SCHLUMBERGER SOUNDING RESULTS OVER THE NEWBERRY VOLCANO AREA, OREGON

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ABSTRACT

Schlumberger soundings were made in the Newberry volcano area of Oregon to categorize the electrical properties of possible Cascade geothermal systems. An east-west geoelectric cross section constructed from the interpreted soundings shows a low-resistivity zone in the caldera, that corresponds to the increase in thermal gradient observed in a U.S. Geological Survey (USGS) test well. Another low resistivity zone about 600 m deep is present just to the west of the caldera boundary. A north-south geoelectric cross section shows the configuration of the western low-resistivity zone.

Maps of interpreted resistivity at depths of 750 and 1000 m show that the main low resistivity area west of the caldera has two tongues, one oriented easterly and the other oriented southerly. On the 750 m depth map, the western low resistivity zone has an areal extent of about 16 km^2. This zone is interesting enough that at least one company has drilled it.

INTRODUCTION

In 1982 and 1984 the U.S. Geological Survey (USGS) made 60 Schlumberger resistivity soundings in the Newberry volcano area of Oregon. These soundings were part of the USGS-DOE effort to categorize the electrical properties of possible Cascade geothermal systems. Geoelectrical cross sections and resistivity depth maps were generated from individual sounding interpretations.

Newberry volcano, located about 40 km south of Bend, Oregon, is one of the largest Quaternary volcanoes in the conterminous United States. The volcano and related flows covers an area of about 1200 km^2. Paulina Peak, at an elevation of 2400 m, is the highest point on the Newberry volcano. The floor rocks and ejecta that form the volcano range in composition from basaltic to rhyolitic (Sammel, 1981).

Newberry caldera, a reserved recreational area, covers an area of about 45 km^2. The present caldera floor is composed mainly of Quaternary age rhyolitic domes, obsidian flows, basalt, and andesite (MacLeod and others, 1981). Two lakes, Paulina and East, are located on the caldera floor. Each lake has a few hot springs that are probably drowned fumaroles.

The Newberry caldera area became interesting after a USGS test well drilled in 1981 encountered 256^o C water at a depth of 930 m. Because of the hot water encountered in the test well and the subsequent industry interest in the area geophysical surveys were conducted to illustrate the resistivity structure underlying the caldera.

SCHLUMBERGER SOUNDINGS

In 1982 the USGS made 21 Schlumberger soundings to half electrode spacings (AB/2) of up to 5000 m (Bisdorf, 1983). In 1984 an additional 39 soundings were made. Figure 1 shows the sounding locations, the caldera boundary, and the

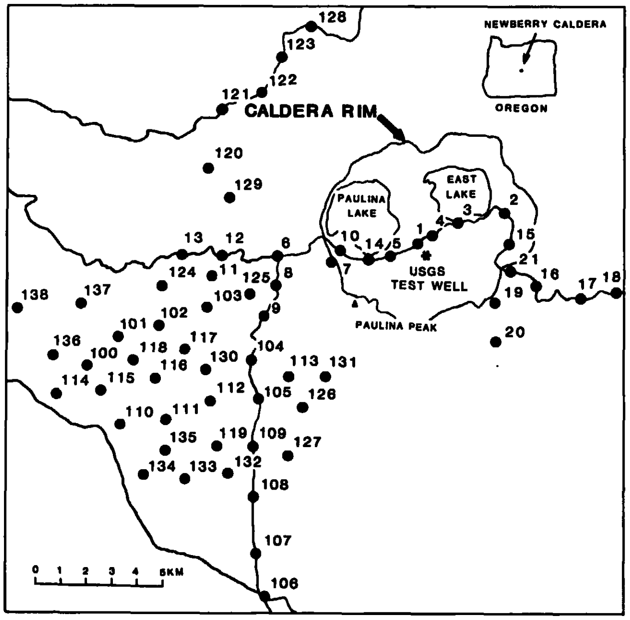

Figure 1. Map of the Newberry Caldera area, Oregon showing the Schlumberger sounding locations.

location of the USGS test well. Soundings numbered 1 thru 21 were made in 1982 and those numbered 100 thru 138 were made in 1984. Schlumberger sounding is a 4 electrode direct-current geophysical technique that is sensitive to the resistivity variations of the earth. This technique looks deeper in a given area by expanding the distance between the current electrodes (AB). Resistivity is largely dependent on the resistivity of the rocks pore fluid. Dry rocks are generally very resistive (>1000 ohm-m), and porous rocks saturated with saline water are not very resistive (<10 ohm-m).

