ELECTRICAL RESISTIVITY SURVEY OF THE PILGRIM SPRINGS GEOTHERMAL AREA, ALASKA

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ABSTRACT

Pilgrim Springs is located on the Seward Peninsula about 50 miles north of Nome, Alaska. This paper presents a case history of the use of electrical resistivity to delineate a geothermal reservoir and for drilling recommendations. Pilgrim Springs water, being saline, has an electrical resistivity value of 1 Ω-m, providing an ideal contrast for resistivity definition of the reservoir. In 1979 several deep Schlumberger and co-linear dipole-dipole surveys were run in and near the 1.5 km^2 thaw window. The results suggest that there is a pancake-shaped reservoir near the surface, approximately 50 m thick, which has the shape of the thaw window but is thicker and deeper to the north under the Pilgrim river. The conduit is suspected to be a small feature which is difficult to find under the near-surface, low-resistivity reservoir.

INTRODUCTION

The high salinity of the Pilgrim Springs water (15 gm/l) and its temperature (80°C) result in an electrical resistivity of 1 Ω-m. Thus we would expect resistivities of a few Ω-m to be characteristic of porous reservoir sediments and rocks containing this hot, saline connate water. On the other hand, sediments and rocks of the Pilgrim valley and the metamorphic rocks of the basement complex with fresh cold connate waters have much higher resistivities. This situation is ideal for use of electrical methods to delineate the reservoir characteristics.

Some preliminary resistivity work had been done earlier by Harding Lawson Associates. They had run an east-west Schlumberger depth profile, and then converted to equatorial dipole arrays to the north and south. Their data suggested an east-west trending fault down-dropped to the north with an offset of 150 m. They suggested that this proposed fault acted as the conduit for the hot water.

By use of two-dimensional computer modelling we found that a co-linear, dipole-dipole survey line run north-south would be very sensitive to the sort of fault model proposed. So such a survey as well as some Schlumberger arrays were planned to determine the structure.

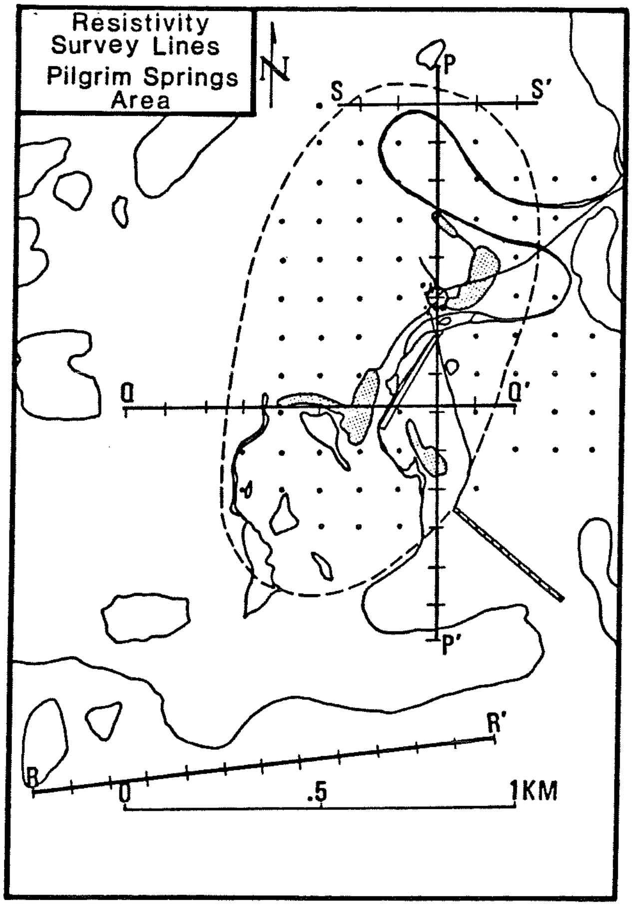

Figure 1. Location of resistivity survey lines. Stippled areas indicate agricultural fields. Origin of grid is at the circle.

1979 Resistivity Surveys

Figure 1 shows the location of the resistivity lines which were run in 1979. A Zonge Engineering and Research Organization GDP-12 receiver was used in conjunction with a Geotronics 4-ampere transmitter at 1/4 Hz. Two Schlumberger depth sounding profiles were run within the Pilgrim thaw ellipse: SS' (to half current electrode spacing, 1/2 AB =

256 m) and QQ' (to 1/2 AB = 512 m). Figure 2 shows the SS' profile. We interpret the data to show a 6.3 Ω-m layer 54 m thick below shallow surface layers and underlain by higher resistivity layers. Figure 3 shows the QQ' profile centered near the area found to have the highest soil temperatures at 4.5 m depth. The interpretation shows a 3.5 Ω-m layer 40 m thick beneath shallow surface layers and underlain by layers of higher resistivity. Computer model curves were run for QQ' putting in thin layers of low resistivity at depth to see what would be detectable, and we found that a 25 m thick layer of 1 Ω-m would have a profound effect if it were at a depth of a few hundred meters.

