E-Field Ratio Telluric Survey Near the Big Maria Mountains

Riverside County, California

by

Donald B. Hoover, Michael M. Broker, and T. Stambaugh

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Introduction

The U.S. Geological Survey (USGS) under the Wilderness Act (Public Law 88-577) and the Federal Land Policy and Management Act (Public Law 94-579) has the responsibility, along with the U.S. Bureau of Mines, to survey certain areas in order to determine their mineral resource potential. This report presents results of three electric-field ratio telluric traverses conducted as part of the Bureau of Land Management Wilderness Program in the Big Maria Mountains, Riverside County, Calif. The telluric traverses were run on the southwest side of the Big Maria Mountains in an attempt to define the location of major buried faults near the eroded front of the range.

E-field ratio tellurics is a descriptive name applied to the electrical exploration technique used in this survey. The telluric method refers to the measurement of the earth′s electric field generated by induction from natural electromagnetic waves arriving at the surface. The E-field ratio telluric method uses a receiving array of three electrodes spaced equidistant and inline. This 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 telluric field at each dipole in the direction of the dipole line, and hence the name. The traverse data is extended by moving the three-electrode array forward one dipole length so that the forward electrode becomes the center electrode for the next ratio measurement.

Electric-field data so obtained are proportional to the square root of the apparent resistivity of the earth at the location of the dipoles. However, because the apparent resistivity can be a function of the dipole direction, it is important to know the orientation of the dipoles with respect to major structures. Because the resistivity of fluid-saturated earth materials is largely dependent on the porosity of the rocks, the salinity of the pore fluid, and the presence of clays or similar material where surface conduction is high, 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 may then be used to infer lithologic or structural changes.

Data Acquisition and Reduction

Telluric field observations were made with two 500-meter colinear dipoles moved along a straight line traverse incremented by 500 meters. By placing one dipole at the previous recording station as the array increments, all data along the traverse can be referenced to one dipole. The field equipment was manufactured by the USGS and is similar to that described by Beyer (1977). It consists of two matched narrow-bandwidth low-frequency amplifiers whose outputs are recorded on a portable X-Y recorder. The signals from the two colinear dipoles then appear as Lissajous figures, from which the ratio of the signal amplitudes may be determined. For this survey the -6db points for the high- and low-pass filters were at 20- and 40-second periods (0.05 and 0.025 Hz). Normally a three-person field crew is used with the equipment being carried on a backpack frame.

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 of 2 to 5 minutes. In most cases the tangent of the angle of the Lissajous figure's major axis is the ratio of the magnitudes of the telluric field at each dipole. The three sets of readings are then averaged to give a voltage ratio at each station. Typically the data accuracy is ±1 degree giving a 3 percent error in voltage ratio when the fields are equal (a 45-degree Lissajous figure). The traverse data are referenced to one of the dipoles on the line and the results are plotted as a variation in telluric voltage versus dipole position.

Traverses are run normal to the expected strike of geological structures and in as straight a line as practical. For two-dimensional structures this corresponds to measuring the electric field of natural electromagnetic signals in the transverse magnetic (TM) mode sometimes called the E-perpendicular case. For this condition the electric field is proportional to the TM mode apparent resistivity along the traverse. If the magnetic field in the same frequency band, .05 to .025 Hz, were known at one dipole position, then the TM mode apparent resistivities would be defined along the entire traverse. These resistivities are calculated when magnetotelluric data is available at some point on the traverse. The apparent resistivities are proportional to the square of the telluric voltage changes. Because telluric fields can be strongly polarized particularly in the vicinity of lateral resistivity boundaries, it is necessary to traverse in a straight line to maintain TM mode polarization. The discontinuity in the TM mode electric fields across vertical boundaries provides an effective means of defining lateral electrical boundaries in the earth. This is well illustrated by Beyer (1977) who shows TM mode responses over various 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,

$$\delta = 500\sqrt{\rho/f} \quad \text{meters}$$

where ρ is the half-space resistivity in ohm-meters and f is the frequency.

At the center frequency used in this survey (0.033 Hz) and in 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 detectability, the spacial wavelength of variations in the telluric fields is proportional to the distance to the anomalous structure. Thus shallow structures may be distinguished from deeper ones. On the short traverses (6-8 km) used in this survey it is the relatively shallow lateral changes which are of interest.

