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The Time Domain IP Method In Geothermal Exploration: Balikesir(Gure) In Turkey

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ABSTRACT

Geothermal energy is heat derived from the earth. It is the thermal energy contained in the rock and fluid (that fills the fractures and pores within the rock) in the earth's crust. These resources are always at a temperature higher than 20°C. Geothermal energy requires no fuel, and is therefore virtually emission free and independent of fluctuations in fuel cost. Since a geothermal power plant doesn't rely on transient sources of energy, unlike, for example, wind turbines or solar panels, its capacity factor can be quite large.

Induced polarization (IP) results at geothermal regions show prominent, extended low resistivity zones. Environmental - IP methods can assist in the assessment of the acid generating potential of waste rock and tailings from mine operations. Resistivity can be used to map contamination plumes.

Resistivity and chargeability values were determined using the IP method on geothermal resources in Balikesir Güre (Turkey). In this study we found low resistance values and high chargeability values at the geothermal resource. Finally drilling and IP results were correlated to verify our findings.

1. INTRODUCTION

People have used geothermal water that flows freely from the earth's surface as hot springs. The oldest and most common use was, of course, just relaxing in the comforting warm waters. But eventually, this "magic water" was used (and still is) in other creative ways. The Romans, for example, used geothermal water to treat eye and skin disease and, to heat buildings. For centuries, people have cooked "geothermally," and, have been heating homes using geothermal water.

Today we drill wells into geothermal reservoirs to bring the hot water to the surface. Geologists, geochemists, drillers and engineers do a lot of exploring and testing to locate underground areas that contain this geothermal water, so we'll know where to drill geothermal production wells. Then, once the hot water and/or steam travels up the wells to the surface, they can be used to generate electricity in geothermal power plants or for energy saving non-electrical purposes.

Geophysical surveys are directed at obtaining indirectly, from the surface or from shallow depth, the physical parameters of the geothermal systems. Geophysical methods play a key role in geothermal exploration since many objectives of geothermal exploration can be achieved by these methods.

Induced Polarization (IP) method is used to determine the ion zones in the rocks. IP method determines these areas with the help of break surface polarization which is made by ions in the rocks. IP reflects electrical resistivity and ion positions in the ground. It is one of the most frequently used methods in recent years. The measurement of the multiple parameters at the same time is an advantage of the IP method. In time domain IP direct current is sent to the ground with the help of two electrodes for a certain time and then it is cut off. Voltage which is coming from the ground will not be zero after we cut off the current. But it will be reached to the zero beginning from the certain value. The voltage that is taken from the ground, although without current, is developed as a result of spoiling polarization order of the ions in the rocks. Actually break surface polarization and their repetition spoiling are physicochemical phenomena (Sumner, 1976). Seigel (1970) relate the complicated IP method with physicochemical fact and conditions. IP depends on the features of the rocks and measurement methods. Wait (1959) named the necessary additional voltage as overvoltage. Flowing current overvoltage is needed to overcome the difficulty of electrochemical effects. Overvoltage is measured with different kinds of methods. The change of over stress depending on time in the time zone has been observed by Tezel (1992). In time domain method, Siegel (1959) gives the mathematical expression of dipolar charge effects. Madden (1959) explained membrane and electrode polarization. Pelton and others (1978a) showed that observation decay voltage can be obtained with a cole-cole electrical period. In addition to this they defined the concepts of charging and time constant. Johnson (1984) calculated the decay curve including the response in time domain IP with the help of a dispersion model. Gasperikova and Morrison (2001) formed IP sections in the self potential area. Measuring multiple parameters at the same time is most important feature of IP. In Time Domain Induced Polarization (TDIP) method when the values of chargeability are determined, resistivity values can be obtained. So, variation of vertical direction of ground layers can be researched with Vertical Electrical Sounding (VES). In other words it's performed like mechanic drilling. Structure limits are determined by the difference of resistivity properties geologic structure's units and utilizing parameters which are measured as a factor of distance (Dizioğlu ve Keçeli, 1981). Zohdy (1974a, 1974 b) evaluated resistivity and chargeability as a comparative and showed that geological units can be differentiated by this method.

