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Geothermal Resources Council, TRANSACTIONS Vol. 7, October 1983

MEGASOURCE ELECTROMAGNETIC SURVEY IN THE BRUNEAU-GRANDVIEW AREA, IDAHO

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ABSTRACT

In August, 1981, a large scale electromagnetic sounding survey was carried out in the vicinity of the Bruneau-Grandview Known Geothermal Resource Area of the Snake River Plain in Idaho to provide information on rock properties to depths at which geothermal reservoirs might exist. In the area of the survey, the section to a depth of about one kilometer has a resistivity of approximately 3 ohm-meters, a value characteristic of lake bed sediments or pyroclastics. This is underlain in turn by a section of about five kilometers thickness, with a resistivity of 30 to 70 ohm-meters, which may be primarily volcanic in nature. High resistivities, which may represent the presence of crystalline rocks of the basement complex, exist at depths below about 6 kilometers.

INTRODUCTION

The Bruneau-Grandview area, lying a few miles southwest of Mountain Home, Idaho, has been classified as a Known Geothermal Resource Area by the U.S. Geological Survey. Several deep oil tests drilled in the general area of the Bruneau-Grandview KGRA have encountered relatively high bottom hole temperatures, indicative of regional high heat flow. One example is the M.T. Halbouty, et al, J.N. James #1, drilled to a depth of 14009 feet near Boise, in which the temperature at the time of logging was 346°F. (See Fig. 1 for the location of the Halbouty well.)

The Bruneau-Grandview KGRA lies on the western part of the Snake River Plain, an area underlain by a considerable thickness of volcanic rocks. The basal layer is Miocene basalt, correlative with the Columbia River basalt, which occurs farther west. This is overlain by the Owyhee rhyolite, which comprises a series made up of basalt and andesite flows interbedded with ash, freshwater limestone, clay, shale, sandstone and conglomerate layers. Above the Owyhee series is the Snake River basalt, of Pliocene, Pleistocene and Recent ages. The Snake River volcanic field covers rocks of the Nevadan batholithic and orogenic complex. The volcanic pile forming the Snake River plain is well expressed as a gravity high on the U.S. Gravity Map (see Fig.1).

THE ELECTROMAGNETIC SURVEY

A magnetotelluric survey of the western Snake River Plain in the area shown in Fig. 1 had indicated the presence of a series of anomalies in resistivity at depths ranging from 10 to 15 kilometers. In the anomalous areas, the magnetotelluric survey indicated the existence of relatively low resistivity in the crust. Often, such areas of low crustal resistivity are associated with high heat flow. In order to investigate the resistivity anomalies seen with the magnetotelluric method in more detail, a megasource electromagnetic sounding survey was organized and carried out in and around the Bruneau-Grandview KGRA. The layout of the survey is shown on Fig. 2.

For the electromagnetic survey, an electromagnetic field was generated by passing a square-wave current through a grounded source wire. The source was located about halfway between the towns of Bruneau and Grandview, as shown on Fig. 2. The source was approximately one kilometer in length, and energized with a square wave current with a peak to peak amplitude of 2000 amperes, at a period of 40 seconds.

The transient electromagnetic field was recorded at 237 receiver sites, as indicated on Fig. 2. The field was sensed using a sensitive cryogenic magnetometer to detect the vertical component of magnetic induction. The output of the magnetometer was differentiated to provide a signal in the proper form for recording. This signal was filtered to reject non-related noise, amplified, and recorded with a digital recording system. In order to further improve the signal to noise ratio, many successive transmissions were added synchronously. 1024 samples were taken from the sensor over a time interval of approximately 20 seconds, at a rate of one sample per 20 milliseconds. The resulting transient voltage curve was then interpreted by simulation using a simple model of the earth beneath a receiver station.

INTERPRETATION OF SURVEYS

A random walk process for simulating the observed curves was used. In this approach, it was first assumed that the resistivity distribution beneath a receiver station could reasonably be represented by a series of horizontal layers. Starting from an initial estimate of the probable sequence of resistivities and thicknesses in these layers, a theoretical curve was calculated for comparison with the observed field curve at each station. The resistivity and the thickness of each layer was then perturbed to find if the mismatch would be reduced or increased. By repeating this process over and over, a set of resistivities and thicknesses was arrived at which provided a close fit to the observed data. Typically, a 3 to 5% root-mean square mismatch could be obtained.

