UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

E-Field Ratio Telluric Survey Near Medicine Lake in the Medicine Lake Highlands Caldera, Siskiyou County, California

by

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Open-File Report 82-900

1982

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards. The use of trade names in this report is for descriptive purposes only, and does not imply endorsement by the U.S. Geological Survey.

Introduction

This report represents results of three electric field ratio telluric traverses conducted in the vicinity of Medicine Lake in the Medicine Lake Highlands caldera in Siskiyou County, northern California. The work is part of the U.S. Geological Survey's program of research on geothermal systems that focuses on geothermal potential in the Cascade Range of the western United States. This report also compares the telluric data results with the results of an airborne electromagnetic survey (AEM) (Dighem Limited, unpub. data).

E-field ratio tellurics is a descriptive name applied to the electrical exploration techique used in the present survey (Beyer, 1977). The telluric method refers to the measurement of the earth's electrical field generated by induction from the natural electromagnetic field at the earth's surface at frequencies lower than about 0.05 Hertz. The E-field ratio telluric method uses a receiving array of three electrodes spaced equidistant and inline. The array is, in effect, two colinear dipoles sharing a common electrode. The potential difference across each dipole is then proportional to the component of the telluric field in the direction of the array. This configuration permits the measurement of the ratio of the electric field at each dipole in the direction of the dipole line, and hence the name. Electric-field data so obtained are proportional to the square root of the apparent resistivity of the earth at the location of the dipoles (Beyer, 1977).

Apparent resistivity is a function of the dipole direction with respect to major structures. E-field ratio data usually is obtained along a line perpendicular to the structure, which corresponds to the E-perpendicular (TM) mode of apparent resistivity. Alluvial fill, argillite and similar rocks tend to have low resistivities, whereas igneous or high-grade metamorphic rocks have high resistivities. Variation in the electrical properties along a traverse then may be used to infer lithologic or structural changes.

Data Acquisition and Reduction

Telluric field observations were made with two 250-meter colinear dipoles moved along a straight-line traverse incremented by 250 meters. The field equipment was built by the U.S. Geological Survey and is similar to that described by Beyer (1977). It consists of two matched narrow-bandwidth low-frequency amplifiers whose outputs connect with two different axes of a portable X-Y recorder. The recorded signal from the two colinear dipoles then appears as a Lissajous figure (fig. 1) from which the ratio of the signal amplitude is determined. The -6db points of the high- and low-pass filters were at 20- and 40-second periods (0.05 and 0.025 Hz) for this survey. A three-person field crew carrying the equipment on a backpack frame generally is sufficient for surveying.

At each field station a minimum of three sets of Lissajous figures is recorded, each set comprising measurements of the natural electric fields for a time span typically 2 to 5 minutes. The tangent of the Lissajous figures major axis determines the ratio of the magnitudes of the telluric field at each dipole. The three sets of readings are averaged to give a voltage ratio at each station and the data are plotted as a variation in telluric voltage versus dipole position. Typically the data accuracy is ±1 degree, giving a 3 percent error in voltage ratio when fields are equal (a 45-degree slant-line fig.).

