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A review of geophysical methods for geothermal exploration

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ABSTRACT

Exploration of geothermal resources is important from the energy point of view. Geophysical methods are among the three main disciplines applied on the surface to explore geothermal resources, including geology and the chemistry of thermal fluids. This paper presents various geophysical methods of exploring geothermal reservoir. Some comparisons, advantages, and disadvantages of each method are discussed. It was found that, the most successful methods are aimed at parameters that are directly influenced by the geothermal activity, such as Geophysical well logs, self-potential, Geoelectrical and thermal methods, and are usually referred as direct methods. Other methods explore the physical parameters of the host rock, including magnetic properties, density and seismic velocity, and are usually referred as indirect or structural methods. It appears that, direct methods give information on parameters that are influenced by the geothermal activity, while the structural methods give information on geological parameters which may reveal structures or geological bodies that are important for the understanding of the geothermal system.

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1. Introduction

Geothermal energy is one of the cleaner sources of energy which are gaining importance as an alternative to hydrocarbons. According to Gupta and Roy [1], more than 20 countries generate

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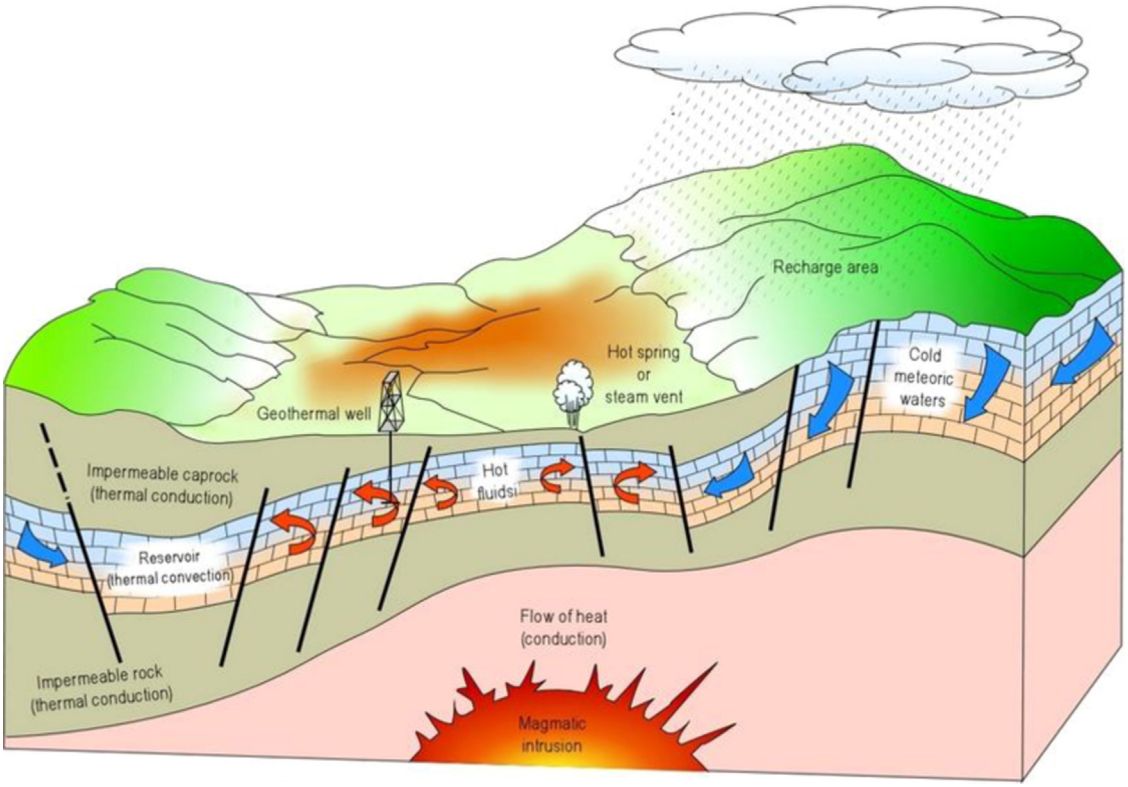

Fig. 1. Schematic representation of an ideal geothermal system by International Geothermal Association (IGA).

