NEW GEOTHERMAL EXPLORATION TECHNIQUE

Editor's Note: Following is a paper on a new geophysical exploration device. Although the success of this technique is unknown to the Council, it has been included in the Bulletin for those who are interested in examining the theory.

Comments are invited.

The editor also invites similar papers containing new ideas or innovative adaptations of old ideas that may serve to further the development of geothermal exploration.

The Geothermal Research Company announces a totally new geothermal exploratory service utilizing the GEOSENSOR(TM) Survey System (Patents Pending). This unique service is designed to locate and outline areas of potential geothermal value quickly and inexpensively. This system utilizes a newly recognized physical phenomenon only recently investigated in detail--the anomalous electrical self-potential or voltage gradient in the earth over areas of geothermal activity.

THE GEOSENSOR SURVEY SYSTEM

By
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Introduction

Much attention is being given to the qualitative and quantitative values of geothermal flux in relation to economic exploitation of geothermal heat for electrical energy. Geothermal power is now being produced in several nations, and with the current worldwide concern for energy, it will quite likely receive even more attention from the energy industries.

As this search intensifies it begins to appear that detailed study of subsurface geothermal heat fluxes will be necessary if economic power production is to be achieved with any degree of efficiency.

As occurred in the early days of the petroleum industry, where oil seeps were the first manifestations to be developed, this also has been the pattern for geothermal power where obvious hot springs and fumeroles have been the early sites for development. However, boreholes drilled near these surface manifestations of geothermal heat have not always led to the development of commercial quantities of geothermal power (as happened in petroleum, too) and as a consequence the need for more understanding of these geothermal processes has become apparent. The various disciplines have their special applications in the better understanding of the geothermal and hydrothermal systems and the eventual evolvement of geothermal specialties will occur.

It is believed that a surface survey method yielding good geographic correlation and large area extent without undue effort and expense while still being capable of supplying highly accurate, easily interpreted detail would be extremely useful to the industry. Such a method is more fully described in this report.

PART ONE - THE HIDDEN ANOMALY

Until recently, geothermal exploration has been directed primarily toward areas of surface leakage of water or steam.

ONE OF THE GREATEST CHALLENGES IN GEOTHERMAL EXPLORATION IS THE EXPLORATION FOR LARGE EXPLOITABLE GEOTHERMAL RESERVOIRS THAT HAVE NO HYDROTHERMAL MANIFESTATIONS AT THE SURFACE.

The method for discovering and evaluating heat flow which is described herein fits the above criteria almost precisely.

While we would like to defer the technical discussion of the new method until the later portions of this paper, it is important to note here that the electrostatic survey method utilizes:

A. A well recognized effect of nature, the NERNST EFFECT.

B. The source of energy for the evaluation derives from the phenomenon under study.

C. The resultant is directly proportional to the intensity of the economic good sought, i.e. the heat from the earth.

Of course, any consideration of the value of a new exploratory tool must ultimately be reconciled with the alternative costs of competing methods and each operator has to subjectively assign a utility value to any method under consideration.

The GEOSENSOR Survey System shows promise of equaling borehole thermister survey techniques and is less costly.

PART TWO - THE TECHNICAL ASPECTS

There has been a continuing study and research program by the authors since mid 1970 on the GEOSENSOR gradient survey method and apparatus for the qualitative evaluation of geothermal resources.

An intensive effort has been underway to devise and design a practical and accurate system to detect, measure and evaluate these suspected Nernst Effect voltages. The GEOSENSOR Survey System is now perfected and with patents pending status is presently available for commercial application.

It would appear in late July, 1973, based on extensive mapping efforts in the field at the Geysers, Susanville, and the Imperial Valley in California and at Steamboat Springs in Nevada, that we can report knowledge and evaluation of certain anomalous aerostatic voltages over areas of high geothermal gradient and that these aerostatic voltages have these characteristics:

A. They are not time-dependent (therefore not magnetotelluric in origin).

B. They are relative constant in spatial displacement. (Obviously the atmosphere moves, as evidenced by wind, but these voltage gradients remain relatively stationery much like a cork bobbing on waves, the waves (wind) move past the cork, it bobs up and down, but experiences but slight lateral movement.)