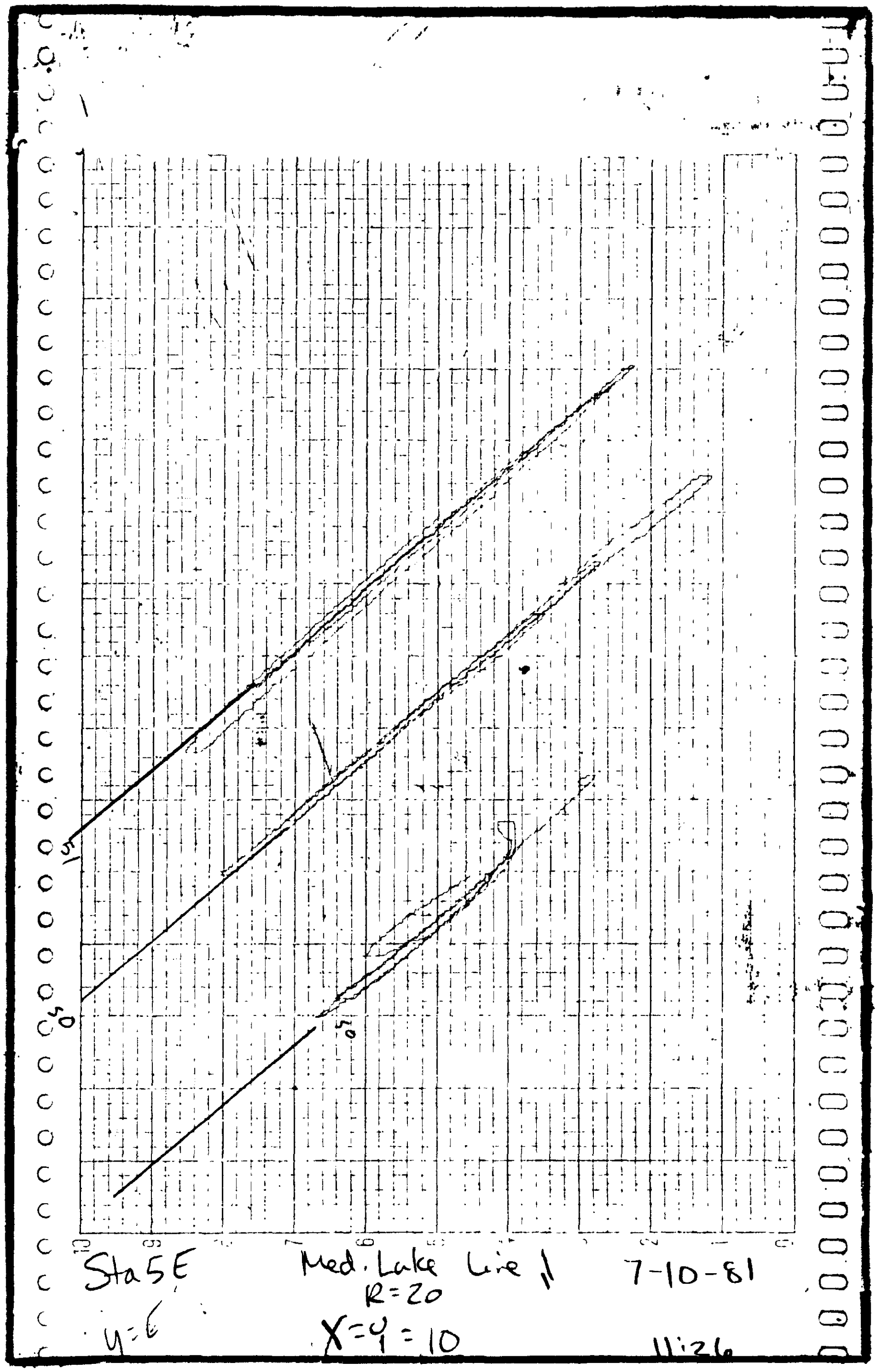


Figure 1. The ellipses are examples of Lissajous figures. Lines drawn at the left indicate general trend and angle of the Lissajous figures.

Traverses are run normal to the expected strike of geological structures and in as straight a line as practical because telluric fields can be strongly polarized, particularly in the vicinity of lateral resistivity boundaries. If the magnetic field in the same frequency band, 0.05 to 0.025 Hz, were known at one dipole position, then the TM mode apparent resistivities would be defined along the entire traverse. These apparent resistivities are calculated when magnetotelluric data is available at some point on the traverse. The discontinuity in the TM mode electric fields across vertical boundaries provides an effective means of defining lateral electrical boundaries in the earth as is illustrated by Beyer's (1977) TM mode responses over theoretical geological models.

The maximum depth of exploration is determined by the electromagnetic skin depth in the earth. For a homogeneous half-space, the skin depth δ in meters is given by

$$\delta = 503 \sqrt{\rho / f} \text{ meters}$$

where ρ is the half-space resistivity in ohm meters and f is the frequency (Hz). At the central frequency used in this survey (0.033 Hz) and for a typical 100 ohm-meter earth the skin depth is 27 km. As a rule of thumb, the detectability limit is about 1/2 a skin depth. However, within the range of dectectability, the spatial dimension of variations in the telluric fields is proportional to the distance to the anomalous structure. Thus, shallow structures may be distinguished from deeper ones.