2. GEOTHERMAL FORMATIONS AND ELECTRICAL FEATURES

To form a geothermal reservoir, four items must be present. These are, heat source (magma is cooled), a porous reservoir rock, impermeable cover layer, and sufficient water. (Figure 1).

Resistivity and chargeability are physical features to heat change conductivity of a porous rock, the volume of pores, and even more importantly the status and the amount of water varies with conductivity.

$$\rho = a\phi^{-m} S^{-n} \rho_w \qquad (1)$$

This is an empirical relation from Archie (1942) and Hamada et al (1996), where:

ρ = Rock resistivity,

ϕ = Pores filled with water rate,

S = Water contained the pores,

ρ_w = Electrolyte resistivity

n, a and m are constants depending on the type of rock. When n~2, a; little less than one in sedimentary rocks, 2-5 for volcanic rocks m; 1.7-2.2 cemented in hard rocks, for loose and unsettled rock to varies from 1.4-1.7 (Telford et al, 1990). The above equation does not show direct dependence on temperature. Showing changes in temperature of electrolyte resistivity. The percentage of water that fills pores and the amount of salinity should be noted since that will cause resistivity of rocks to fall. The above relation, known as Archie's Law, has the ρ_e / ρ_w ratio, i.e. "formation resistivity factor" defined as

$$F = \frac{\rho_e}{\rho_w} = a\phi^{-m} \qquad (2)$$

where ϕ; V_e / V_r (volume of water /volume of rock). ρ_e; dry rock resistivity Conductivity of the water; molten chloride, sulfate and other minerals depending on the environment changes. The relationship between conductivity and temperature is;

$$\sigma = \sigma_0 e^{-\frac{b}{T}} \qquad (3)$$

σ = Rock conductivity (Mhos/m),

σ_0= Rock conductivity at specific depth,

T= Temperature (Kelvin scale).

3. INDUCED POLARIZATION METHOD (IP)

The main reason for using IP in a mineralized rock is passing reaction of stimulated electron and current between metal and electrolyte ions. An IP event is the ion polarization between the electrode filled with electrolyte in the pore and the mineral conducting the electron. When the free pore passages of the metalic mineral are filled with electrolyte, the electric current sees a freeway. The mineral constructing the rock itself is highly resistant to the current passing from this freeway as usual, and the rocks resistance decreases in an important measure. Polarization is related to the amount of the current passing trough the rock, structure of the pores, type of the electrolyte, property of the rock and the faults.

