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AIRBORNE ELECTROMAGNETIC SURVEYS AS A RECONNAISSANCE TECHNIQUE FOR GEOTHERMAL EXPLORATION

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ABSTRACT

INPUT* airborne electromagnetic (AEM) surveys were conducted during 1979 by the U.S. Geological Survey (USGS), in cooperation with the U.S. Department of Energy, Office of Advanced Technology Projects, in five Known Geothermal Resource Areas (KGRA's). AEM work has not been significantly utilized in the past for geothermal purposes because it was thought that a shallow exploration technique would not be effective. Extensive audio-magnetotelluric (AMT) work by the USGS in KGRA's showed that many geothermal systems do have a near-surface electrical signature which should be detectable by an AEM system.

INPUT responses in the form of nested electromagnetic (EM) profiles and channel ratio maps defined the same conductive zones mapped by AMT in five KGRA's, showing that AEM methods can be useful in exploration for and defining geothermal systems.

INTRODUCTION

INPUT surveys flown in 1979 over five KGRA's by the USGS in cooperation with the Department of Energy, Office of Advanced Technology Projects, have proven to be effective in mapping near-surface conductive zones which in some instances are related to geothermal systems. These conductive regions had been previously mapped by the USGS using the AMT method, and although AMT is considered a deeper-looking technique, it seemed likely that the electrical signature of the geothermal systems extends close enough to the surface to be detectable by AEM methods.

In all five KGRA's there is correlation between conductive regions mapped by the AMT and those apparent from INPUT responses. The five KGRA's flown were Surprise Valley and Long Valley, California, Steamboat Springs and Wabuska, Nevada, and Raft River, Idaho, Surprise Valley and Wabuska are discussed in this paper.

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METHOD

The AMT system used by the USGS (Hoover, et al. 1978) measures natural signals at 12 frequencies between 7.5 and 18,600 hertz. Scalar apparent resistivities are calculated for each frequency from a ratio between electric and magnetic field responses in orthogonal directions. For comparison purposes, the deepest-looking frequency, 7.5 hertz, is used in this study. The INPUT surveys, operated at a fundamental frequency of 144 hertz, measure ground response at six time delays (channels) to a time-domain signal. Comparison in this paper is made to nested profiles of channel 6 (deepest-looking of the channels) along the flight lines.

SURPRISE VALLEY, CALIFORNIA

The Surprise Valley, California, KGRA lies in the north-east corner of California in a valley of about 4500-feet elevation bounded by Miocene and Tertiary volcanic mountains to the east and west. The valley is covered by Quaternary alluvium and lake deposits and there are a few exposures of Tertiary intrusives. Two partially dry lakes, Upper and Middle Alkali Lakes, are prominent features in the valley. Surface geothermal manifestations include numerous hot springs along the east side of the lakes and mud volcanoes just north of Lake City on the southwest side of Upper Lake.

The AMT apparent resistivity map at 7.5 hertz (fig. 1, Hoover et. al., 1975) defines a major northwest trending low (approximately 1 ohm-meter contour) which differs in orientation from the lakes, which trend more north and define the central part of the basin.

The INPUT survey was flown with north-northeast flight lines about 1/4 mile apart. Nested profiles of channel 6 (fig. 2) show increasing conductivity to the right of the profiles. Lower resistivities occur over the lakes (as would be expected) (fig. 1), but the lowest values occur just east and north of Middle Alkali Lake and trend north-northwest. These low resistivities could be the result of clay and saline deposits of an older, larger lake or could be the result of