Results

In fig. 1 the location of the three traverses is shown. All traverses were run in a northeast-southwest direction normal to the long axis of the Big Maria Mountains and some of the major exposed faults in the area (Warren Hamilton, oral commun., 1981, Jennings 1977). Traverse 1 is located just north of the end of the Big Maria Mountains on the edge of Rice Valley. The other two lines start on the lower slopes of the Big Maria Mountains and extend out onto broad alluvial fans. Details of each line and station location are given in figs. 2 to 4.

Line 1 (fig. 2) starts at the southwest on outcrops of metamorphosed Jurassic granitic rocks and extends northeastward onto alluvium of Rice Valley. The telluric data (fig. 5) indicate a high relative voltage at dipoles 0-1 and 1-2, an abrupt drop at dipole 2-3 and generally decreasing voltage along the rest of the traverse except for a distinct rise at dipole 4-5. The data are consistent with a fault near station 2 that drops the metamorphics on the northeast beneath consequently thickened alluvium. The telluric high at dipole 4-5 may represent a basement ridge or narrow horst extending out from the Big Maria Mountains. The lowest value at dipole 8-9, is about 80% of the voltage at dipoles on either side. This low value is attributed to a major basement fault, which has been mapped in the mountains and which projects along strike to cross the traverse at this position (Warren

Fig. 1. Location map of telluric traverses 1, 2, and 3 near the Big Maria Mountains, Riverside County, California Major faults identified in this survey are indicated by the heavy dashed