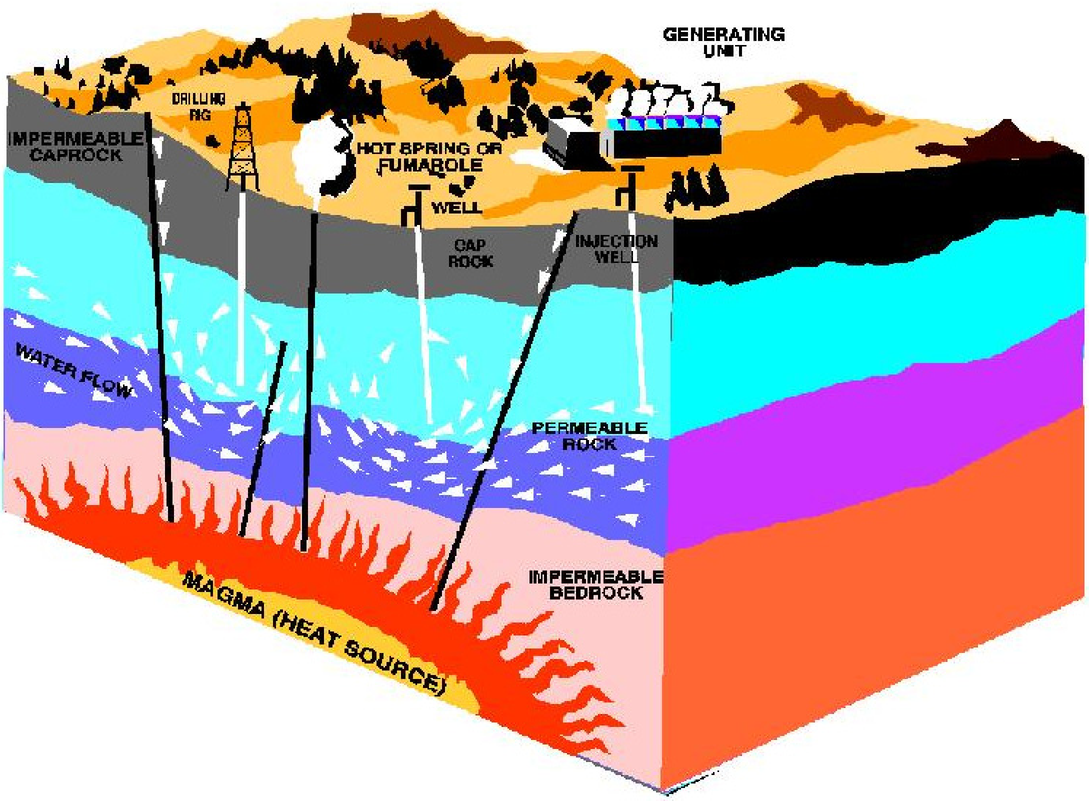

Figure 1. Formation of geothermal resources (http://commons.wikimedia.org)

An IP event is not seen in metallic minerals only. An IP impression is seen in non-metallic minerals existing underground, for example in sedimentary rocks. The source of this type of IP event is the existence of the clay particles. The surface of the clay particles is negatively charged. Because of this, the clay attracts positive ions from the electrolyte in the capillary pipes. They form an electric double layer. The concentration of the (+) ions becomes more at the surface of the clay particles. They push back the other (+) charged ions and move like an impermeable membrane that hinders their movement in the capillary pipe. When the current passing from the clay is cut, the (+) charges disperse again to take the balance condition. This dispersion event results in a decreasing voltage between two electrodes touching the clay, and it causes to the IP effect (Figure.2).

In this method time domain polarization is researched by using a pulse transient technique. Positive and negative current into the ground are cut off. Then the decay, voltage between the potential electrodes, dependent on the time is measured. Here V_0 is used to normalize the measured parameters with time. These parameters give information to us from the curve of lower voltage (Figure 3). The decay curve is determined at the t_1 and t_2 time. And we calculate the area under the curve between the two time limits. As a result chargeability is explained by Equation (4) and named as a millisecond this expression was explained as an m chargeability factor by Seigel (1959).