Because of the winding nature of the roads a technique was used to correct the sounding data made along the winding portions of the roads to a more conventional Schlumberger sounding (Zohdy and Bisdorf, 1981). Figure 2 shows an uncorrected sounding, a corrected sounding, and the road trace. The amount of correction is extreme, but shows the effect that making a conventional Schlumberger sounding along winding roads could have on sounding data. The interpretation of the uncorrected data would be misleading at best if no effort were made to take into account the effects of the winding road. The sounding data were then interpreted as a series of horizontal layers using a computer program developed by Zohdy (1973).

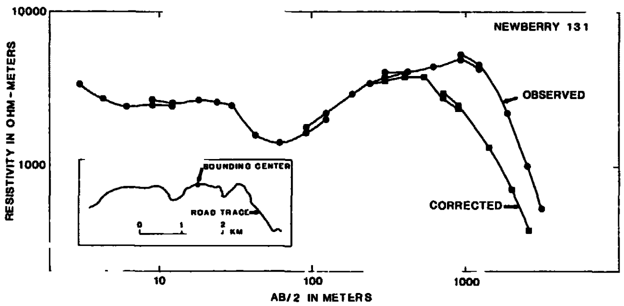

Figure 2. Log-log plot of a corrected and uncorrected Schlumberger sounding and a plot of the appropriate road trace.

Figure 3 shows an example of the field data, interpreted model, and corresponding theoretical sounding for Newberry 1. Newberry 1 is located about 400 m north of the USGS test well. As is usually the case in volcanic terrain, some of the sounding curves were noisy. These curves were manually smoothed and the smoothed curve interpreted. In the caldera, a buried telephone cable ran parallel to and crossed the road at several locations. This cable was interpreted to be the cause of noise on some of the soundings made inside the caldera. In addition, the high contact resistances encountered in parts of the area may have resulted in current leakage at longer electrode spacings, and limited the amount of injected current to only tens of milliamperes. This low current level combined with a low resistivity layer at depth limited the probing depth.

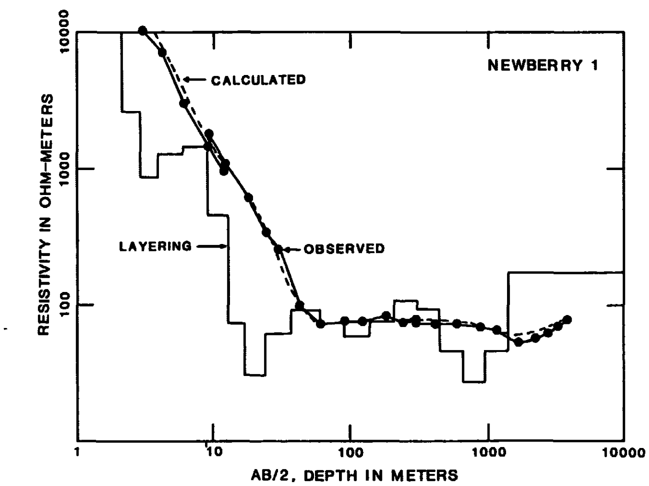

Figure 3. Log-log plot of the observed data, interpreted model and corresponding theoretical curve for Newberry 1.

GEOELECTRIC CROSS SECTIONS

When using Schlumberger soundings it is not advisable to interpret on the basis of an individual sounding because it may not be possible to detect the presence of lateral effects, or current leakage on a single sounding. In practice a series of soundings should be made, and the individual sounding interpretations put together to form a geoelectric cross section. The procedure used to generate such cross sections as described in Bisdorf (1982, pages 5-7) was modified for this report, to include topography. This was necessary because large topographic changes can affect the interpretation of the geoelectric cross sections.

Figure 4 shows an east-west geoelectric cross section that runs through the caldera. The figure consists of two parts, a cross section with no vertical exaggeration and a cross section vertically exaggerated 4 times. Because of plotter limitations, the cross section with no vertical exaggeration does not have the detail of the vertically exaggerated cross section and is only presented to show the horizontal character of the cross section. On the right hand side of the figure, a scale relating interpreted resistivities to shades of gray is presented. Darker shades indicate higher resistivities and lighter shades indicate lower resistivities. The triangles at the top of the cross sections indicate the Schlumberger sounding locations. The caldera boundary and the projected location of the USGS test well are also shown. At the bottom of each cross section there is a wavey line which approximately represents the probing depth and is related to the length of the sounding and the geoelectrical structure.