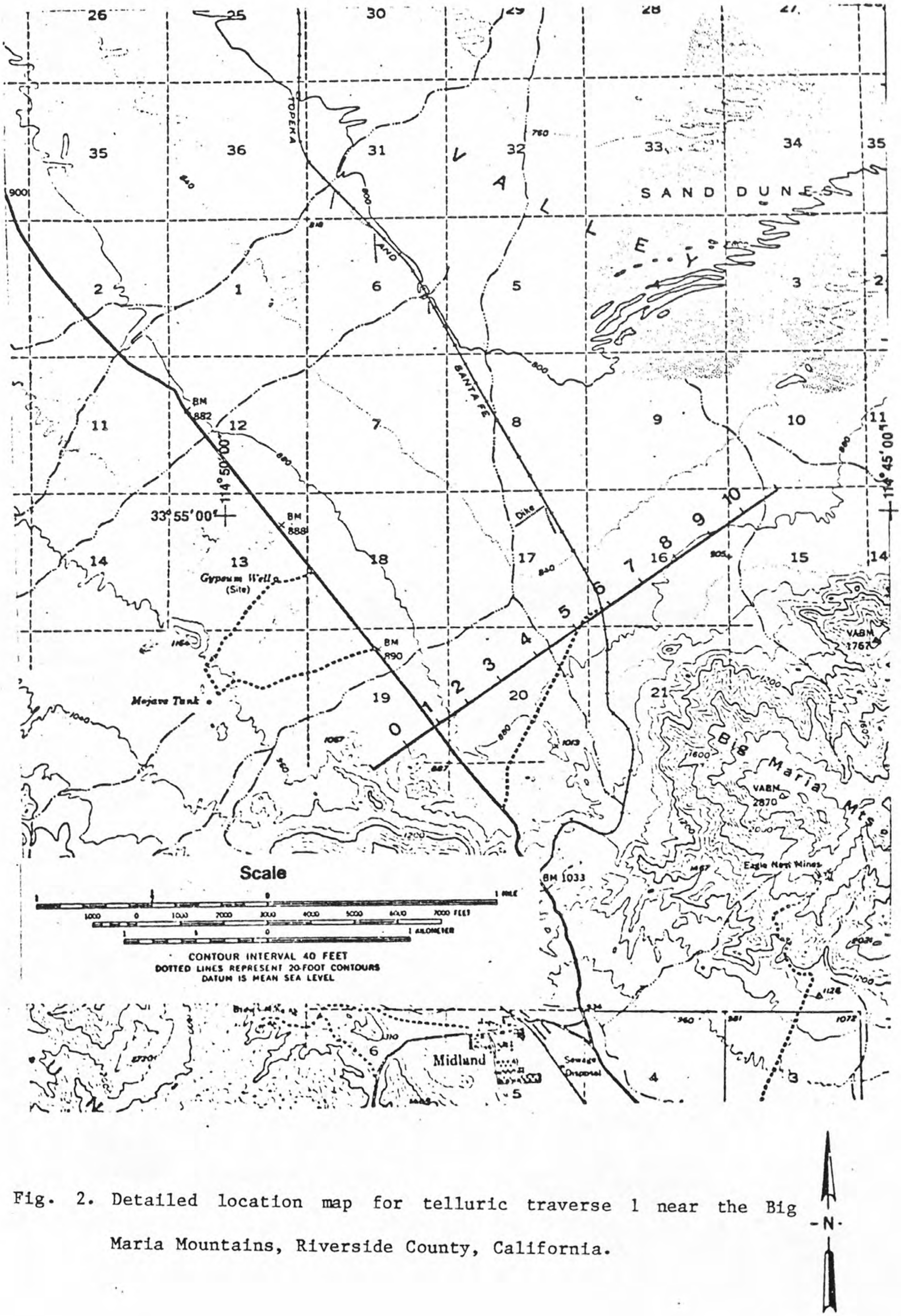

Fig. 2. Detailed location map for telluric traverse 1 near the Big Maria Mountains, Riverside County, California.