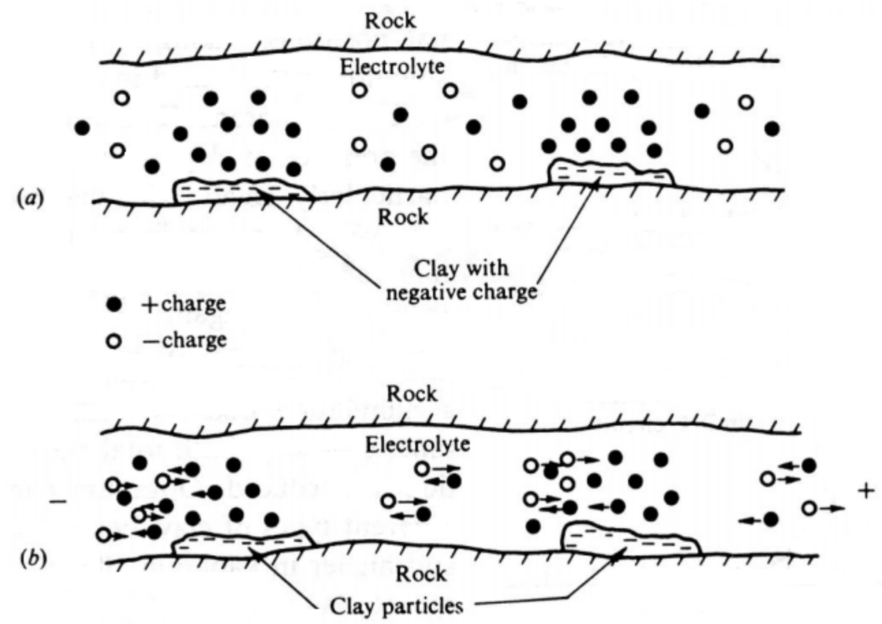

Figure 2. The membrane polarization constitution in the rocks (Fraser, 1964). a)The situation of the pore passage before the current applied. b)The situation of the pore passage after the current applied.

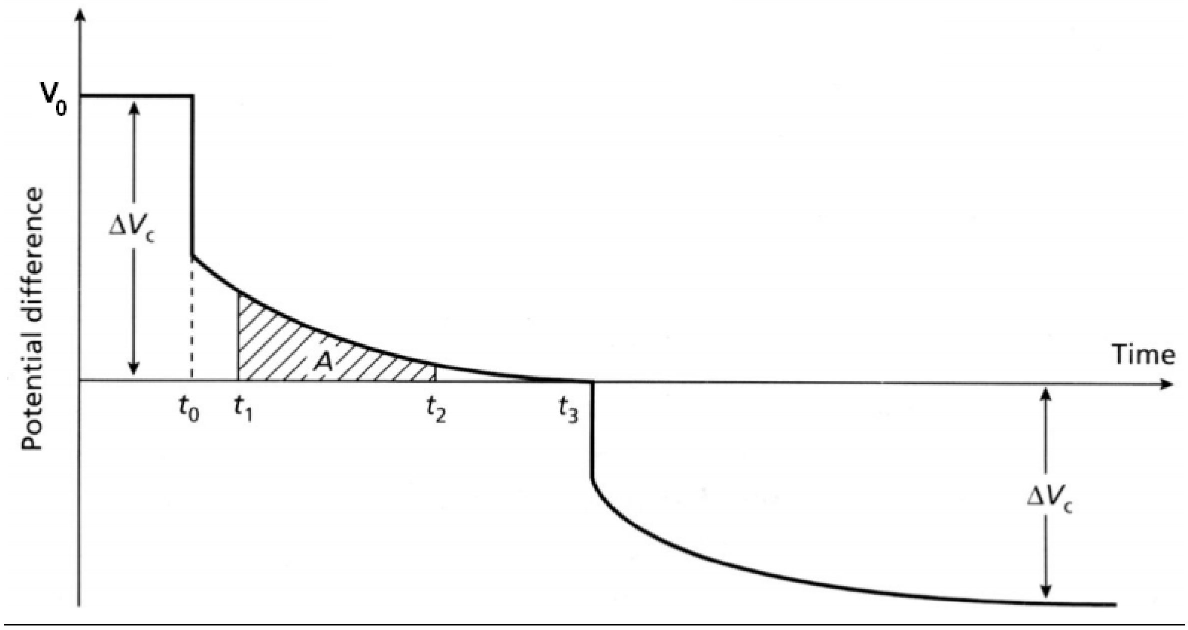

Figure 3. Illustration of a decay curve.

$$m = \frac{A}{\Delta V_c} = \frac{1}{V_0}\int_{t_1}^{t_2} V(t)dt \qquad (4)$$

4. CONCLUSION

The study area is Balıkesir (Turkey) within the borders of the province Güre (Figure 4). Geothermal resources in the area of the review are currently operated. Work performed on these sources was investigated by methods of compliance with the land data. Locations of the wells being operated are shown Figure 4. Data for these wells are presented in Table 1. Time domain IP measurement was taken at point G1. AB = 800 m in accordance with BD metric around for an opening and Schlumberger electrode arrangement was used. The extent of the evaluations obtained by the apparent resistivity (1D) was true layer parameters (Figure 5). The software IPI2win was used for determination of apparent resistivity. However, the time taken in four-window environment which is most suitable for IP response (M2) and it appears selected as a comparison with load Figure 6 shows apparent resistivity.