The purpose of an AEM survey is to locate good electrical conductors in the earth, down to a depth of approximately 100 meters, which produce discrete anomalies over such conductive media as faults, shear zones, graphitic schists, and massive sulfide mineralization (Ward, 1967). AEM and telluric survey results can be compared because near-surface layering effects the telluric data, even though telluric depth capabilities are greater (see Beyer, 1977). For a complete description of the airborne resistivity mapping technique used for the present survey, see Fraser (1978).

Results

The location of the three traverses is shown in figure 2. All traverses were run across areas of low surficial resistivity as identified by the AEM data. Similarities and dissimilarities of data profiles in figures 3, 5 and 6 may be the result of the different depth-penetrating capabilities of AEM and telluric data and slightly differing flightline and traverse locations.

Traverse 1 (fig. 2) was run near the north shore of Medicine Lake in an east-west direction. Starting on the west end, south of Badger Peak, platy andesitic lava flows outcrop. The line runs over glacial deposits between stations 6W and 1W, over alluvium between stations 1W and 2E, and over basalts from 2E to 8E (Anderson, 1941). The telluric data (fig. 3) indicate a gradual decrease of relative voltage (hence decreasing resistivity) from dipoles 7-8W to 1-2E. A small high in telluric voltage occurs between dipoles 2-3E to 5-6E. A large and abrupt increase occurs between dipoles 5-6E to 6-7E.

The abrupt increase of relative voltage between dipoles 5-6E and 6-7E correlates with a mapped fault at that location (Anderson, 1941). Because traverse 1 runs at an acute angle to the mapped fault, the telluric response is not representative of the TM mode (Beyer, 1977) and the increase in relative voltage as shown in figure 2 may be distorted. Other mapped faults cut traverse 1 between dipoles 1-2W and 3-4W, the latter correlating with the