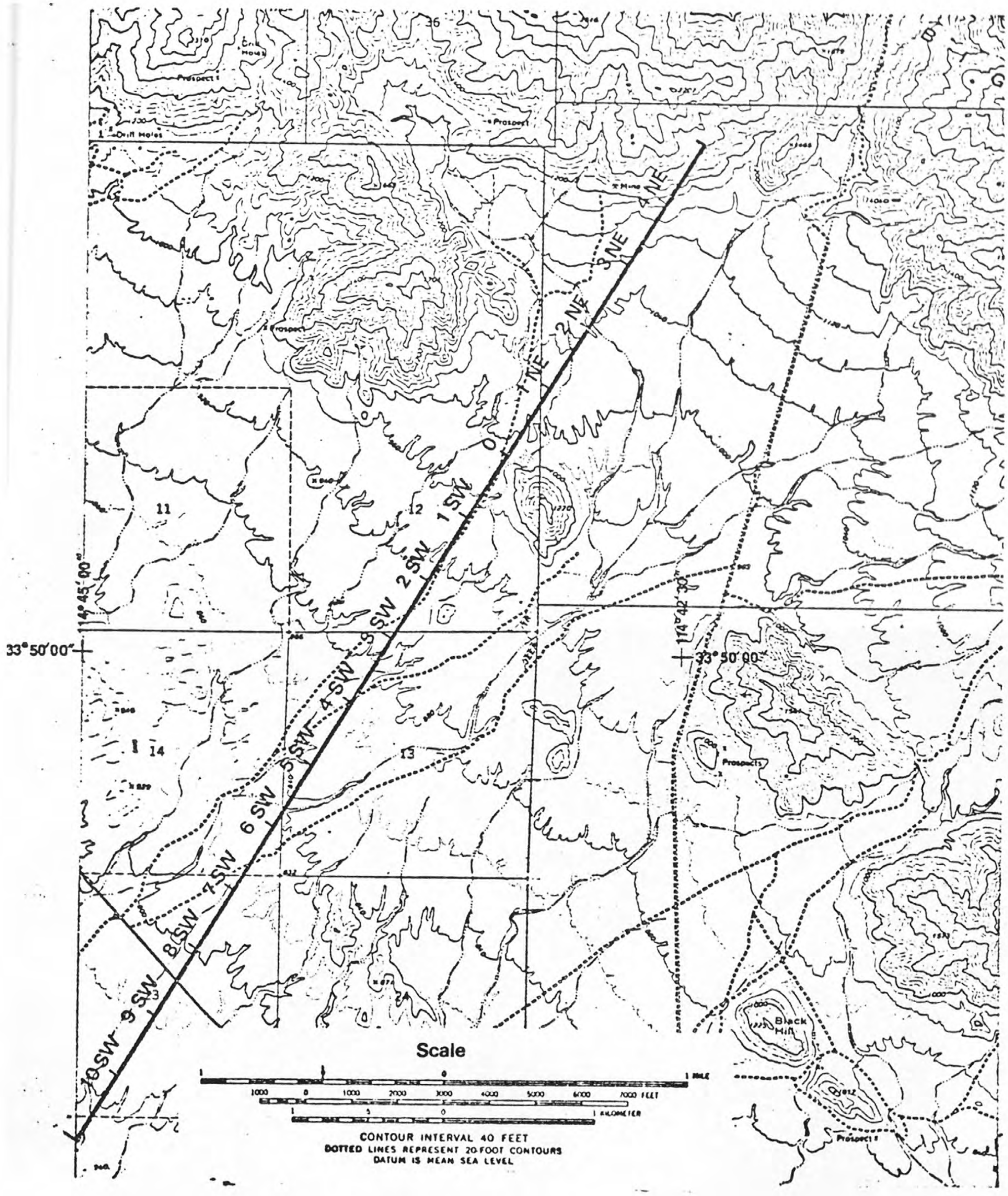

Fig. 3. Detailed location map for telluric traverse 2 near the Big Maria Mountains, Riverside County, California.

