SEAPEX Proceedings Volume II, 1975, pp. 160-162.

MAGNETO-TELLURIC METHOD APPLIED TO GEOTHERMAL PROSPECTING *

By

Gerard Cormy

BEICP, France

ABSTRACT

Experience has shown that geothermal fields are usually associated with strong resistivity anomalies. Reservoir resistivity is a function of porosity, permeability and formational water salinity. In particular, increased temperature reduces resistivity. For example, a temperature increase of 100°C will reduce formation resistivity to one-fifth or even one-tenth of its value. In many cases, increased temperature is accompanied by increased water salinity.

Thus, an originally resistant rock is rendered conductive by a large temperature increase. If it is porous and permeable, the presence of high temperature salt water or steam results in a still greater reduction of resistivity.

BEICP's new five component magneto-telluric equipment with exponential solutions, "M.T.-5-E.X.", is being effectively used in geothermal prospecting to detect low resistivity zones that indicate high temperature, permeable formations. In seeking such low resistivity zones, the "M.T.-5-E.X." measures the apparent resistivity of the underlying formations at each recording station as a function of natural electromagnetic spectrum. Various parameters used for interpretation, notably conductance, can be calculated from these measurements. Conductance is higher when the beds are thick and of low resistivity.

Results show that, in the low frequency ranges, the apparent resistivity variations are highly distinctive between cold or tight zones and those productive of steam. In other words, geothermal anomalies are represented electromagnetically by anomalies in conductance.

* Presented at SEAPEX meeting on November 26, 1974.

Conventional magneto-telluric (M.T.) methods have so far been considered suited to broad and medium scale reconnaissance. The results now obtained show that "M.T.-5-E.X." is well suited to detailed problems in geothermal prospecting, particularly where the reservoir zones are narrow.

Furthermore, geothermal prospecting is often concerned with fractured zones invaded by hot water or steam. Standard four-component M.T. is not reliable in these cases, but the "M.T.-5-E.X." can quickly detect faults.

Successful examples are cited where B.E.I.C.P. used the "M.T.-5-E.X." for geothermal prospecting in:

1. Italy, east of the Larderello field, where stations were laid out at an average spacing of 800 meters over an area of about 30 sq. kms. Results of mapping, confirmed by drilling, showed resistant areas were those in which hot water reservoirs were virtually absent, while large and abrupt lateral variations (the conductive zones) showed localized development of highly permeable formation containing hot water.

2. Gaudalupe, West Indies, using an average spacing of 250 meters, 33 stations were surveyed in an area of about 5 sq. kms. Maps constructed from analysis of the records showed several closely localized elongate conductive anomalies were separated by resistive areas. The small geothermal field of Bouillante was clearly defined and, as well, were small fracture zones and large anomalies which deserve to be drilled.

3. U.S.A., but areas examined and problems encountered remain confidential.

Before deciding if a "M.T.-5-E.X." program can be successfully executed, it is necessary to make a preliminary study based on geological data and the results of existing wells. The results of this study are presented to the client, so that a full-scale operation is only commenced if it appears to be justified.

Field operations depend on the country and nature of the ground. In areas of easy access, the equipment is mounted in an air-conditioned cabin on a "4 x 4" truck.

A crew comprising observers with 3 or 4 helpers and

accompanied by a survey party can occupy three to four "M.T.-5-E.X." stations per day.

In areas of difficult access, portable air-conditioned equipment is used. The crew is generally larger than above, providing for 2-3 stations to be occupied each day.

To obtain maximum accuracy the various electric and magnetic sensors are positioned by theodolite.

The signals from recording channels constructed to specifications patented in several countries (especially U.S.A., Germany, France, England, etc.) are digitalized simultaneously by two independent recording cassette systems, in order to ensure reliability. A monitor accompanies the two-digital recorders.

Field records are carried on a compatible computer tape, providing for various processings - in particular the "M.T.-5-E.X." process, which is based on an analysis method which does not use the Conventional Fourier transform.

In fact, the recording method provides for a new concept in analysis. The signals are initially processed so as to be regarded as sums of real exponentials. The mathematical tool thus created avoids the obstacle of the dispersion of the phase shift values obtained after any harmonic analysis. The whole of the processing is highly sophisticated and requires the use of a CDC 7600 computer. Interpretation which follows involves comparision and adjustment of the processing results with theoretical calculations based on geological data and electric well logs. The resulting interpretation is furnished in the form most suited to its final user - the geologist or the reservoir engineer.

Editor's Note: Mr. Cormy has sent to SEAPEX his technical paper, "Five-Component Magneto-Telluric with Exponential Solutions (M.T.-5-E.X.)", which contains mathematical theory supporting development and application of the M.T.-5-E.X. process. Copies of that paper are available from the Editor of SEAPEX.