C. The present methods of measuring electrostatic atmospheric voltages do not reflect these voltage gradients because they have always been taken (on the earth's surface at least) with the measuring device at rest.

1. There is compelling evidence that only a dynamic or moving detector will discern these aerostatic voltage gradients.

2. Consequently, the classic or traditional dimensions (microvolts per meter do not apply and it further appears at this writing that an entirely new set of parameters will have to be established.

D. There seems to be compelling evidence that these aerostatic voltage gradients establish themselves in vertical "walls" or sheets which seem to be oriented in special relation to the geomagnetic field. This sheeting or wall effect would explain why only a dynamic or moving detection system would discern them, i.e. the ground neutral for an electrostatic detector would soon assume the earth neutral charge when the device was at rest and remain that way probably for hours unless a wind blew a charge sheet over the probe.

However, when the ground neutral or the detector is a motor vehicle which has rubber tires, the body of the vehicle becomes the plate of a moving condenser and when that vehicle moves into an electrostatically charged region the probe detects a voltage difference between the air charge and the vehicle body charge which has not had time enough to leak off during transit from a region of differing charge where the body of the vehicle had assumed the previous air charge or voltage. This, of course, can be readily proven with present equipment for this makes the present system velocity or speed dependent. And the velocity effect (lower gradient values at reduced survey speeds) can be easily demonstrated. This makes survey speed a factor in the system.

Thus, only a dynamic or moving-capacitance type of electrostatic voltage gradient detector would ever discern these Nernst Effect induced aerostatic voltage gradients over a thermal anomaly.

E. There is "Compression of values read out during the heat of the day. This interesting phenomona is another case where theory and practice are in agreement. From the statement of the Nernst Effect, we are taught the voltage gradient develops orthogonally to the direction of the heat flux which means that the polarity of the voltage is dependent upon the direction of the heat flow, which in this case is either in or out of the earth. During warm days the differences between high and low reading tend to come closer together. This is as might be expected since the solar heat is tending to cancel the geothermal energy moving out of the earth. Obviously the atmosphere will be influenced most by the portion of the crust nearest it and this is coincidental to the area receiving the solar warmth. The greater "contrast" in these aerostatic voltages consistently appears just before sun-up in the summer months.

The Geothermal Nernst Effect

Thermoelectric effects were first discovered early in the 19th Century when Seebeck noted that a current was established at the junction of two dissimilar metals when they were heated. The present-day employment of this effect is seen in thermocouple applications such as the automatic gas water heater. This was followed by the discovery of the Peltier and Thompson effects which involve heat conduction.

The interaction of heat with a magnetic field in a conductor was first described by Nernst in 1886, where a heat flux Q, incident on a slab of material which is subjected to a magnetic field B, applied perpendicular to the heat flux produces a voltage gradient which is transverse to Q and B.

$$V = N \times B \times T \times L \quad \left(\text{From } V = \frac{N\,B\,\Delta T\,k\,L}{k}\right.$$

where k is the thermal conductivity)[1]

Thus it will be seen that a Nernst voltage is proportional to the thermal gradient ΔT over a length L of conductor.

Therefore, in a geothermal flux with a temperature gradient ΔT flowing perpendicular to the earth's natural geomagnetic field, there should be a voltage (and hence an earth current) which is transverse and proportional to that geothermal gradient and also perpendicular to the geomagnetic field.