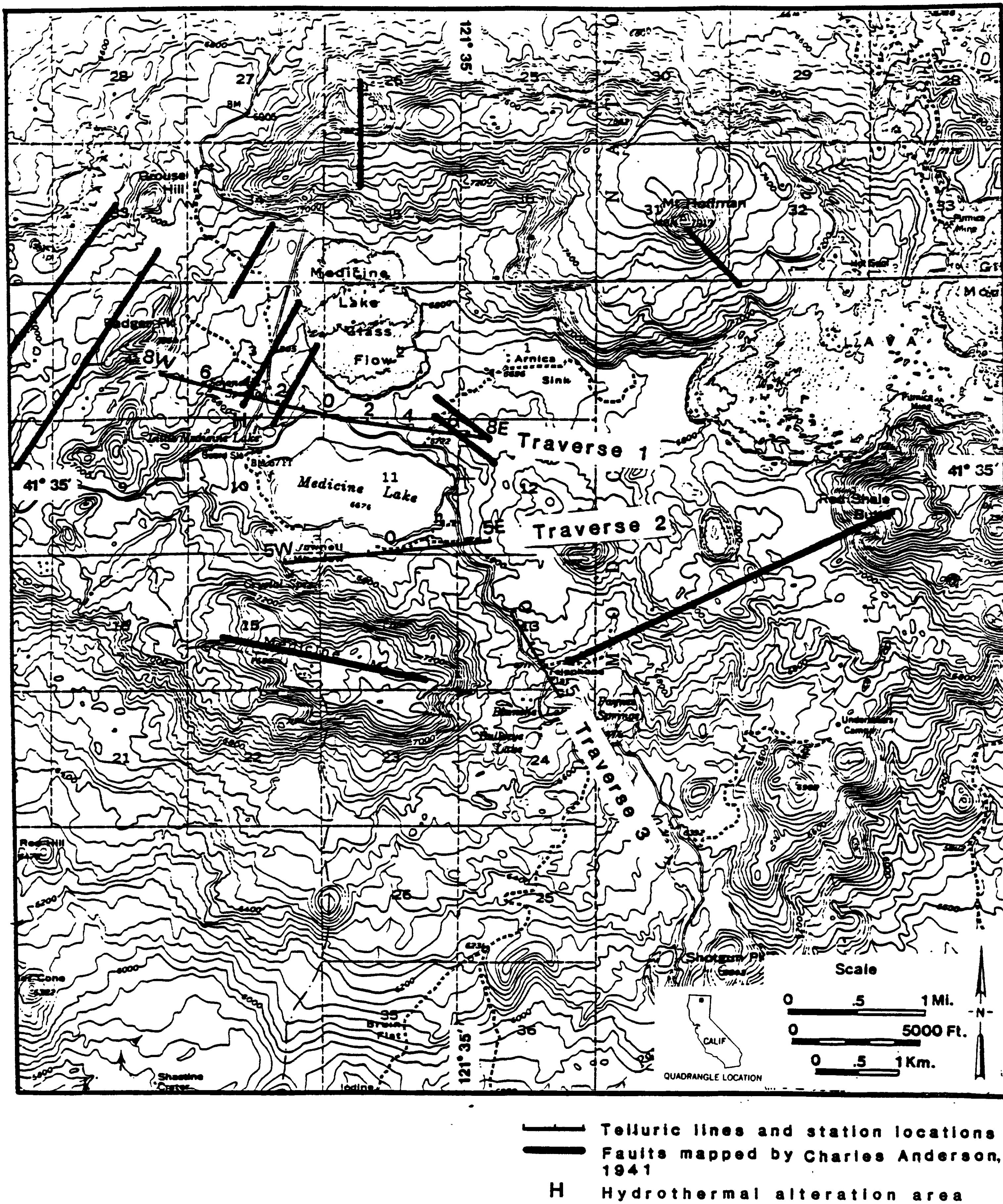


Fig. 2. Location map for telluric traverses and mapped faults in the Medicine Lake Highlands Caldera, Siskiyou County, California.