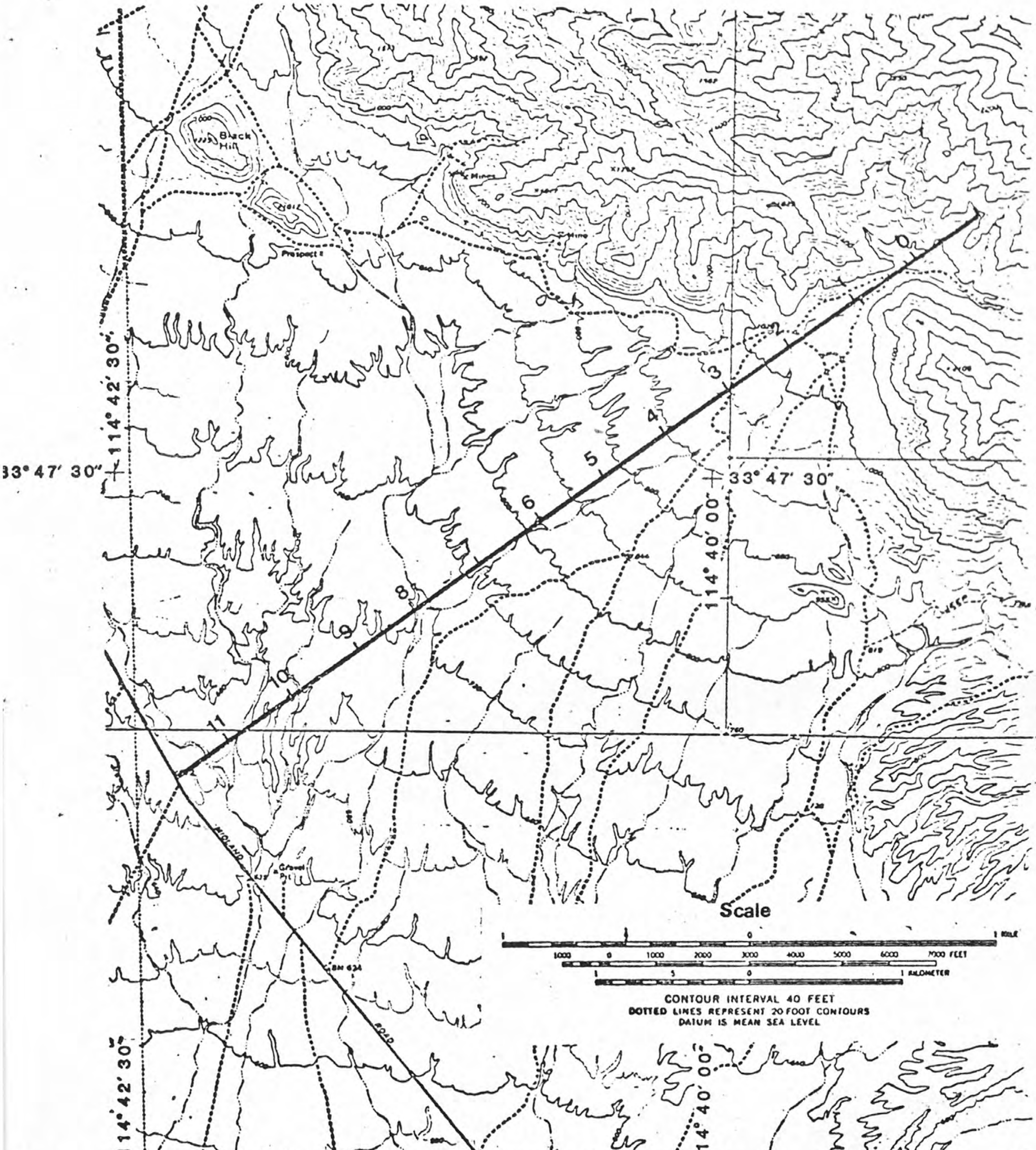

Fig. 4. Detailed location map for tellurice traverse 3 near the Big Maria Mountains, Riverside County, California.