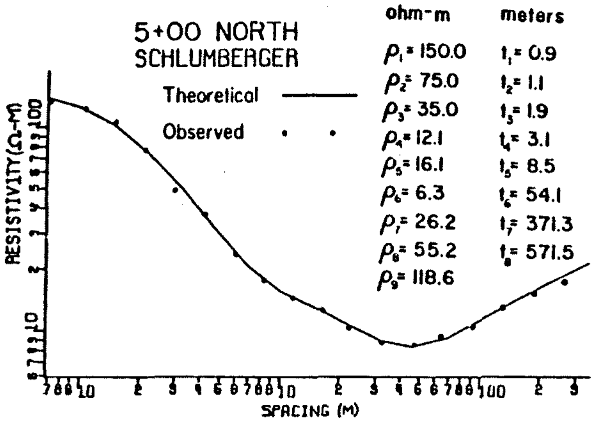

Figure 2. East-west Schlumberger depth sounding at a station 5N (500 m north of origin). The model resistivities and bed thicknesses are shown.

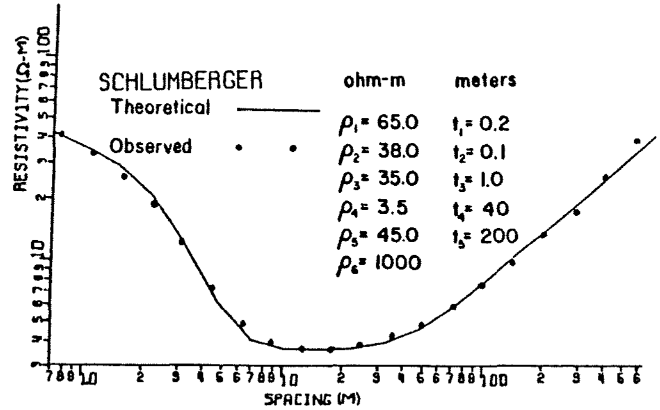

Figure 3. Field data points and calculated model curve of a Schlumberger depth profile run east-west and centered on the ground temperature anomaly at 290 m S, 290 mW of origin.

The co-linear, dipole-dipole line was run using 100 m dipoles, and spreads to n = 5. To interpret the dipole-dipole data, we used a two-dimensional computer code developed by Dey and Morrison (1975) using a mesh of discrete resistivity values. The model has a 25 x 25 m minimum size for resistivity features. Work towards three-dimensional modelling of the data is under way at this time.

Figure 4a shows the pseudo-section plot of the measured apparent resistivity values. Two n = 1 resistivity values were 2.5 and 2.6 Ω-m respectively. In general, we apparently found the reservoir edge on the right or south side, but not on the north or left side. Figure 4b shows the basic model calculations, with 25 m thick, 3 Ω-m plate, underlain by a 25 m thick, 1 Ω-m plate, on a 200 Ω-m infinite substratum. We ran a large number of other models including the proposed fault model, a plume model, and various thicknesses of reservoir which gave poor fits to the data. The models, however, are insensitive to the inclusion of low-resistivity layers at depth. For instance Figure 4c shows the model pseudo-section when a 50 m thick layer of 1 Ω-m is included at a depth of 150 m. We must point out that these are two-dimensional models, when clearly the thaw anomaly is roughly circular.

A dipole-dipole resistivity profile RR' confirmed an N-S trending fault which runs by the west side of the thaw anomaly, but which did not seem to be a conduit for hot water, at least south of the thaw anomaly. Another dipole-dipole survey over a small thaw window about 4.5 km NE of Pilgrim Springs showed resistivities of about 30 Ω-m at a depth of a few tens of meters.

SUMMARY OF RESULTS

The interpretation of the resistivity profiles suggests a reservoir of hot saline water approximately 50 m thick in an elliptical area 1.5 km^2 aligned NE. Analysis of the data rules out the sort of fault model proposed earlier. The conduit system was not discovered, and it is probably small and fault controlled. The basement complex was not found, and it is probably at a depth greater than 250 meters. The data are consistent with heat flow evidence that most of the hot water discharge flows at depth to the north under the Pilgrim River. Two shallow (50 m) exploratory wells confirmed the reservoir, but did not reach the predicted bottom.