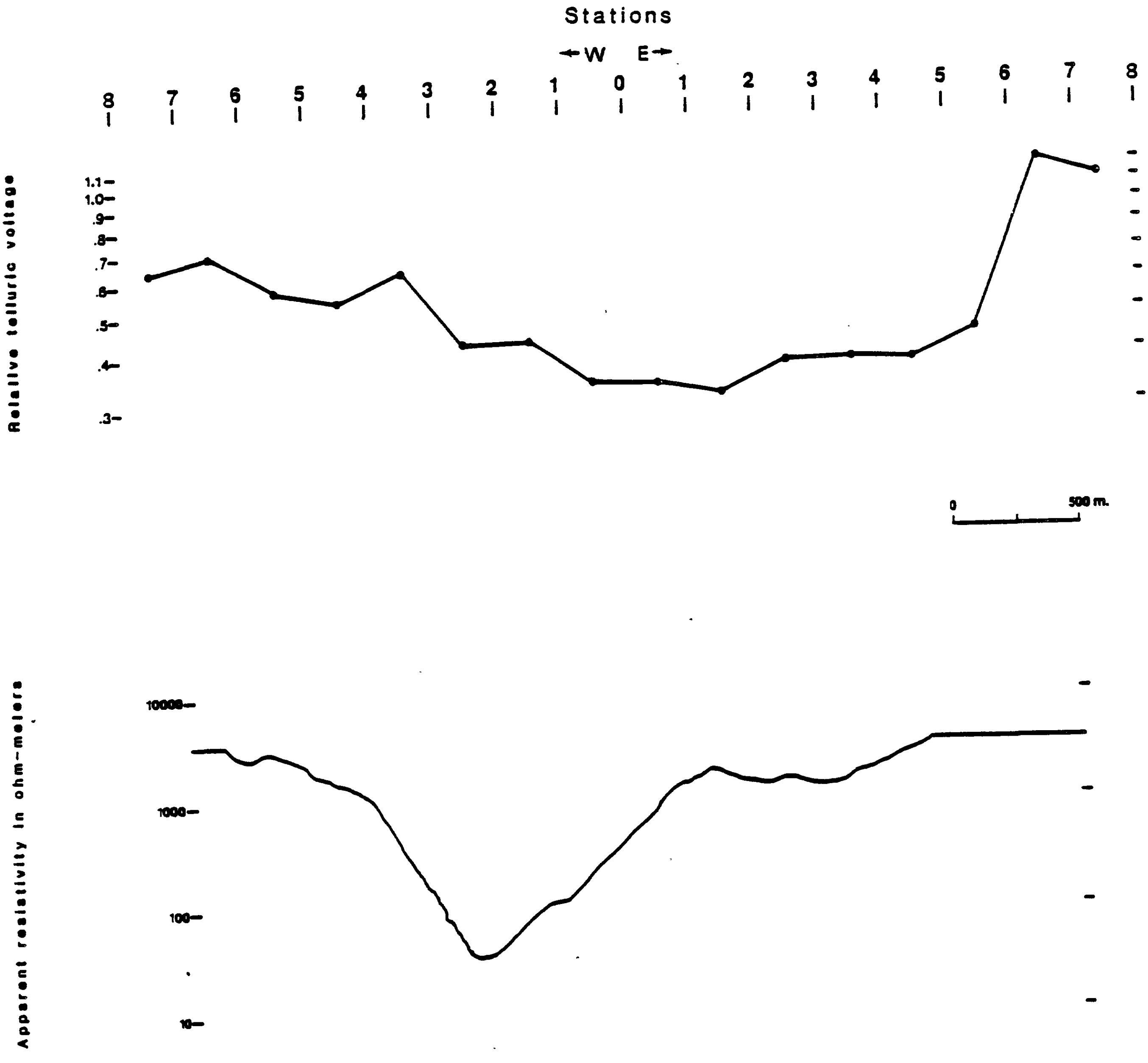