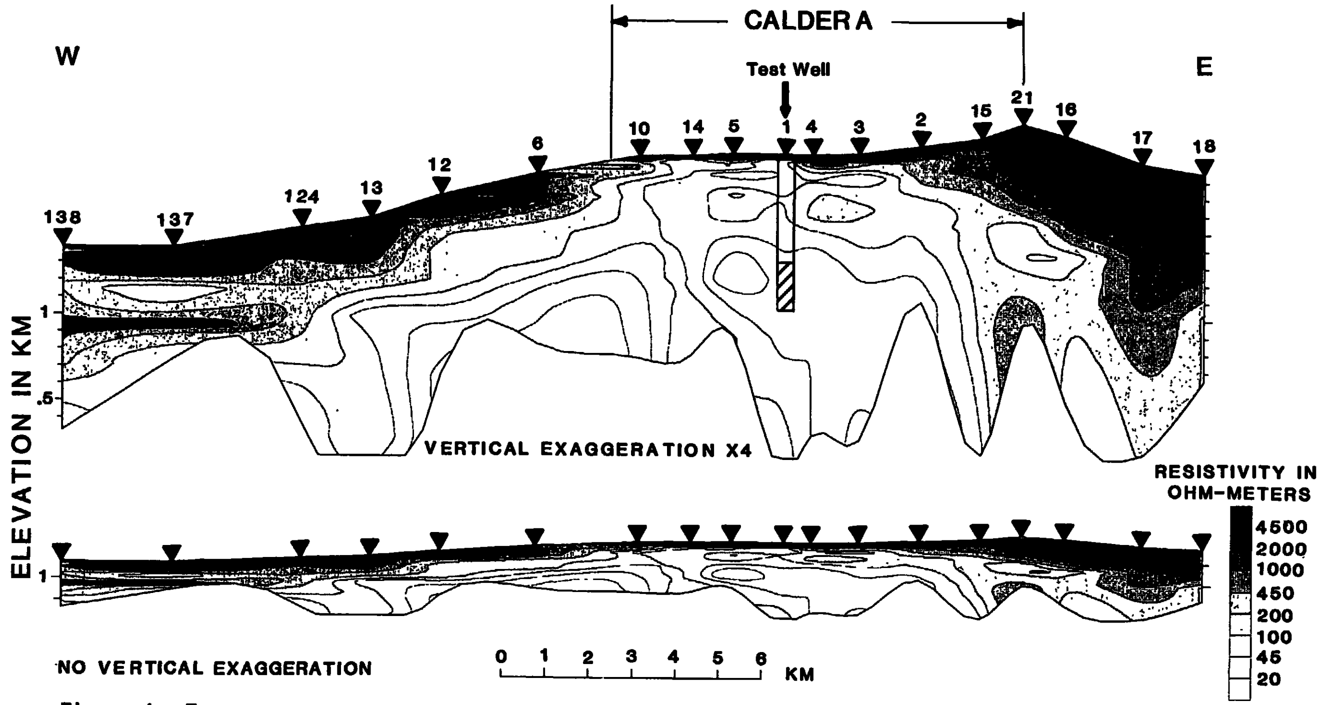

Figure 4. East-west geoelectrical cross section. The upper and lower cross sections are vertically exaggerated 4 and 1 times respectively.

The geoelectrical structure of this cross section consists of high resistivity (>1000 ohm-m) volcanic materials in the upper 500 m and pockets of lower resistivity material. The lower resistivity material is interesting because in the center of the caldera in the vicinity of the USGS test well its top corresponds in depth with the start of a large thermal gradient observed in the test well from a depth of about 675 m. Because of this correspondence with thermal gradient low resistivities are probably associated with increased alteration and hot water. Another pocket of low resistivity material is present just west of the caldera. This pocket does appear to be hydrologically connected to the inter-caldera zone, but based on the test well results it should