ACKNOWLEDGEMENTS

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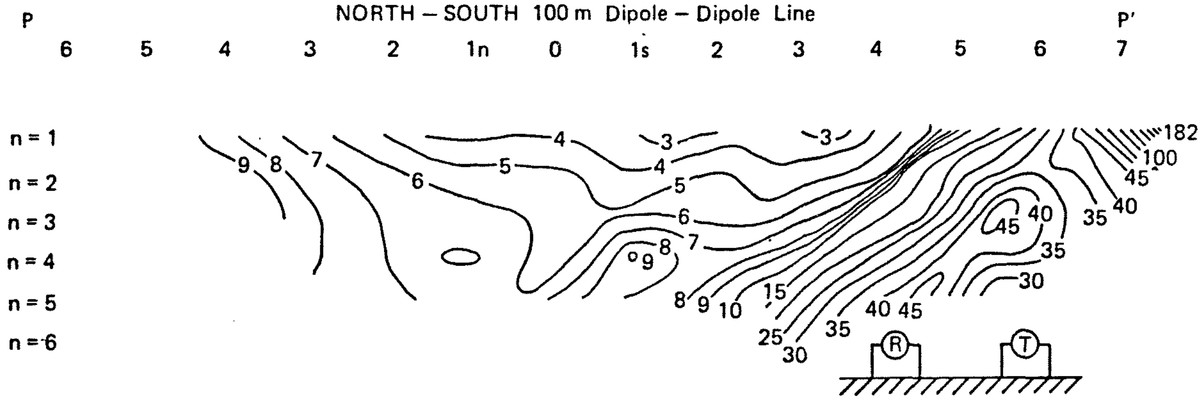
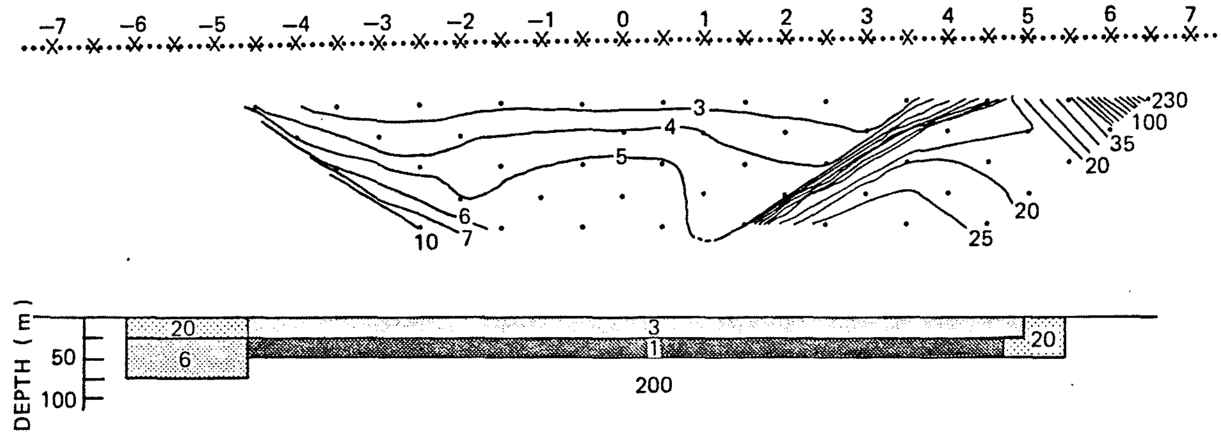
Dey A., and H. F. Morrison, Resistivity modelling for arbitrarily shaped two-dimensional structures, Engineering Geoscience and Lawrence Berkeley Laboratory, University of California, 1975.





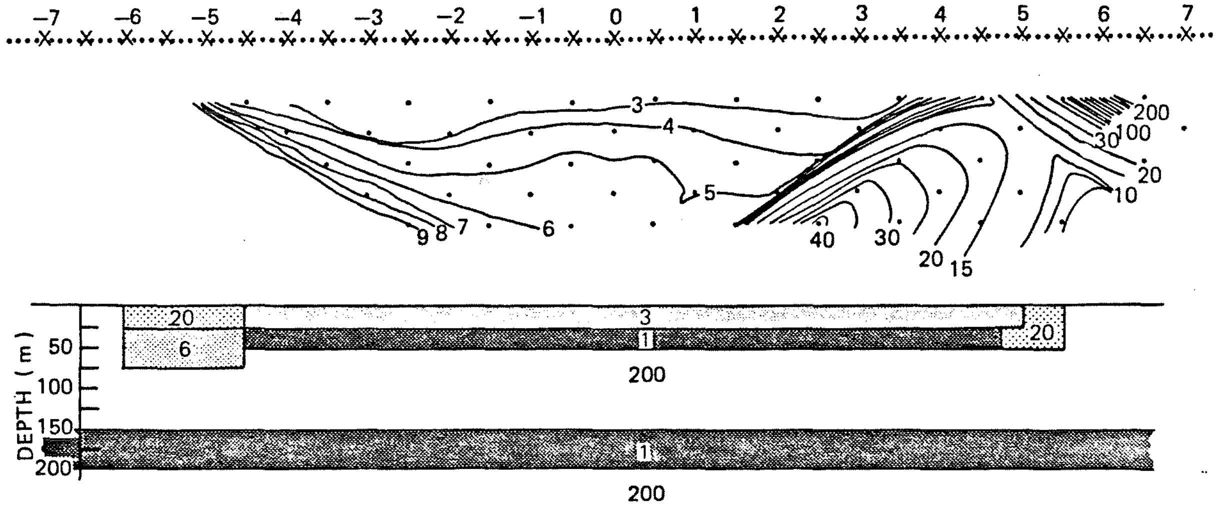


Figure 4a. Field Data, N-S 100 m dipole-dipole pseudosection. Station numbers in hundreds of meters (e.g., 1S = 100 m south of origin).

Figure 4b. Two-dimensional computer model of the basic shallow reservoir structure underlain by rocks of greater resistivity. All values in Ω-m.

Figure 4c. Two-dimensional computer model with a second, deeper hot brine layer at 150 m depth. All values in Ω-m.