A match between an assumed model and a set of field data does not assure that a unique interpretation has been achieved. However, the stability of the interpretations of the survey data is indicated by the three resistivity profiles shown in Fig. 3. These are profiles obtained for a field curve recorded at a single site, station 1015. A different sequence of resistivity and thickness values for four layers was assumed as a starting point for each of the three simulations. Despite the different starting points, very similar final interpretations were arrived at.

The form of the interpretation shown in Fig. 3 is similar to that obtained for most of the sounding locations from which results could be obtained. In each case, a surface layer with a resistivity of about 3.4 ohm-meters was determined to be present. The thickness of this surface layer was least along the axis of the Snake River, but was quite large to the northeast and southwest. A cross section along the profile A-A' as indicated on the map in Fig. 2 is shown in Fig. 4. The thickness of the surface layer is a kilometer or less beneath the central part of the Snake River Plain, but is as great as 4 kilometers at the ends of the traverse A-A'. The numbers shown on the cross section are resistivity values.

The surface layer is underlain by a layer with moderately high resistivities, averaging 41 ohm-meters. The second layer has a thickness of at least several kilometers, and in places has a thickness of nearly ten kilometers. A statistical summary of the interpretations of the properties of the first and second layers is shown in Figs. 5 and 6. Fig. 5 shows cumulative frequency of occurrence curves for the interpreted values for the resistivity of the top two layers, while Fig. 6 shows a histogram for the thickness of the second layer.

Most of the interpretations indicated the presence of a highly resistive zone beneath the second layer, and at still greater depths, usually beyond 12 kilometers, a zone with a moderately low resistivity.

SIGNIFICANCE OF INTERPRETATIONS

Several deep wells have been drilled in the area, as indicated on the map of Fig. 1. Resistivity profiles from three of these wells -- The Griffith 1A (sec. 25, T4S, R1E), the Anschutz Federal 60-13, no. 1 (sec. 13, T5S, R1E), and the Halbouty, et al, James No. 1 (sec. 27, T4N, R1W) -- are shown in Fig. 7. These curves are block diagrams taken from the induction and short normal logs run in the three wells. All three wells show the presence of low resistivity rock in the first kilometer of section, which in turn is underlain by rock with a resistivity ranging from tens to hundreds of ohm-meters. It appears that the low resistivity surface layer seen with the electromagnetic sounding survey probably consists of lake beds and/or pyroclastics. The second layer is probably largely volcanic with interbeds of more porous rock so that the average resistivity is only moderately high, on the average, 40 ohm-meters. The very high resistivity zone seen at greater depths might be dense volcanic rock, or crystalline rock of the basement complex. The lowermost zone of relatively low resistivity may possibly reflect the effect of high temperatures in the crust.

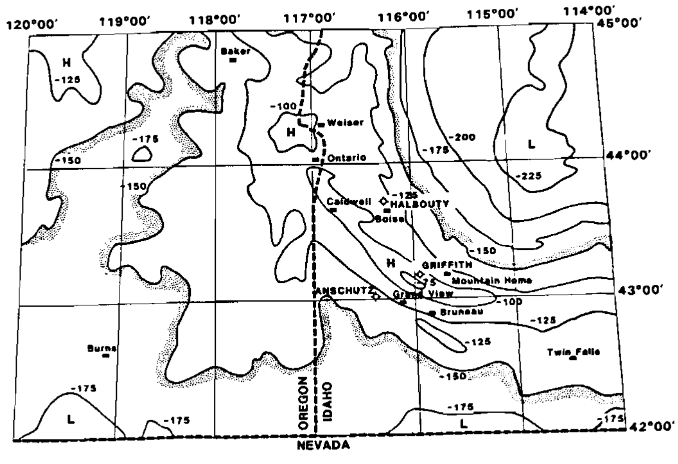

Figure 1. Gravity Map of the Lower Snake River Plain (from U.S. National Gravity Map)