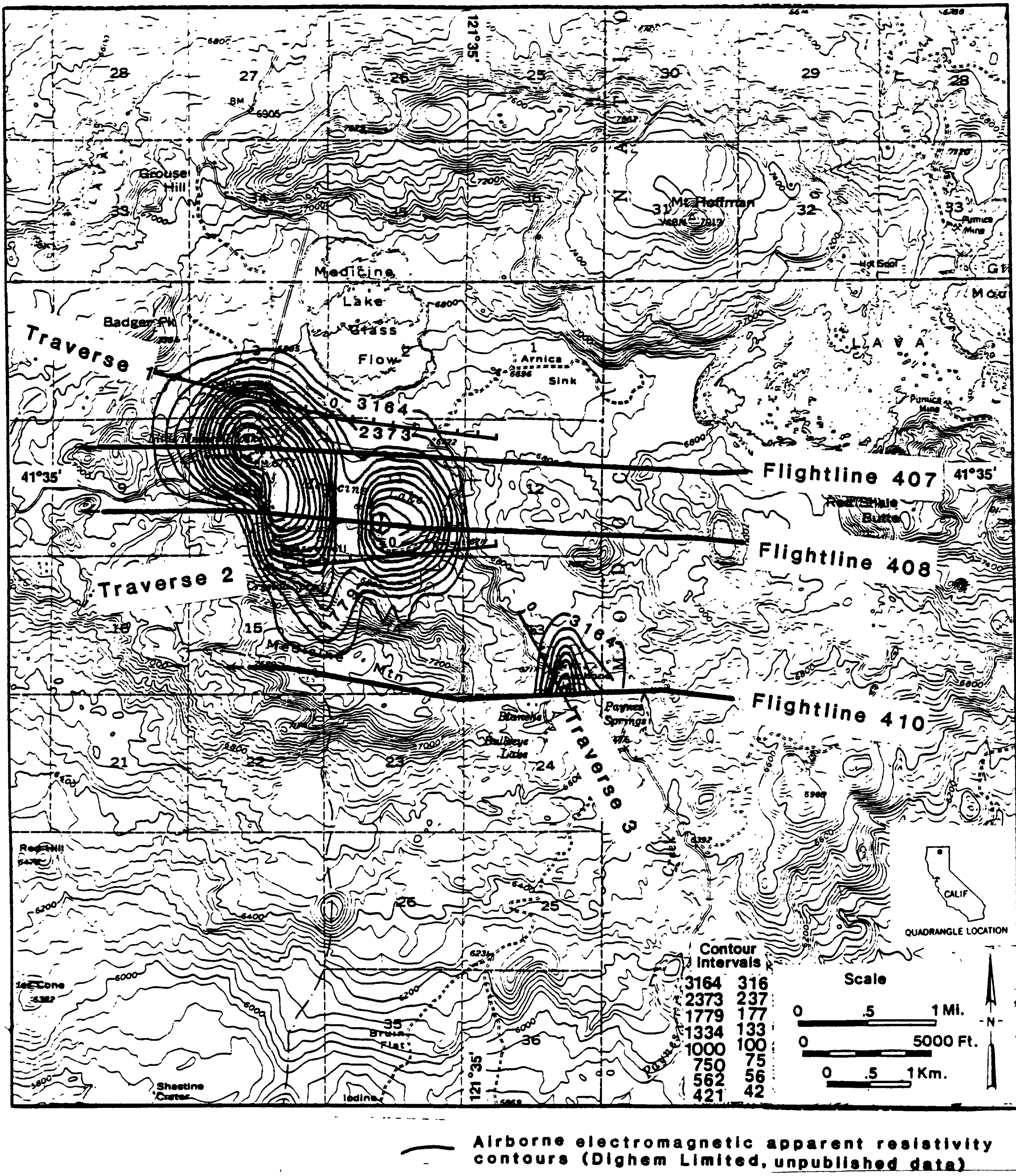