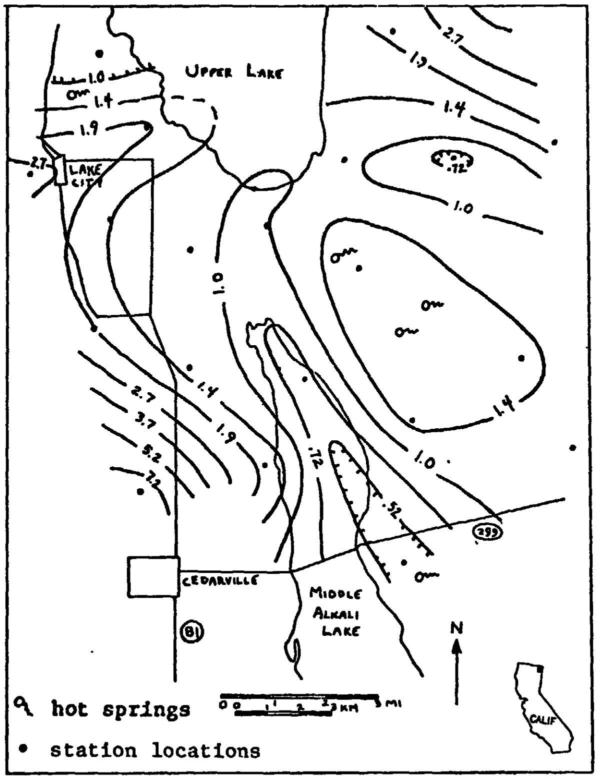

Fig. 1 Audio-magnetotelluric apparent resistivity map at 7.5 hertz, Surprise Valley, California KGRA. Logarithmic contours in ohm-meters.

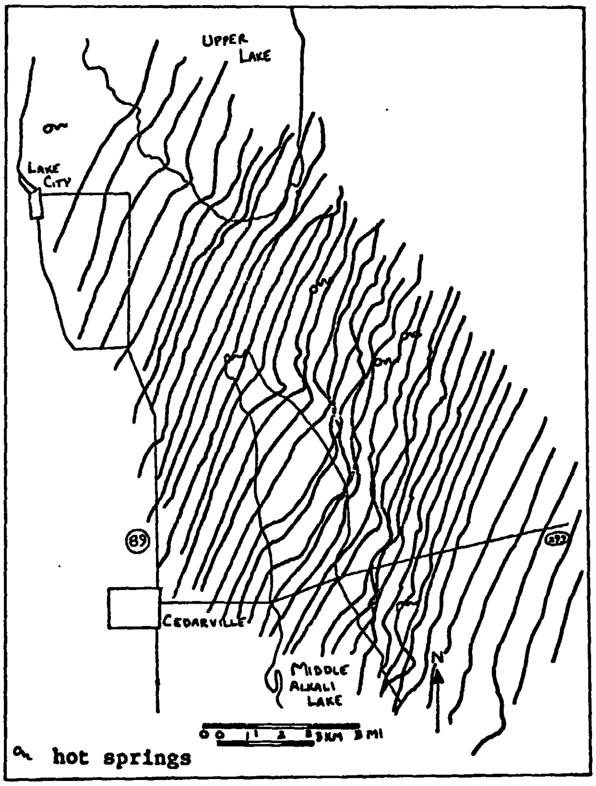

Fig. 2 Nested INPUT profiles, Channel 6, Surprise Valley, California KGRA.

geothermal alteration. Regardless, they represent the major conductive areas and trend in a similar pattern to the AMT data. Other series of lows, 2 to 3 miles long and trending northwest, occur along the southern edge of Upper Lake and to the northeast of Middle Alkali Lake. These low resistivity areas could be indicative of faults or lake deposits.

WABUSKA, NEVADA

The Wabuska KGRA lies in western Nevada south of Reno. Most of the KGRA is flat and covered by Quaternary pluvial and alluvial sediments. Along the northern part are hills of Tertiary sediments and Jurassic and Triassic metavolcanics and metasediments. Just north of the KGRA are exposures of Quaternary-Tertiary basalt. Hot springs are in the mid-northern part of the KGRA.