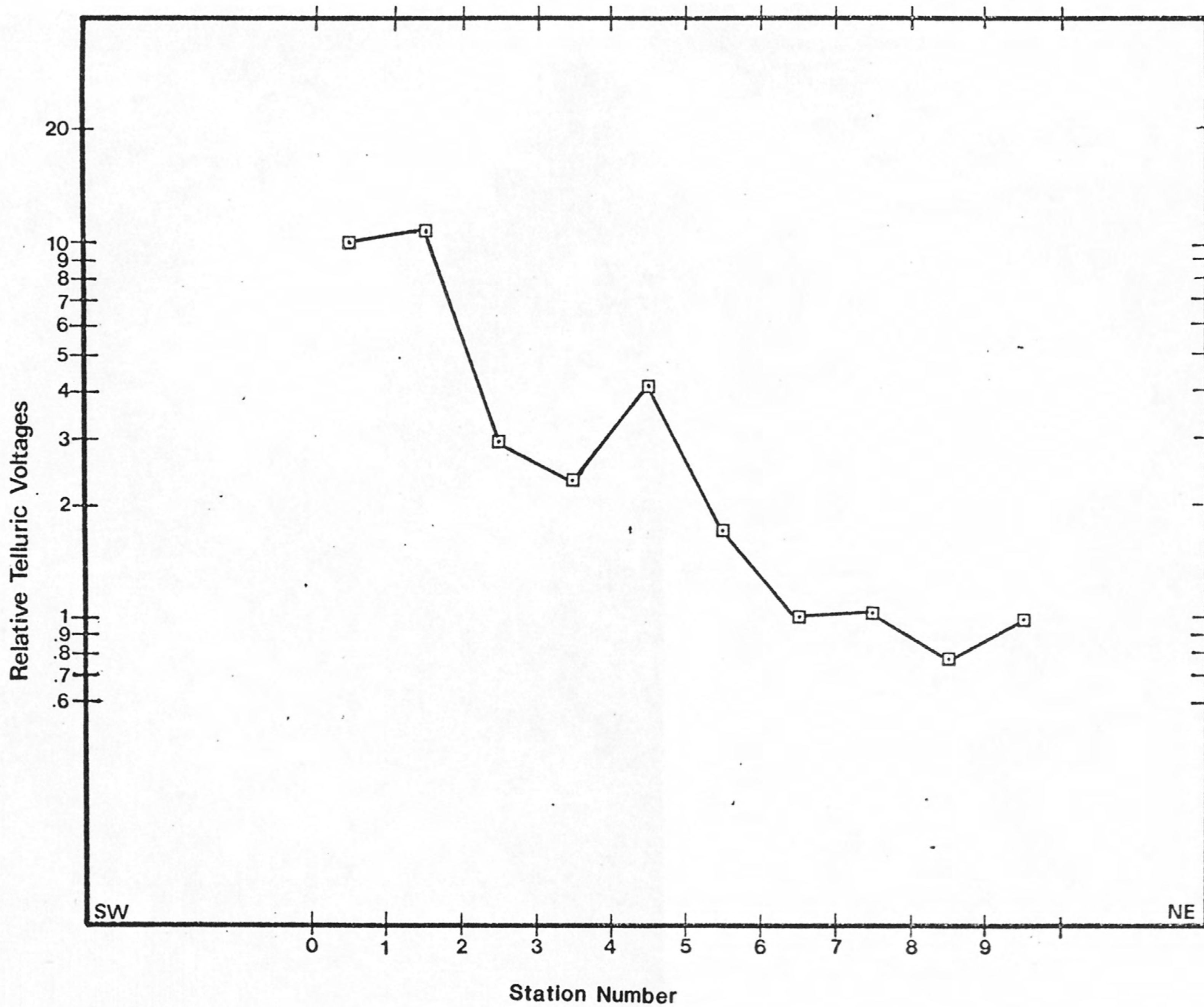

Fig. 5. E-field ratio telluric data for traverse 1 near the Big Maria Mountains, Riverside County, California. The telluric data is proportional to the square root of the apparent resistivity variation along the traverse.

Hamilton, oral commun, 1981). The lower voltage here, and hence lower resistivity, is attributed to a zone of low resistivity in the basement rocks due to increased fracturing and porosity along the fault zone. As this traverse runs across the end of the Big Maria Mountains, three-dimensional effects may perturb the data so that it does not represent true TM mode apparent resistivity variations.

Traverse 2 (fig. 3) starts on the northeast in metamorphosed Jurassic granodiorite variably covered by thin alluvium, passes close to exposures of Paleozoic and Mesozoic metasediments near stations 0 to 2 NE, and then continues on alluvial fans. The telluric data for this line are shown in fig. 6. Near the northeast end, dipoles 1NE-2NE to 3NE-4NE show lower values than on either side. This would be consistent with a graben along this part of the line, the lower voltages being due to a thickening of the alluvium or unconsolidated deposits. The major fault identified at dipole 8-9 on traverse 1 is mapped crossing this traverse near station 1NE. No fault is known from surface geology (Warren Hamilton, oral commun., 1981) near station 4NE, although a subsurface fault may be suggested by these telluric data. Alternatively the change in voltage might represent a lithologic change in the basement rocks at this location. The major change in voltage from dipole 2SW-3SW to 4SW-5SW is attributed to a major buried range-front fault which has resulted in down dropping of the valley on the southwest. The low voltages are due to thickening of the alluvium. The small decrease in voltage on dipole 1SW-2SW could be a local thickening of the alluvium or a fault zone.

Traverse 3 (fig. 4) also starts in the metasedimentary basement rocks on its northeast end and extends southwest onto alluvial fans. The electrical data (fig. 7) indicates the same sort of picture as seen on traverse 2. A greater drop in voltage, however, is seen on this traverse from the maximum at