Fig. 3. E-field ratio telluric data for traverse 1 (top) and AEM apparent resistivity for flight line 407. Analogue equipment recorded the EM data at approximately 3600 Hz.



Airborne electromagnetic apparent resistivity contours (Dighem Limited, unpublished data)

Flightlines flown by Dighem Limited

Telluric lines

Fig. 4. Location map of telluric traverses and AEM apparent resistivity anomalies.

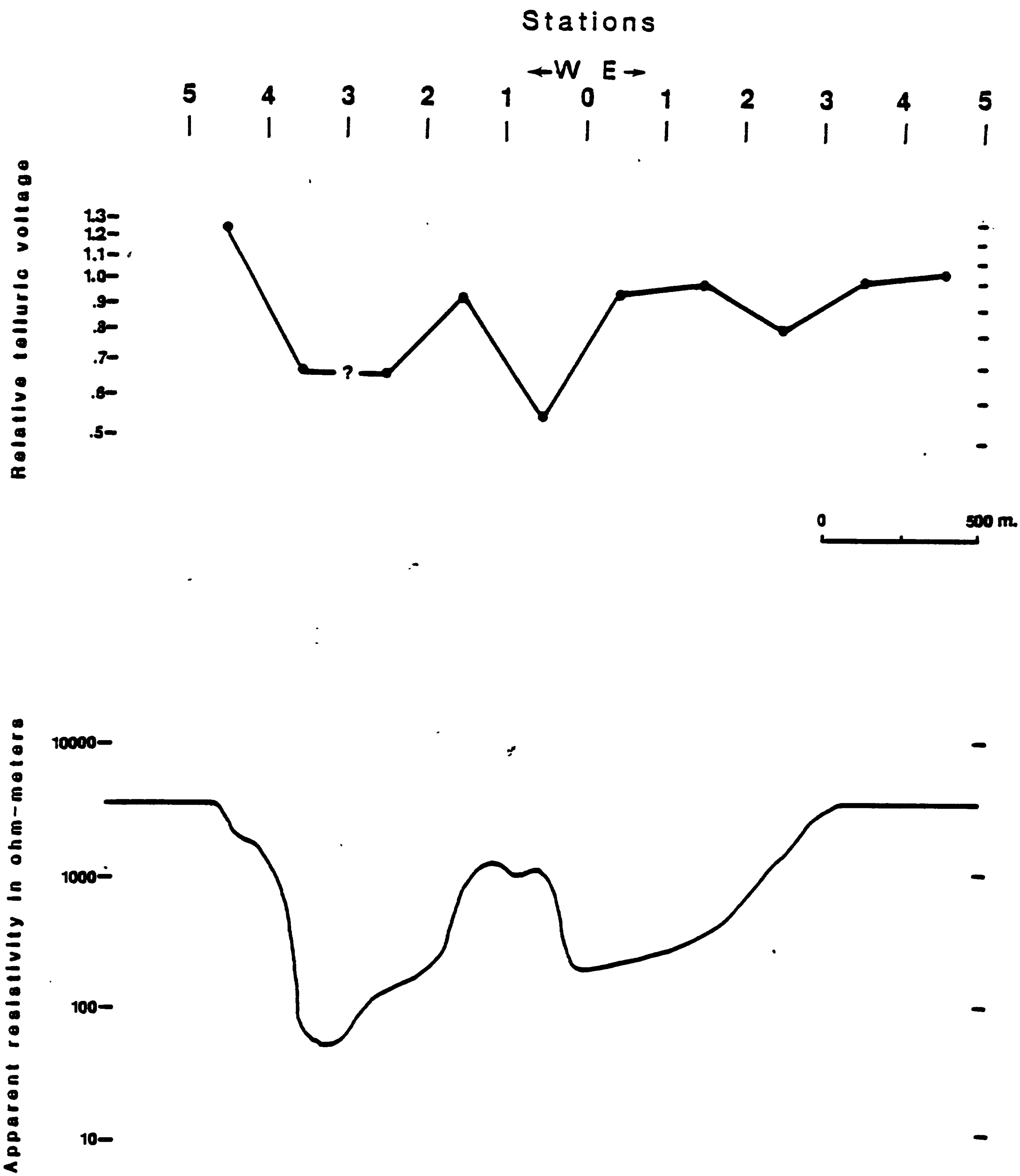


Fig. 5. E-field ratio telluric data for traverse 2 (top) and AEM apparent resistivity for flight line 408. Analogue equipment recorded the EM data at approximately 3600 Hz.

telluric data of figure 3, and near where hydrothermal alteration exists (Julie Donnelly-Nolan, pers. commun., 1981) (fig. 2), and was observed by the authors.

Traverse 2 (fig. 2) was run near the south shore of Medicine Lake across glacial deposits from stations 5W to 2W and over platy andesitic lava flows on the remainder of the line. Cultural electromagnetic interference prevented a reading at dipoles 3-4W. The relative voltage at dipole 3-4W is arbitrarily plotted as that of dipole 2-3W (fig. 5), therefore the true difference between dipoles 2-3W and 3-4W is unknown. Variations of relative voltage across traverse 2 are similar with AEM resistivity (fig. 5) observed along flightline 408 (fig. 4) and suggest several faults with possible hydrothermal alteration or lithology differences. However there is no correlative geological evidence to support this suggestion. The uncertain telluric lows between stations 2W to 4W correspond to a similar feature in the AEM profile. This correlates with mapped glacial deposits (Anderson, 1941) which may in part explain the AEM data.

Traverse 3 (fig. 2) runs across platy andesitic lava flows except for an area approximately between stations 2 and 3 where glacial deposits cover an area known as Telephone Flat. The AEM data plotted with the telluric data in Figure 6 was taken from the contour map (fig. 4) because traverse 3 was not run parallel to the flightlines. The large telluric voltage decrease from dipoles 2-3 and 3-4 probably indicates the location of an extension of a mapped fault trending northeast (see fig. 2). There is a correlative AEM resistivity low, but no surface indications were observed to suggest a cause such as sediments or hydrothermal alteration along traverse 3.

Conclusions

The AEM and telluric data show somewhat similar results. Similarities between telluric data on traverse 2 (fig. 3) and the AEM data (fig. 4) suggest a north-northwest trend fault near the west shore of Medicine Lake that cuts traverse 2 near station 4. Another fault possibly may be found cutting traverse 2 near station 0 and striking north over an area of AEM recorded low resistivity to cut traverse 1 near dipoles 1-2E and 2-3E. High relative voltage at dipole 1-2W on traverse 2 and the corresponding AEM resistivity high over central Medicine Lake (fig. 4) probably indicate that a northward-striking, narrow resistive block is present which has undergone less hydrothermal alteration or which may be distinctive lithologically.

