p^2 - 2\left(\frac{1-\nu}{1-2\nu}\right)V_s^2}}}{2(\rho_s - \rho_f)}$$

- Porosity from resistivity data

$$\phi_r = \sqrt[m]{a\frac{R_s}{R_f}}$$

6) Hydrothermal modeling using a finite difference scheme.

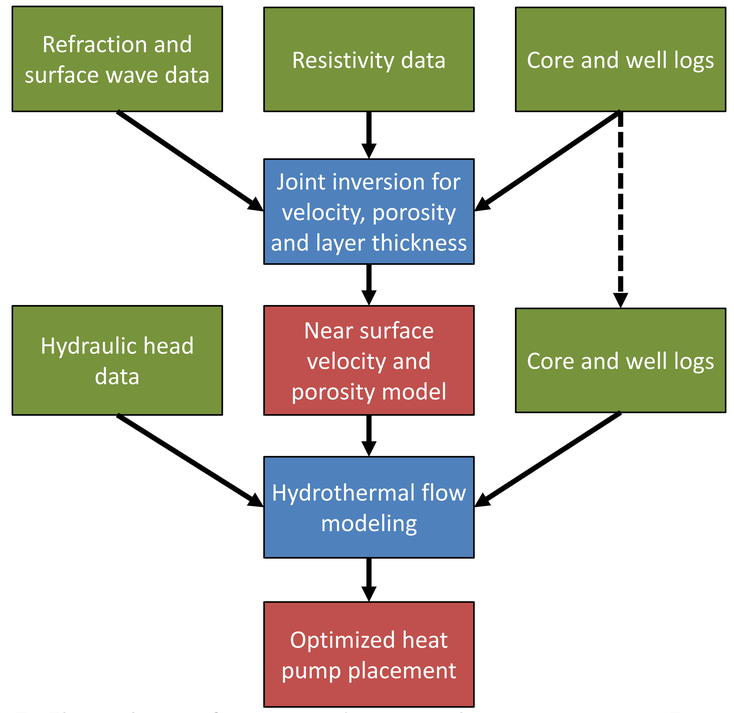

FIG.5. Flow chart of proposed site evaluation routine. Data is highlighted in green, processes in blue, and products in red.

Future work

- Heat flow modeling to examine the thermal behavior of different minerology soils and rocks.
- Synthetic data joint inversions to prepare the workflow for real data.

Acknowledgements

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