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A discussion of major geophysical methods used for geothermal exploration in Africa

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ABSTRACT

Geophysics provides a range of methods for the exploration of geothermal sources. This range is so broad that it can sometimes embarrass the geophysicist. The present paper classifies these methods according to several criteria: best-fitted geological environment, main assets and limitations of each method, preliminary or detailed nature of each method and even the specific objective of the exploration to be carried out. This classification could therefore help to significantly reduce costs and time loss related to trial uncertainty and bad choices in selecting the appropriate method. In order to provide necessary information for potential geothermal investors in Africa, the paper addressed several aspects such as the geological setting and the geothermal potential, the population density, the energy needs or demand, the current electricity tariff and the business environment or opportunities in the continent.

Contents

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1. Introduction

The fight against climate change is a challenge that currently enrolls the whole world. Both developed countries, responsible for the situation and developing countries, virtually victim are expected to work together in order to curb the problem. Currently, greenhouse gases produced by fossil and oil sources (hydrocarbons) are indexed as the main cause of global warming. Hence, it is necessary to explore renewable and cleaner energy sources like geothermal sources [1]. However, Geophysics provides a so broad range of methods that professionals may be embarrassed. It becomes then important to classify those geophysical methods according to some criteria such as best-fitted geological environment, main assets and limitations of each method, preliminary or detailed nature of each method and even the specific objective of the exploration to be carried out.

Geothermal energy is formed deep within the earth's crust, and is exploited for electricity generation and other direct uses. The medium of this energy transfer is geothermal fluid. On the surface, these are manifested as hot grounds, fumaroles, geysers, mudpools and hot springs [2]. The main geological parameters of the geothermal reservoir to be determined are: geological formation (lithology), tectonic structures (faults), permeability (hydraulic conductivity), temperature, and stress field. The depth to which these parameters are located must also be considered. However, the needs are not exactly the same for a hydrothermal or petrothermal project. Some of these parameters can be estimated from the surface, mainly by geophysical methods while others let themselves be measured in a borehole [3]. Anyway, geophysical methods are among the best to explore these sources [4].

Domra Kana et al. [4] drew up a review of the main geophysical methods used for this purpose. Their study classifies these methods into four groups based on the physical measured parameter and into two main categories depending on whether they are said to be direct or indirect methods. The present paper aims at promoting the use of geothermal sources by reducing costs across the world including Africa.

To achieve this prodigious idea, the present paper is as an additive one designed to reduce ambiguity and speculation in choosing a method. In fact, some methods are essentially preliminary and may be used only for a "pre-exploration", others are more conducive to well-defined geological settings.

The main objective of the present paper is to clarify the assets (strengths) and limitations of each method, then classify major geophysical methods into preliminary and detailed categories.

2. Methodology

The study conducted by Domra Kana et al. [4] performs a review of the most geophysical methods used for geothermal exploration. That investigation of a paramount importance was discussed mainly in terms of advantages and disadvantages for each method. The present study is a thorough analysis of these geophysical methods used in geothermal exploration. It presents the assets, the limitations and the best-fitted geological environment of each of them. These methods have also been classified into preliminary and non-preliminary ones.

The asset of a method is defined as its success rate, or its ability to deliver positive results while the advantage represents a positive point of a method compared to others. Similarly, the limitation of a method lets know on its inability to perform a task while the disadvantage refers to defects or deficiencies or hazards related to a method.

3. Results

For an easy operation, the main results are presented in tables.

3.1. Presentation of results

The results are reported in two summary tables. Table 1 summarizes the assets, the limitations and the preferred environment of each method.

3.2. Explanatory notes

3.2.1. Seismic methods

Seismic reflection predicts the depth and thickness of a desired geological formation. This may be the thickness of an aquifer for a hydrothermal project or the depth of the crystalline basement roof for a petrothermal project, for example. The permeability of a geological formation, which guarantees the success of a hydrothermal

Table 1
Summary of the main strengths and limitations of different geophysical methods.

Methods	Assets	Limitations	Environment/geological setting
Seismic refraction	Allows us to image directly basement (geological formations, presence and geometry of faults, predictive surveys profile).	Does not directly determine the permeability of a geological formation [5].	Volcanic and sedimentary rock assemblage [6].
Seismic reflection	Good resolution of layering from depths of 20 m to more than several hundred meters.	Extracting precise interval velocities from multilayered media is sometimes difficult [5].	Volcanic and sedimentary rock assemblage [6].
Magnetic	A significant depth resolution (magnetotelluric).	Vertical sounding applications (no 2D or 3D interpretation) [7].	Volcanic environments [8].
Gravimetric	Simpler and less expensive.	Does not allow an unambiguous interpretation.	Volcanic environments [8].
Thermal	Efficient for detecting geochemical haloes.	Limited to detecting relatively shallow features [7].	Any geological context [9].
Remote sensing	Autonomously and complementarily skilled.	Inefficient in areas covered by thick vegetation.	Basement with faults [9].
γ-ray spectrometry	High accuracy and enormous penetrating power.	Intended primarily to detect radionuclides contained in a [10] rock.	Basement [8].
Direct current (DC)	Simple rule of thumb with existence of several electrode configurations.	Ambiguity in the interpretation of results (determination of the structure or its geometry).	Any geological context [9].
Induction	A comparatively efficient reconnaissance tool because the cap response is strong in both polarization modes.	Requires large current sources (up to 100 A) and large receiver loops (40 m 340 m) [11].	All geological setting away from power lines [9].
Frequency domain electromagnetic (FDEM)	Very effective for the rapid reconnaissance of an area for mapping.	Topography can be a problem in interpreting FDEM data. TDEM is not widely used for shallow studies (less than 20 m).	All geological setting away from power lines [9].