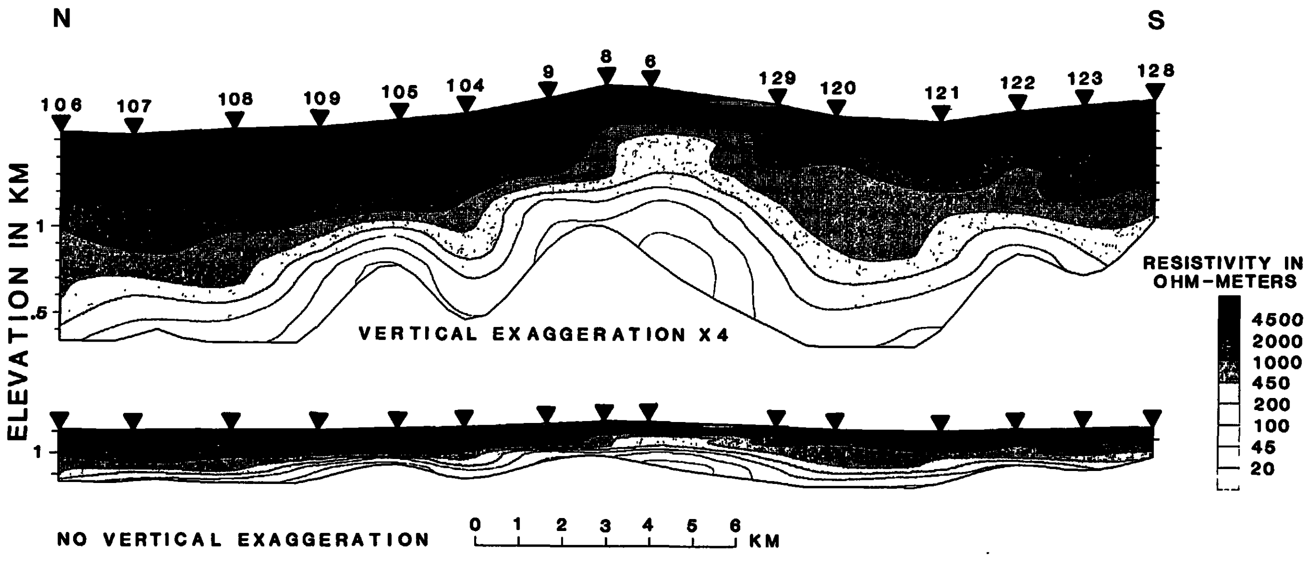

Figure 5. North-south geoelectrical cross section. The upper and lower cross sections are vertically exaggorated 4 and 1 times respectively.

be a good geothermal target considering that the caldera area will probably not be open for economic exploration.

Figure 5 shows a north-south geoelectric cross section that passes through the westernmost low resistivity zone. Again the high resistivity volcanic material is present and another smaller and deeper pocket of low resistivity material is present about 3 km south of the first. These low resistivity zones, especially the larger one, should make nice drilling targets, and, in fact, some geothermal companies have drilled this anomaly.

RESISTIVITY DEPTH MAPS

When sufficient data are available a map of interpreted resistivity at a particular depth can be generated (Bisdorf and Zohdy, 1980). Interpreted resistivities at the desired depth are selected from a continuous variation of the