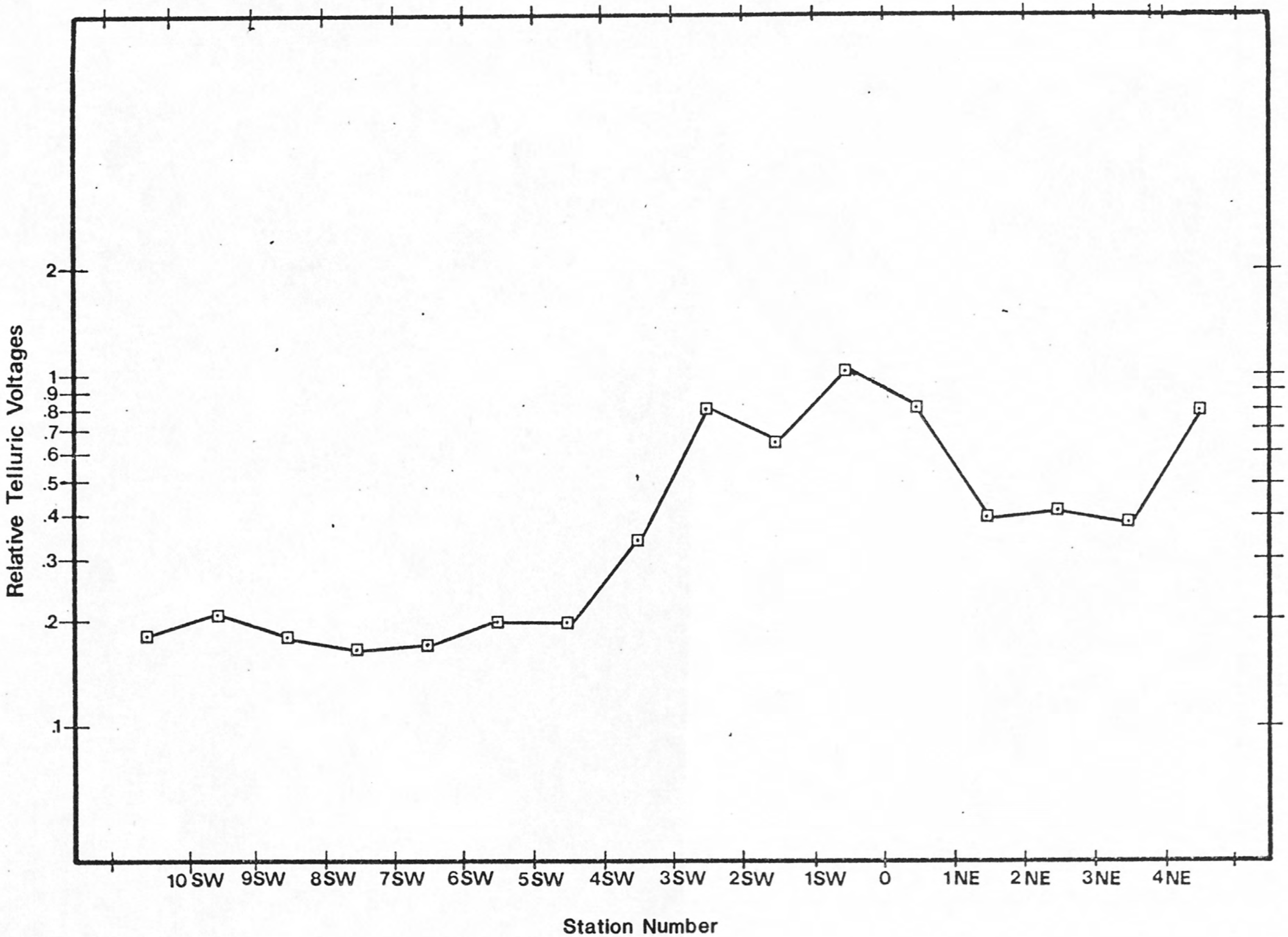

Fig. 6. E-field ratio telluric data for traverse 2 near the Big Maria Mountains, Riverside County, California. The telluric data is proportional to the square root of the apparent resistivity variation along the traverse.