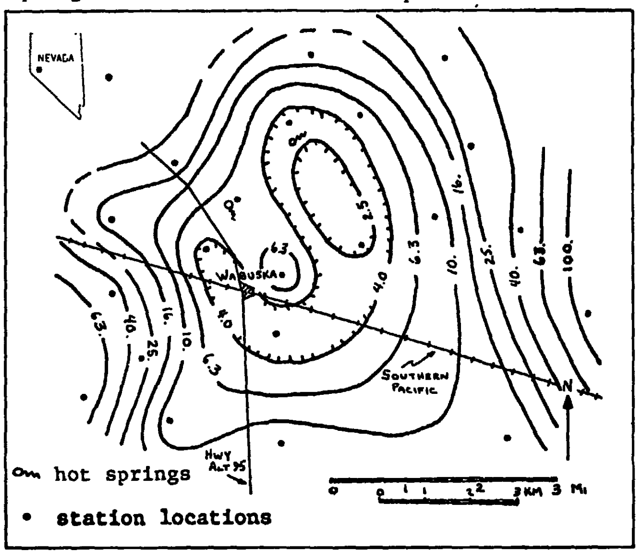

Fig. 3 Audio-magnetotelluric apparent resistivity map at 7.5 hertz, Wabuska, Nevada KGRA, logarithmic contours in ohm-meters.

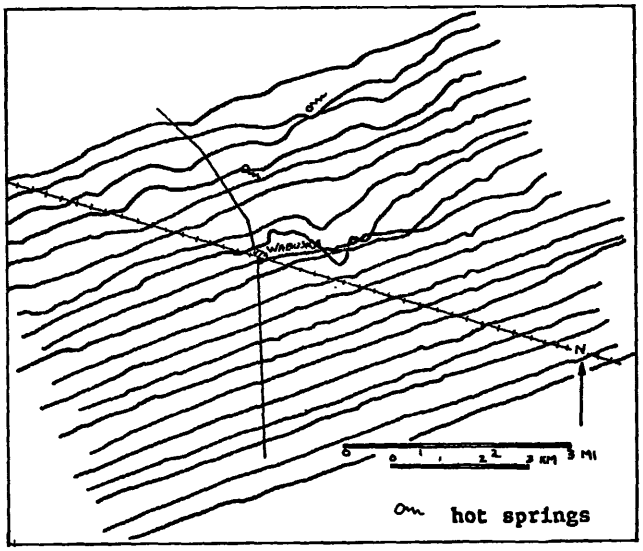

Fig. 4 Nested INPUT profiles, Channel 6, Wabuska, Nevada KGRA.

The 7.5 hertz AMT apparent resistivity map (fig. 3, Long et al., 1975) shows a major low (less than 10 ohm-meters) in the middle of the KGRA. The 4 ohm-meter contour outlines a horseshoe-shaped region with the lowest values to the northeast of Wabuska.

Results of the INPUT survey, with northeast-trending flight lines at 1/4-mile spacing, are shown in fig. 4 as nested profiles of channel 6. Increasing conductivity is to the southeast of the profiles. The major low occurs northeast of Wabuska, near the southern part of the lowest AMT resistivities. The southern part of the KGRA shows no major conductors. Lows trending north and northwest in the northern part of the KGRA could be indicative of fault zones associated with metamorphic and volcanic hills.

CONCLUSION

In the five KGRA's studied, the INPUT AEM surveys proved very effective in detecting major conductors indicated by previous AMT work. At the same time, the AEM work provided a larger data base capable of denoting smaller conductors and better defining conductive trends. For these reasons, air-borne techniques, such as INPUT, can be a useful tool for locating areas of low resistivity for further study within a geothermal region.

REFERENCES

Hoover, D. B., S. Gardner, and J. M. Williams, 1975, Audio-magnetotelluric apparent resistivity maps, Cedarville, California 15′ quadrangle, USGS Open File Report 75-102.

Hoover, D. B. and C. L. Long, and R. M. Senterfit, 1978, Audio-magnetotelluric investigations in geothermal areas, Geophysics, vol. 43, no. 7, 1501-1514.

Long, C. L. and R. H. Brigham, 1975, Audio-magnetotelluric Data Log for Wabuska, Nevada, USGS Open File Report 75-444.