There are reasons to believe that volcanoes do indeed generate electric currents during eruption.[2] While Johnston and Stacy ascribe the magnetic anomalies to the piezomagnetic effect[3] and Rikitake and Yokoyama[4] invoke thermal magnetization and demagnetization of volcanic rock near its Curie point, a strong case can be made for the Nernst Effect type of interaction of the earth's geomagnetic field with the thermal gradient of the volcanic process. This could generate vertical earth currents which would themselves yield transient magnetic anomalies. If earth currents were set up in accord with the Nernst Effect, orthogonal to the thermal gradient which would be a horizontal gradient in the case of a volcano neck, one current would flow into the earth on the easterly side of the normal N-S geomagnetic field and upward on the westerly side and we should be able to describe a line from the epicenter of the positive to the negative geomagnetic declination anomaly, which would be nearly perpendicular to the normal N-S declination. The declination maps of both Minakami, T. et al[5], and Rikitake, T.[6] show a decided orientation of positive and negative anomalies, perpendicular to the normal geomagnetic declination for the locality.

The striking similarity of both declination maps to a pair of current carrying wires may be indicative of an earth current process[7,8] around erupting volcanoes.

High earth currents in or about a hidden geothermal anomaly are not particularly germaine to the electrostatic detection method. Voltage gradients in the earth, however, are a vital factor as we visualize matters. But the Nernst Effect, operating in the huge geomagnetic field of the earth's interior, could induce a voltage gradient with very little current present in the low conductivity skin or shell of the earth's crust from the heat flowing out of the mantle.

One would expect a Nernst Effect voltage to develop on an axis perpendicular to the normal N-S geomagnetic field (with declination), with no noticeable upward or downward polarization since here the heat flux is presumably upward and unipolar (as compared to sideways out the neck of an erupting volcano).

Thus, if the heat flux from a buried geothermal anomaly has stabilized, these voltages should be rather constant.

The excellent repeatability of the GEO-SENSOR electrostatic surveys agrees well with this conclusion.

The exact cause of these gradients may be subject to speculation - are they the result of streaming potentials of a hydrothermal system in active transport or a thermomagnetic (Nernst Effect) manifestation or even a thermoelectric (Thompson or Seeback Effect) phenomenon?

Regardless of the genesis of these anomalous voltage gradients in the earth over geothermal anomalies, efficient and effective detection of these voltage expressions is the essential concern.

PART THREE - THE CORROBORATIVE EVIDENCE

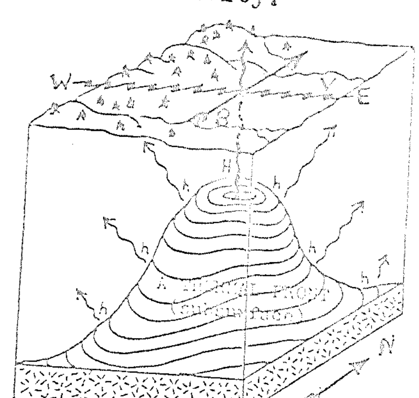
1. If one were to look for corroborative evidence of a Nernst-type thermomagnetic manifestation in nature, the most likely place to find such evidence would seem to lie in the discovery of earth currents which are related to the geomagnetic field on or about volcanoes. Here the geothermal gradients in the earth's crust would be expected to be at their maximum. Chapman and Bartel's report on earth current up the side of Vesuvius which flows downward during volcanically quiet times, and is reversed during times of volcanic activity.[9] Unfortunately, the writer makes no reference as to whether these earth currents are related to the direction of geomagnetism, so all we can conclude is that some mechanism is at work which is thermoelectric. Of course, the observation of lightning in and from volcanic ejecta has been known for centuries.[10] While there could be many other processes at work here, it is at least reasonable to conclude that part of the electrical charge (seems always to be positive) might be due to an original thermomagnetic or at least thermoelectric mechanism associated with a thermal change in the throat of the volcano during eruption.

2. Another link in the chain of evidence in the statement May 9, 1973, at the U.S.C. Symposium on Geothermal Power by G. V. Keller that a definite "self potential" of $1\frac{1}{2}$ volts per mile exists in an area under resistivity study in Hawaii.[11] He further declared that it extends to 2 volts when measured from the bottom of a borehole being drilled for the study.