Configuration as seen from working method is very simple. One difficulty is to measure progress is slow in retrieval. However, after the extent of each of the data and different parameters can be monitored on a chart can be evaluated together constitute an important advantage.

The results obtained after the work of the land data that has been in full compliance with. In line with expectations; 73.53 m from the conductor in excess (2,895 Ωm) of the peak value of the only chargeability on the apparent reaches were followed for 859 ms. These results compare well to the data presented in Table 1 of this conductive environment containing geothermal water is deemed to correspond to the unit.

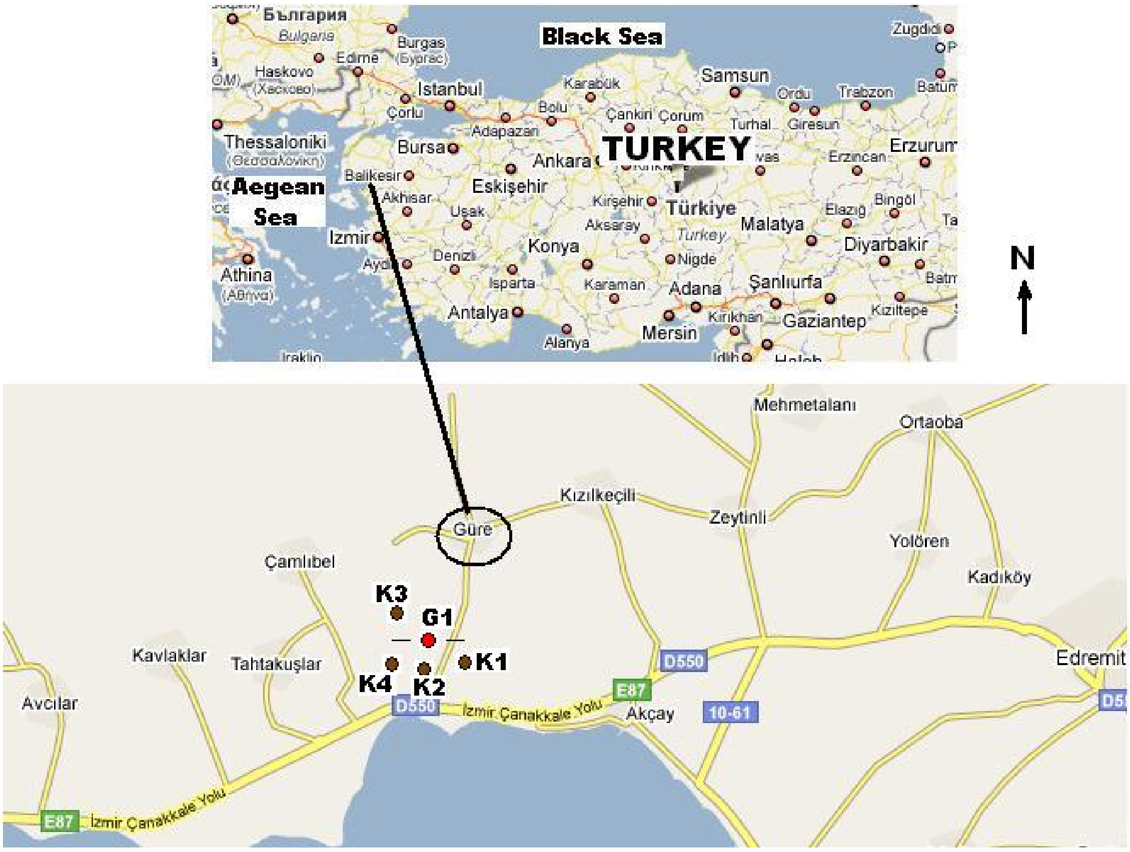

Figure 4. The study area, (measurement point G1), is in operation with four geothermal wells (K1, K2, K3, K4).