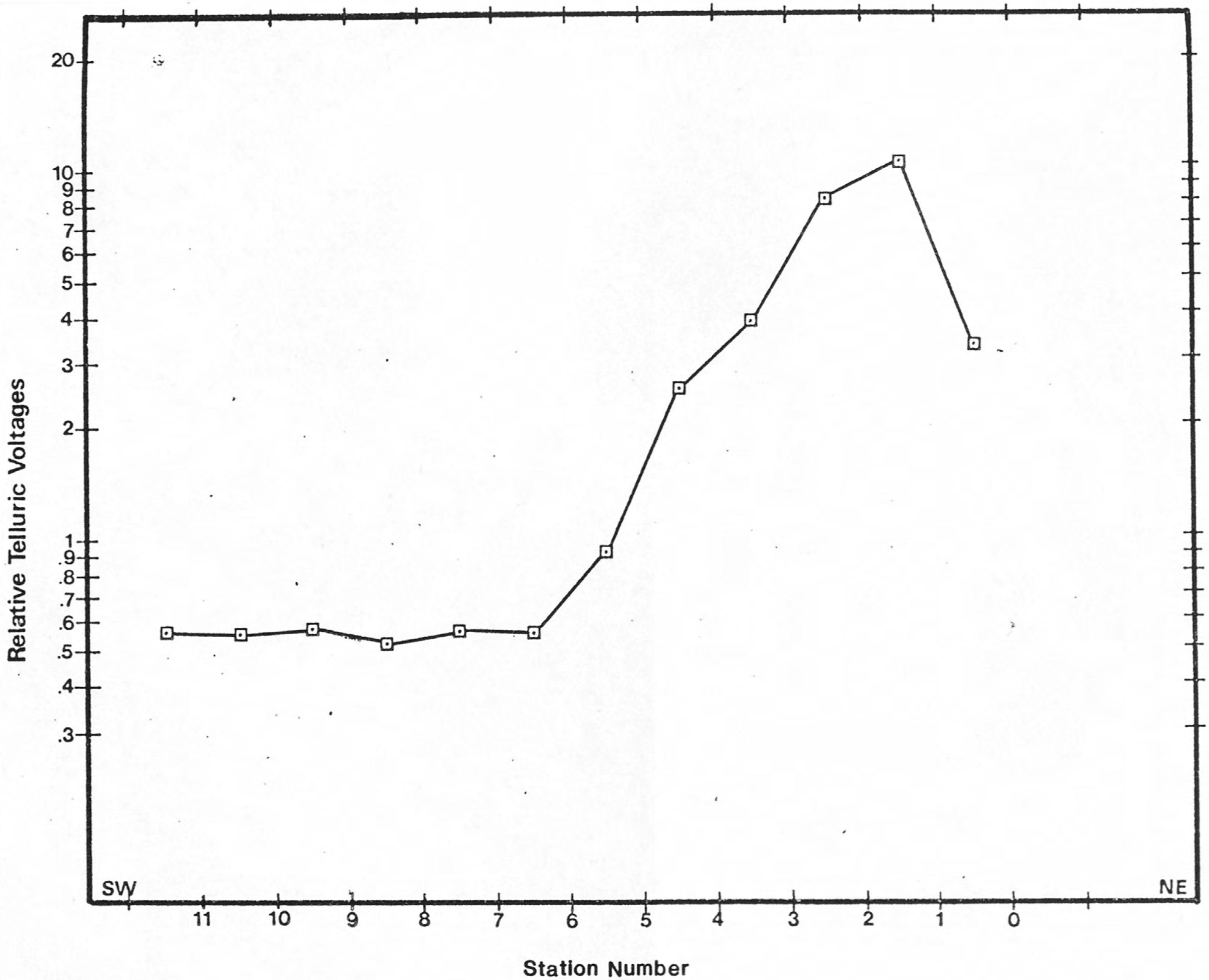

Fig. 7. E-field ratio telluric data for traverse 3 near the Big Maria Mountains, Riverside County, California. The telluric data is proportional to the square root of the apparent resistivity variation along the traverse.

dipole 1-2 to the minimum at dipole 6-7. The large drop is consistent with thickening of the alluvium probably on more than one fault between stations 1 and 6. The abrupt decrease in voltage on dipole 0-1 is related to the mapped fault, identified on both other traverses, which crosses this line near station 1. The major fault near station 3SW on traverse 2 probably crosses traverse 3 near station 5.

It is considered unlikely that the alluvial fill in the valley would have significant lateral variation in resistivity between lines 2 and 3. If this is correct then the differences between maximum and minimum values of resistivities on these two traverses would be due to increased thickness of alluvium on traverse 3 or about an order of magnitude increase in basement resistivity on the northeast end of traverse 3 relative to traverse 2. Thickening of the alluvium appears more probable and thus a scissors fault is suggested. If the range-front fault identified on traverses 2 and 3 is extended parallel to the mapped fault within the Big Maria Mountains, then it would cut traverse 1 near station 2 where a fault is suggested. The two principal faults identified in this survey are located on the map in fig. 1.

References

Beyer, J. H., 1977, Telluric and D.C. resistivity techniques applied to the geophysical investigation of Basin and Range geothermal systems: Univ. of Calif. Lawrence Berkeley Lab report LBL-6325.

Jennings, C. W., 1977, Geologic map of California: Calif. Div. of Mines and Geology, Sacramento Calif., scale 1:750,000.