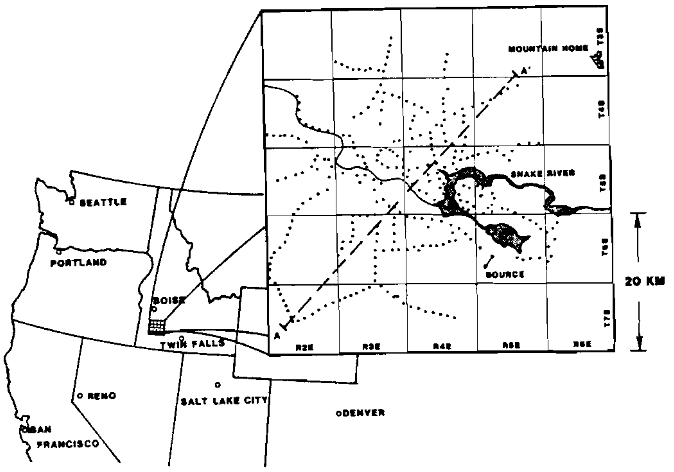

Figure 2. Layout of an Electromagnetic Sounding Survey in and Around the Bruneau-Grandview KGRA

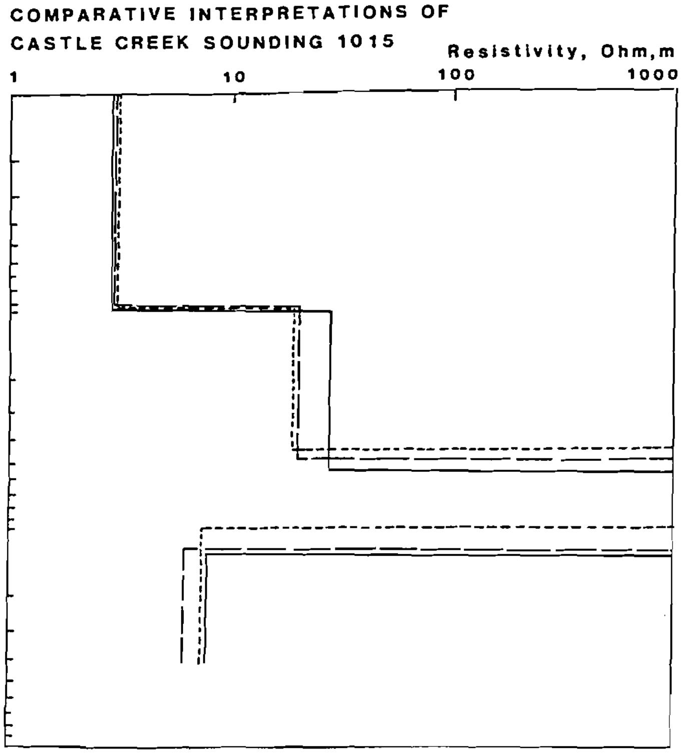

Figure 3. Comparison on Three Interpretations of the same EM sounding curve, using 3 Different Starting Models