3. Very strangely, to the author, a diligent search of the literature since 1950 reveals only two references to any study of earth currents on or about volcanoes,[12,13] both of which were done in Japan and only abstracts are presently available to the author. A complete paper on the corroborative evidence of a thermomagnetic effect in nature will be forthcoming when this data is available.

4. In the meantime, let it suffice to say that there is compelling secondary evidence in the literature of an anomalous earth current system in or under a volcano which is oriented to the earth's magnetic field,[14,15] and further strong persuasion that the same processes are observable in known geothermal fields.[16,17]

a. The following diagram illustrates the proposed nature of these thermomagnetic currents in areas of geothermal activity.



The heat H radiating perpendicular to and interacting with the geomagnetic field B produces voltage V, which is transverse to H and B. The voltage gradient V is directly proportional to the thermal gradient H.

If the earth in a particular location has a voltage gradient at the surface, the air over that location must, by electrostatic induction, assume an equal but opposite polarity voltage gradient. By traversing the area with the GEOSENSOR, designed to detect electrostatic variations through aerostatic regions, geothermally active regions can be outlined. Obviously this method is considerably faster than earth electrode methods. A strip-chart record of the area surveyed makes the compilation of an electrostatic gradient map possible. This is then interpreted in correlation with other information available on the area under study.

Thus the GEOSENSOR is a dynamic or moving detection system which yields a graphic record on a strip-chart being fed at a rate directly proportional to the forward movement of the "Geosensor-equipped" vehicle.

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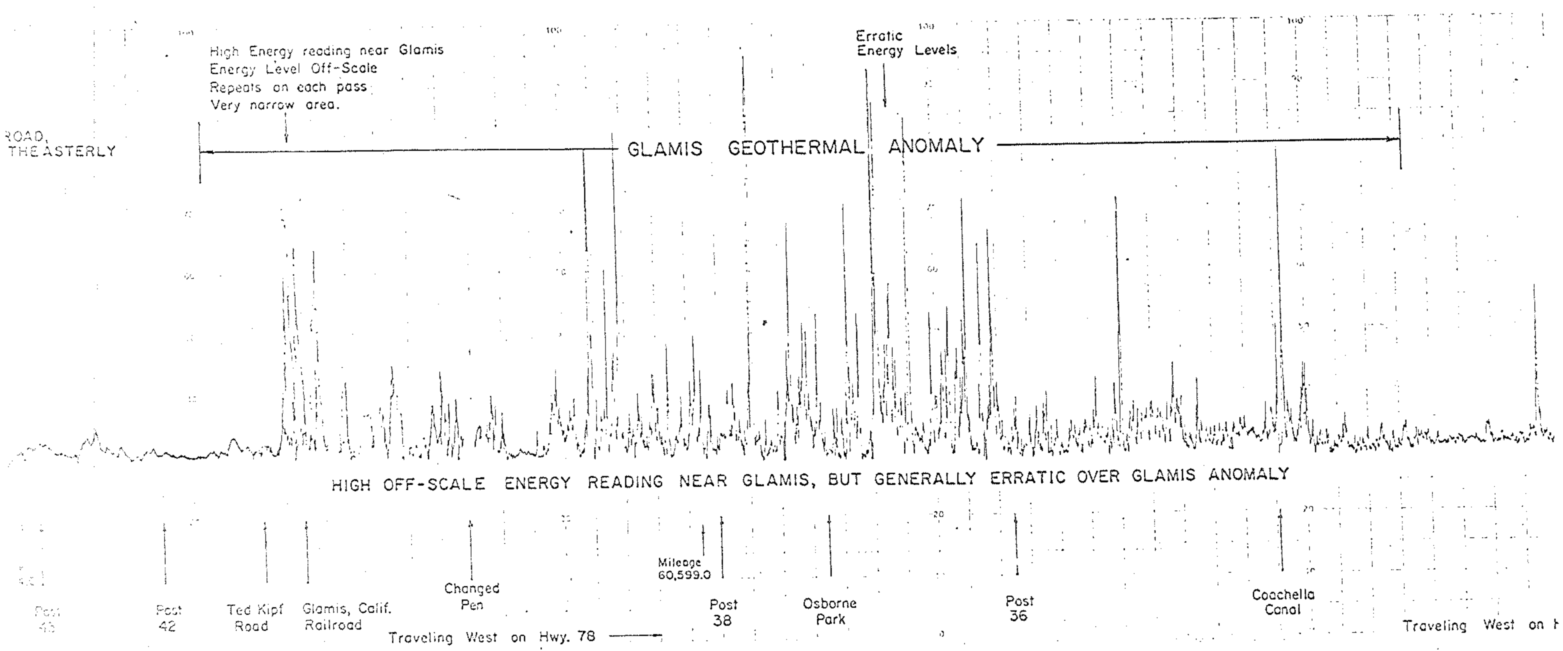