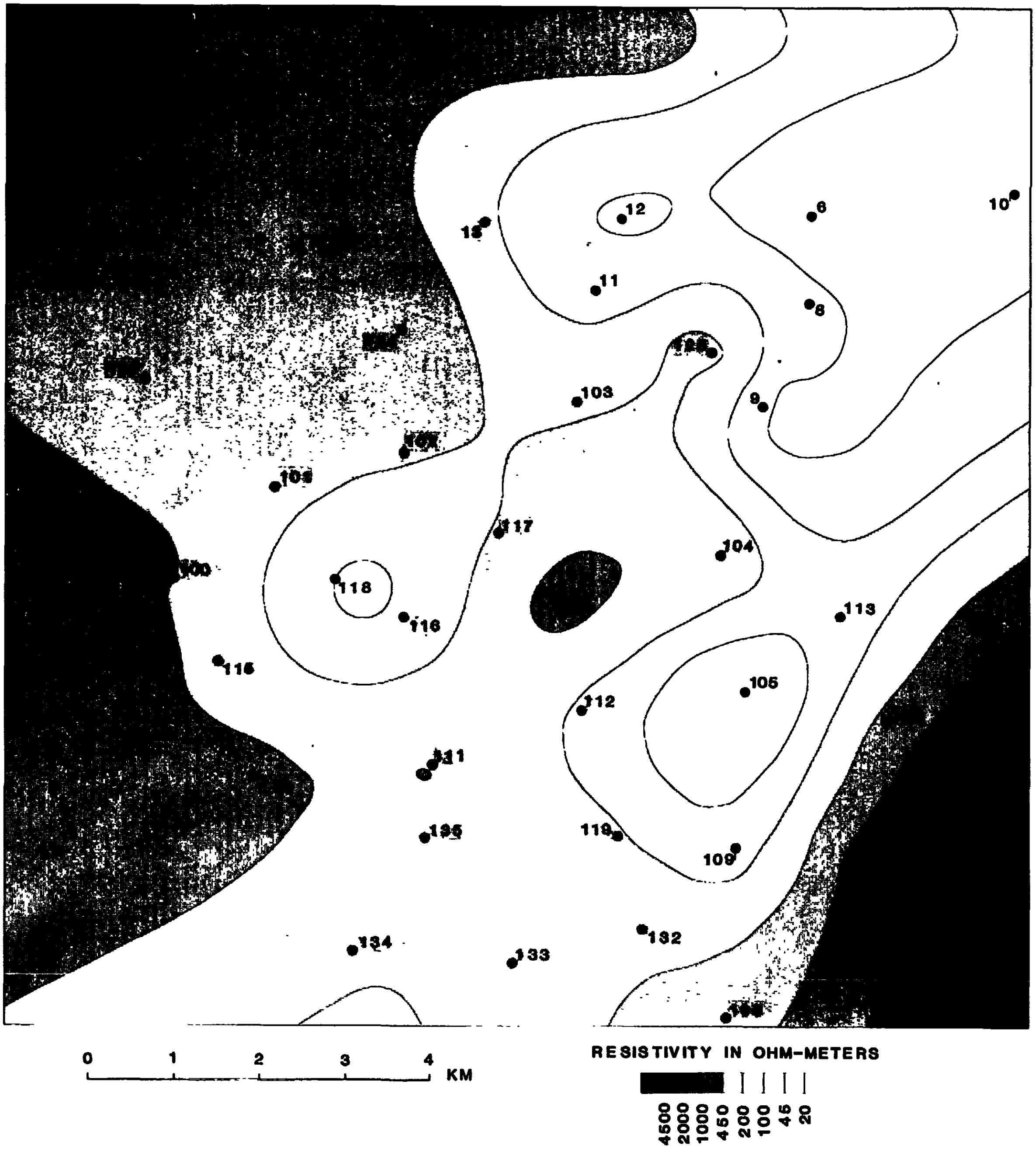

Figure 6. Map of interpreted resistivity at a depth of 750 meters.

resistivity model. These resistivity values along with the sounding locations are input to a minimum curvature gridding program (Webring, 1981). The resultant grid is contoured and shaded. This type of presentation can help in understanding the areal distribution of resistivity. Figure 6 shows a map of interpreted resistivity at a depth of 750 m. The lowest resistivities are concentrated around the area of sounding 6, with low resistivity tongues extending westerly toward sounding 12 and southerly toward sounding 9.

Figure 7 is a map of interpreted resistivity at a depth of 1000 m. At this depth the low resistivity zone is lower in resistivity and larger in area than at the 750 m depth. The westerly tongue turns south from sounding 12 toward sounding 103. The southerly tongue of low resistivity has extended to about sounding 109.