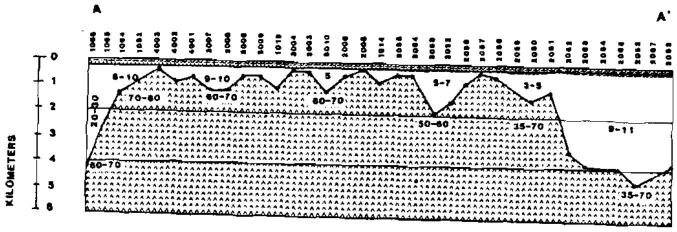

Figure 4. Interpreted Resistivity Cross Section Along A-A' on Figure 2

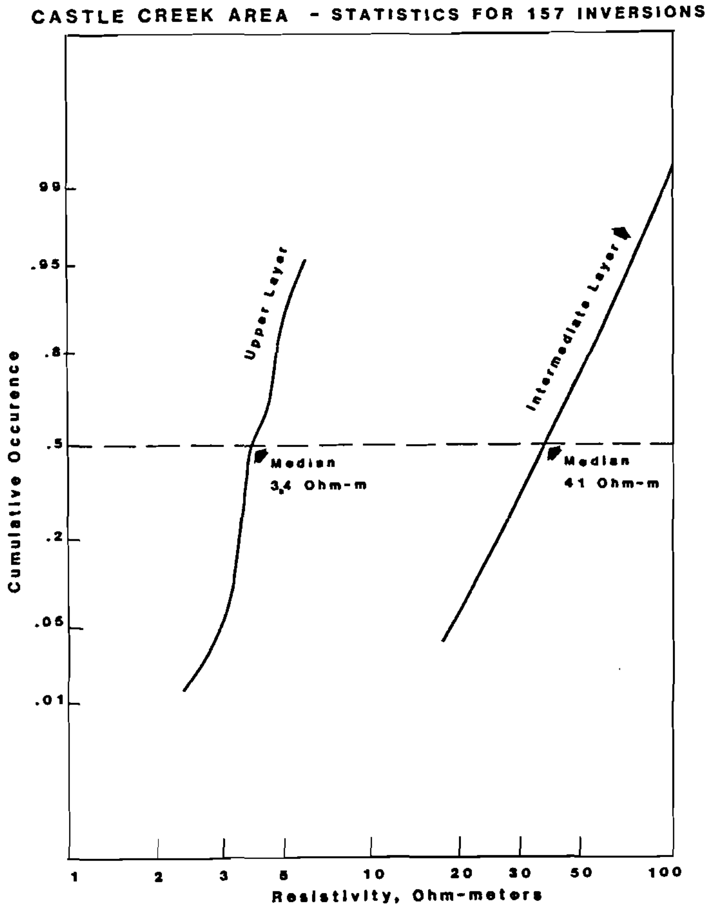

Figure 5. Cumulative Frequency of Occurrence Curves for Interpreted Resistivities in the Upper Layer (Lake Beds, etc.) and in the Intermediate Layer (Volcanics)

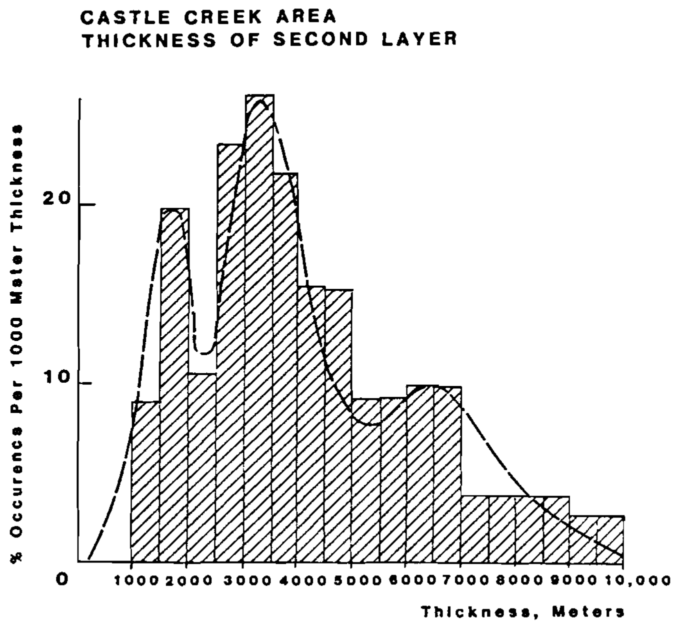

Figure 6. Histogram of Interpreted Thicknesses for the Intermediate Layer (Volcanics)

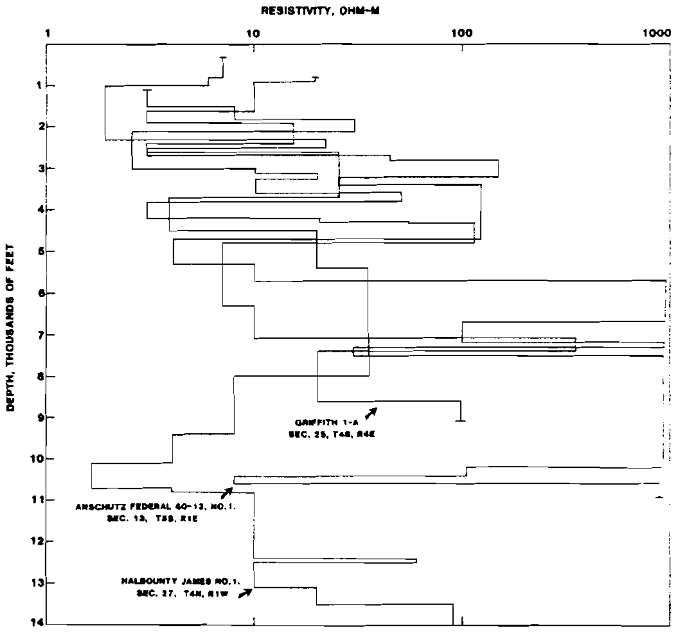

Figure 7. Block-averaged Resistivity-depth Profiles from 3 deep Wells in the General Area of the Survey

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