Geothermal Resources Council, TRANSACTIONS Vol. 7, October 1983

APPLICATION AND INTERPRETATION OF MULTIPLE POLE-POLE RESISTIVITY SURVEY, MT. CAYLEY, B.C.

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ABSTRACT

In the Mt. Cayley area of southwestern British Columbia, the multiple pole-pole resistivity method has yielded data in terrain conditions which precluded continued use of conventional survey arrays.

An anomaly of potential geothermal significance has been found, providing an unambiguous explanation for earlier dipole-dipole array data, and outlining a specific target for further evaluation.

In the course of achieving measurements in the extreme terrain, a data set of substantial depth and utility was obtained, leading to the development of logical and statistical interpretation tools which stand alone, and enhance existing modelling and interpretation methods.

INTRODUCTION

The Cenozoic Garibaldi volcanic belt of southwestern British Columbia is being explored for geothermal potential at two sites, the Meager Creek geothermal project of B.C. Hydro, and at Mt. Cayley, 60 kilometres south of Meager Mountain.

At Mt. Cayley, a broad spectrum evaluation has been under way since 1979 by Energy, Mines and Resources Canada (Souther, 1980), including temperature gradient drilling, geochemistry, geologic mapping and resistivity surveys. A recent summary overview of the area given by Souther (1983) suggests that the combined results support the possible presence of a high temperature resource at Mt. Cayley.

Mt. Cayley was selected in 1982 for the first field evaluation of E-SCAN*, a multiple pole-pole electrical resistivity system designed for use in areas of extreme terrain or of geologic complexity (or both). The new method derives from research conducted by the author in 1977 and 1978 (Shore, 1978, Fairbank et al, 1979) in the Meager Creek geothermal area which defined the operational and data requirements for practical operation in rough terrain. The 1982 Mt. Cayley survey (Shore, 1983) was operated on behalf of Energy, Mines and Resources Canada.

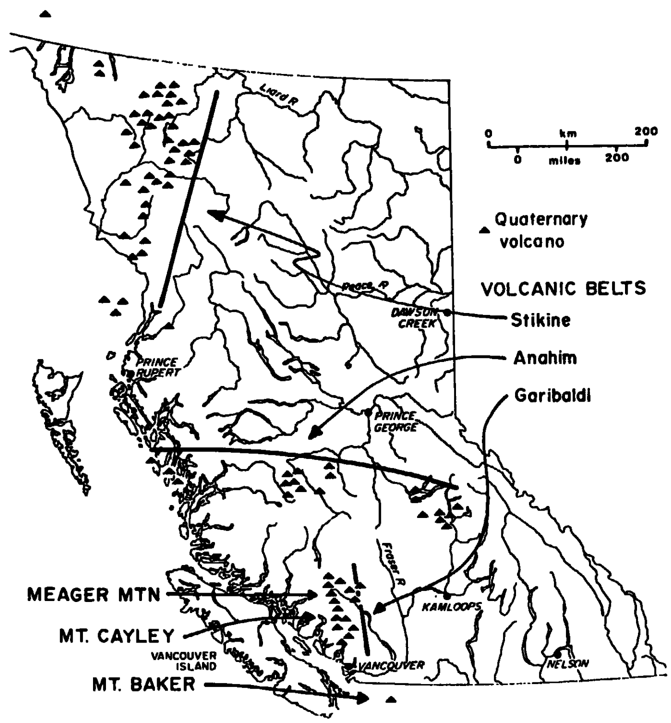

Figure 1 Map of British Columbia showing location of Mt. Cayley in the Garibaldi volcanic belt. The Garibaldi belt is a continuation of the U.S. High Cascades.

EXPLORATION CONDITIONS

The terrain around Mt. Cayley is very rugged, limiting severely the opportunity to lay out conventional resistivity arrays. A reconnaissance dipole-dipole resistivity survey through an area of interest in 1980 (Shore, 1980) used the only available linear route in that part of the prospect. A significant anomaly was detected, but it was not possible to obtain sufficient data to unambiguously define either the anomaly magnitude or its location relative to the survey line. It was anticipated that a multiple pole-pole survey would resolve both questions, and extend the exploration coverage into the more rugged terrain as well.

* T.M. Premier Geophysics Inc.