SUMMARY

The USGS test well has shown the presence of

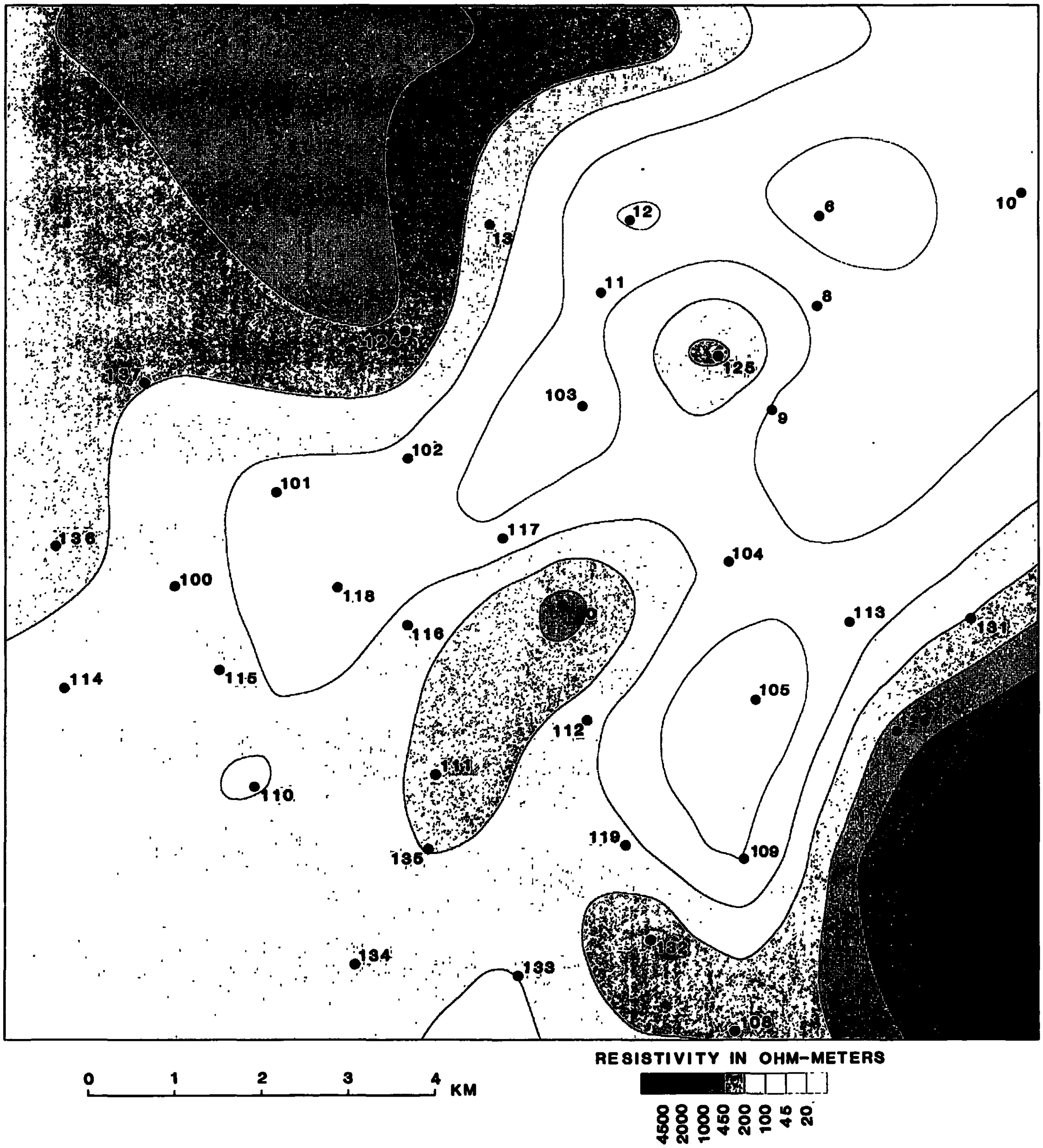

Figure 7. Map of interpreted resistivity at a depth of 1000 meters.

hot water in the Newberry caldera. The Schlumberger sounding data show a low resistivity zone in the caldera that corresponds with the drill hole indications of increased thermal gradient. The sounding data show another low resistivity zone as seen on the geoelectrical cross sections just west of the caldera. Because the caldera is a reserved recreational area this zone is the most probable geothermal target. At a depth of 750 m this low resistivity zone has an area of about 16 km^2. The areal extent of this zone increases with depth.

REFERENCES

Bisdorf, R. J., 1982, Schlumberger sounding investigations in the Date Creek Basin, Arizona: U.S. Geological Survey Open-File Report 82-953, 55 p.

Bisdorf, R. J., 1983, Schlumberger soundings near Newberry Caldera, Oregon: U.S. Geological Survey Open-File Report 83-825, 51 p.

Bisdorf, R. J., and Zohdy, A. A. R., 1980, Schlumberger soundings in the Fish Springs Flat area, Juab County, Utah: U.S. Geological Survey Open-File Report 80-384, 73 p.

MacLeod, N. S., Sherrod, D. R., Chitwood, L. A., and Makee, E. H., 1981, Newberry Volcano, Oregon: Guide to some Volcanic Terranes in Washington, Idaho, Oregon, and Northern California (D. A. Johnston and J. Donelly-Nolan, eds), U.S. Geological Survey Circular 838, p. 85-103.

Sammel, E. A., 1981, Results of test drilling at Newberry Volcano, Oregon: Geothermal Resources Council Bulletin, Dec. 1981.

Webring, Michael, 1981, MINC: A gridding program based on minimum curvature: U.S. Geological Survey Open-File Report 81-1224, 12 p.

Zohdy, A. A. R., 1973, A computer program for the automatic interpretation of Schlumberger sounding curves over a horizontally stratified media: available only from U.S. Department of Commerce, Natl. Tech Inf. Service, Springfield, Va. 122161, as U.S. Geological Survey Report USGS-GD-74-017, PB232 703.

Zohdy, A. A. R., Bisdorf, R. J., 1982, Schlumberger soundings in the Medicine Lake area, California: U.S. Geological Survey Open-File Report 82-887, 162 p.