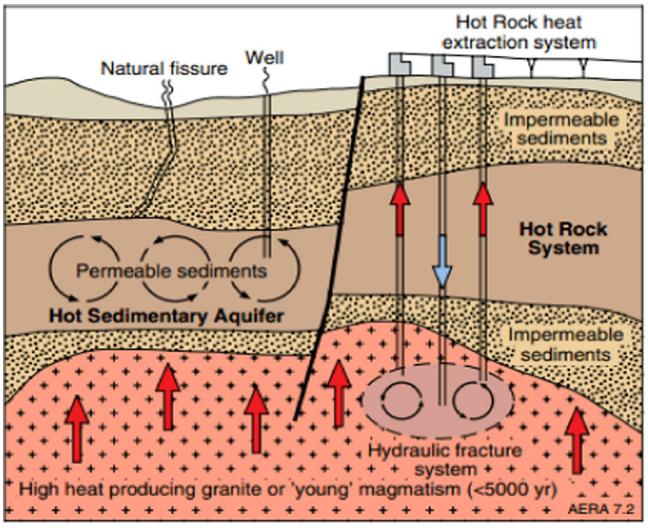

Fig. 2. Hot rock and hot sedimentary aquifer systems.

electricity from geothermal resources and about 60 countries make direct use of geothermal energy. Geothermal studies have been carried out by many researchers to quantify the thermal characteristics of different geological region over the world and to evaluate their suitability for geothermal exploration.

Several types of geothermal resource can be distinguished [2], but an ideal conventional geothermal system requires heat, permeability, and water (Figs.1 and 2). The heat from the earth's core continuously flows outward. Sometimes the heat, as magma, reaches the surface as lava, but it usually remains below the earth's crust, heating nearby rock and water, sometimes to levels as hot as several hundred degrees Celsius. When water is heated by the earth's heat, hot water or steam can be trapped in permeable and porous rocks under a layer of impermeable rock and a geothermal reservoir can form. This hot geothermal water can manifest itself on the surface as hot springs or geysers, but most of it stays deep underground, trapped in cracks and porous rock. This natural collection of hot water is called a geothermal reservoir. Although the deeper crust and interior of the earth is universally hot, an enhanced geothermal system lacks two of the three ingredients required for a naturally occurring geothermal reservoir.

Most geophysical exploration methods have been developed for the oil and gas industry, and ever more sophisticated tools and refinements in the different approaches are designed to solve specific problems associated with the detection and characterization of hydrocarbon reservoirs. The exploration of geothermal resources has profited greatly from these developments, however, the methods cannot always directly transferred from oil and gas to hot water and/or steam. First of all, physical properties of H_2O differ from those of hydrocarbons, resulting in differing responses of physical measurement methods. Second, geothermal reservoirs can be found in highly varying geological environments, mostly associated with volcanism, where hydrocarbons are usually not present. Third, the economically most interesting geothermal reservoirs are much hotter than any oil or gas reservoir. At the moderate temperatures comparable to those of hydrocarbons many of the advanced exploration methods are simply cost prohibitive, as the economic potential of a medium-enthalpy geothermal reservoir is much lower than for an oil or gas well. For these reasons, some of the existing geophysical methods have to be adapted to meet the needs of geothermal exploration or different methods have to be developed and applied [3].

The use of renewable energies is shot down in many situations because of the relatively high start-up costs and long-term commitment it requires to actually become profitable. It is reason that, underdeveloped country like African ones doesn't use geothermal energy. Nevertheless they have great potential for this form of power. For example the basin of Rio del Rey and Douala basin in Cameroon (Fig. 3), where many geophysical explorations are made for oil and gas research, showed interesting geophysical results.