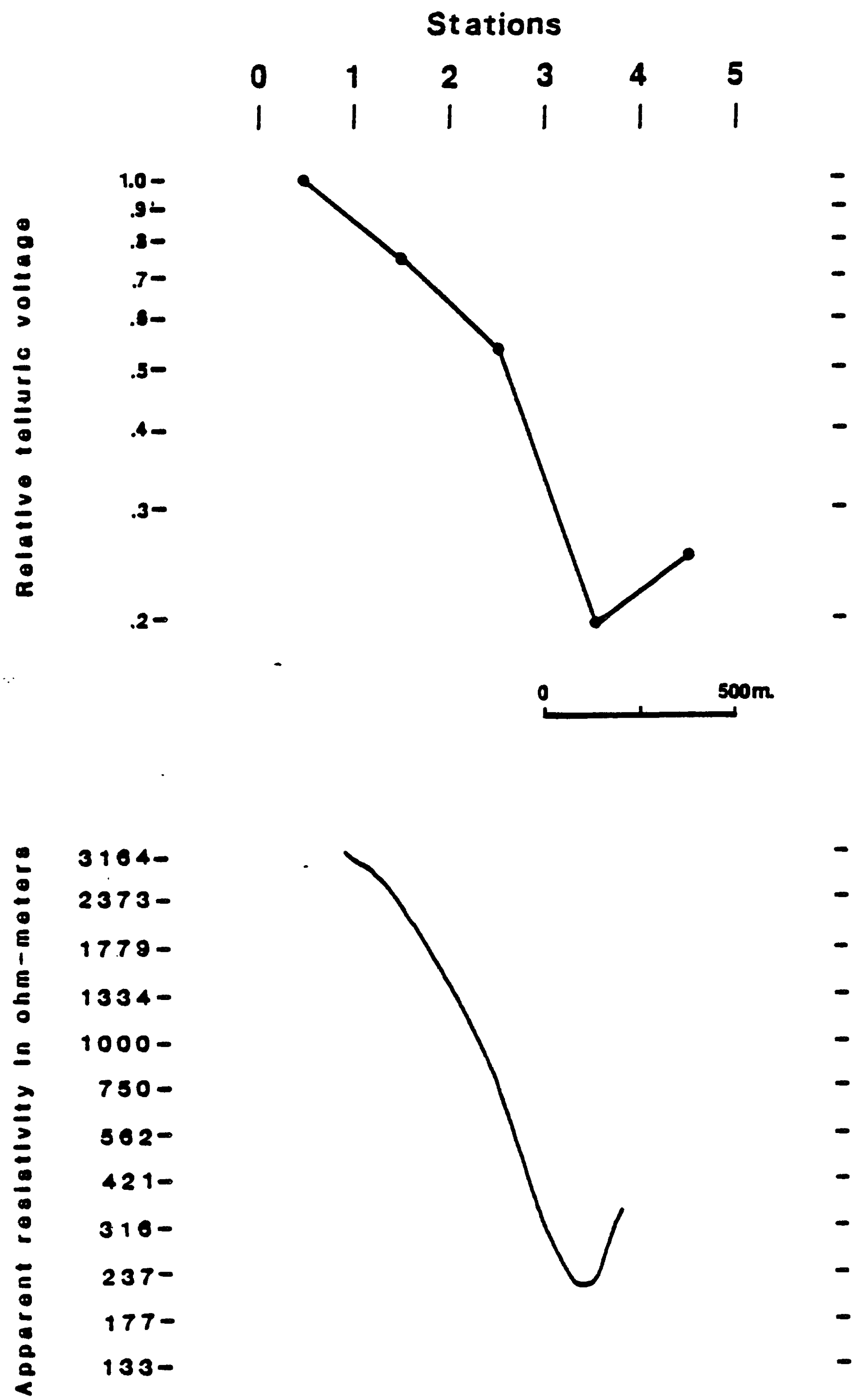


Fig. 6. E-field ratio telluric data for traverse 3 (top) and AEM apparent resistivity from contours of flight line 410. Analogue equipment recorded the EM data at approximately 3600 Hz.

References

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