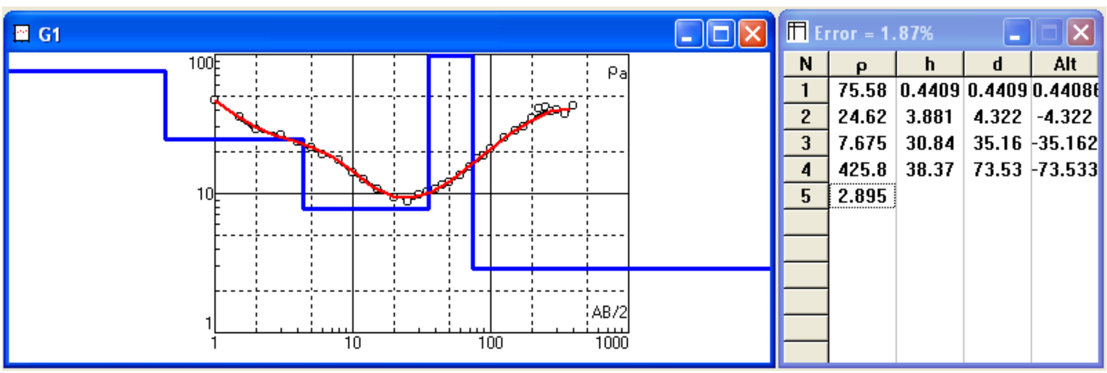

Figure 5. G1 Measurement points for the actual layer parameters (1D).

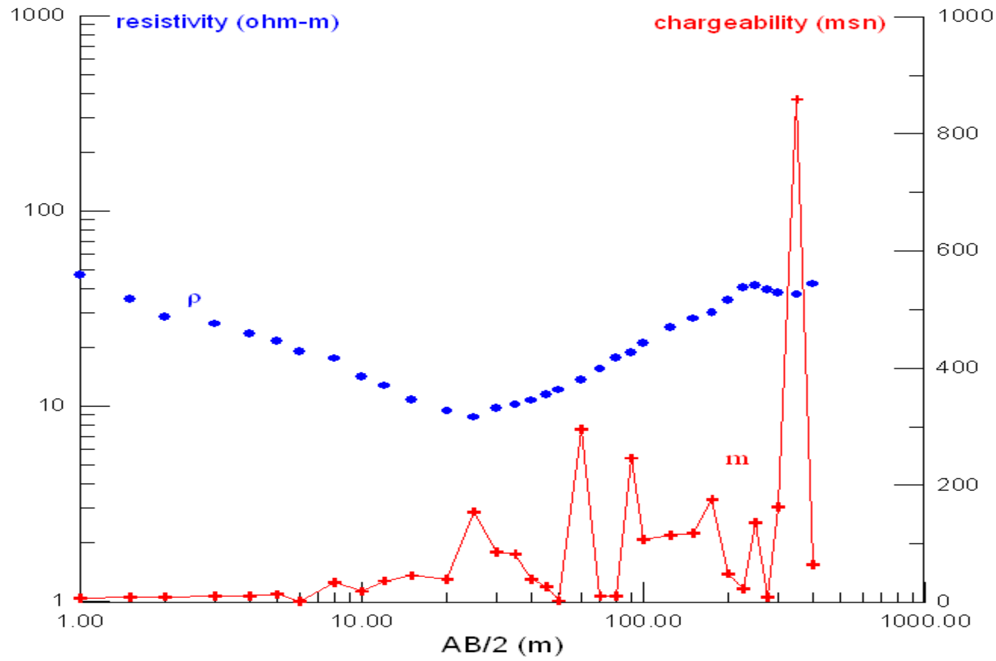

Figure 6. Apparent resistivity measurements for G1 point, and changes in the chargeability.

Table 1. Information on geothermal wells for which data are processed. (Source: Güre municipality center geothermal heat)

Well	Well depth (m)	Temp. (°C)	Flow (lt/sec)
K1	88	55	7
K2	63	61	11
K3	73	54	4
K4	55	55	6

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