Reproduction of a graph over Glamis Geothermal Anomaly, Imperial Valley, Calif.

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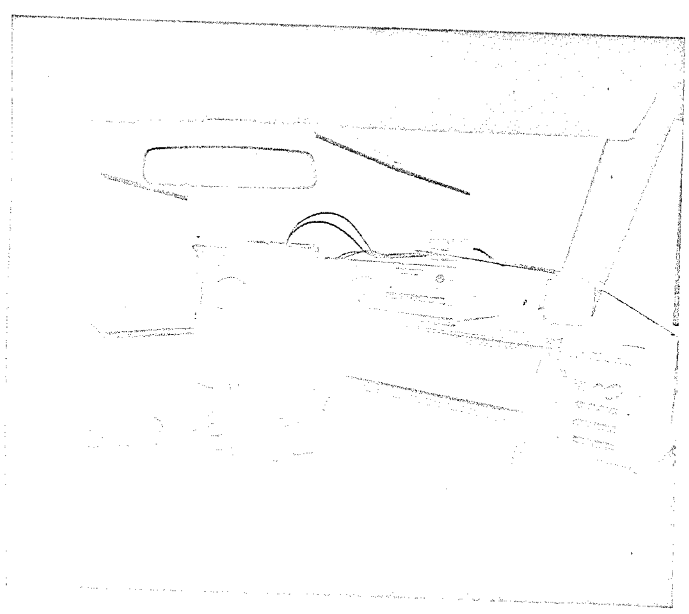

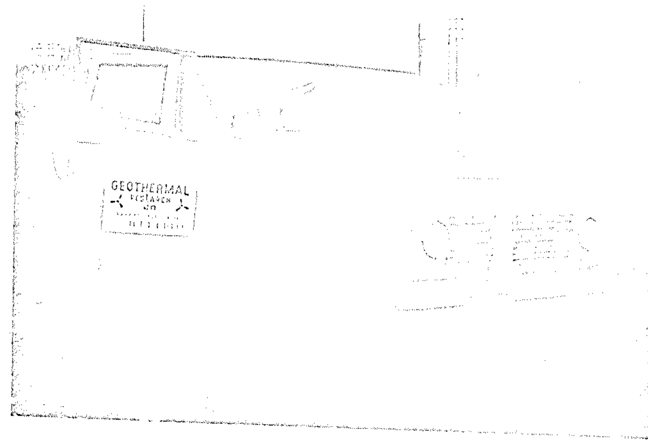

GEOTHERMAL REGULATIONS STUDY GUIDE

Publication of the complete Study Guide to the recent GRC Special Short Course No. 2, "Geothermal Regulations", has once more been delayed. We now anticipate that the Study Guide will be available sometime in September.

Copies may still be ordered at the pre-publication price of $10 (California residents add 60¢ sales tax) from Geothermal Resources Council, P.O. Box 1033, Davis, California 95616. Tel. (916) 758-2360.

All those who participated in Special Short Course No. 2 will receive the second half of the Study Guide in September as well.