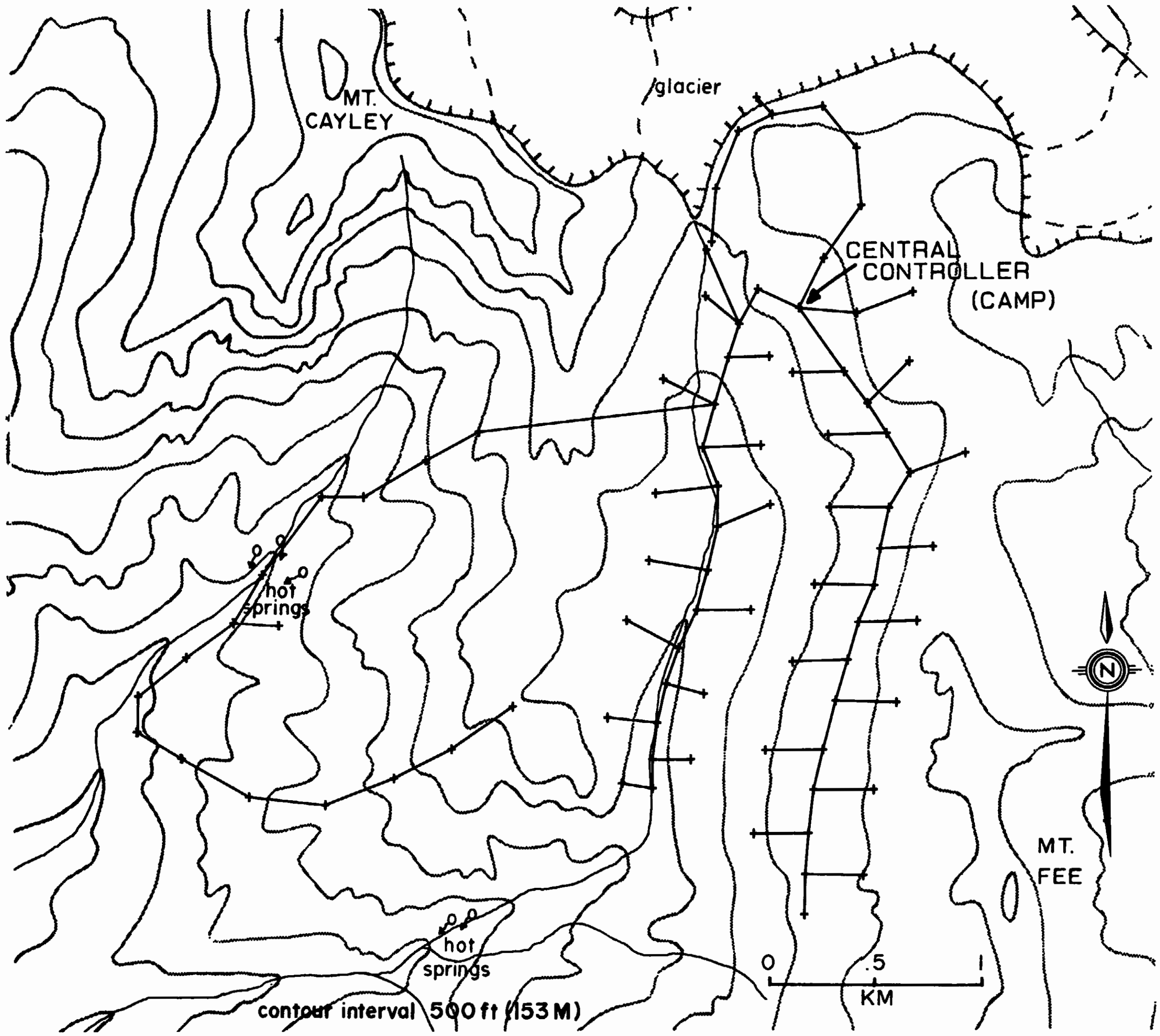

Figure 2 E-SCAN multiple pole-pole electrode array layout at Mt. Cayley. + indicates a potential electrode accessible through the network from the central controller. Remote-controlled switches are placed at points showing two or more wires leading from a potential electrode.

MULTIPLE POLE-POLE ARRAY

Even in the roughest terrain, it is usually possible for skilled crew workers to get to points on a proposed grid, provided a roundabout route is acceptable. Trailing the two-conductor communication and analog signal wire, the crew team installs remote-controlled switch boxes and electrodes in a best efforts approximation of grid coverage. In the Mt. Cayley grid, a helicopter and climbing gear were used occasionally, but most of the layout was achieved by foot, operating from a central campsite. Four days were required to set out the network, and two days were needed to remove it after operations were completed. "Infinite" (reference) electrodes were installed distant from the grid for both current and potential circuits.

Because no potential electrode movement is required for the balance of the operation, the data set increments rapidly, with up to 85 individual pole-pole measurements obtained by sampling the field established from each current input point. In the 2 1/2 days of measurement operations, 2288 pole-pole measurements were taken and recorded, using 36 current input electrode sites scattered throughout the east array area.

SURVEY RESULTS

The multiple pole-pole survey data provide an unambiguous low resistivity anomaly located west of the dipole-dipole coverage of 1980 (Figure 4). The area beneath and east of the dipole-dipole lines is shown to be resistive, at or near the nominal 1000

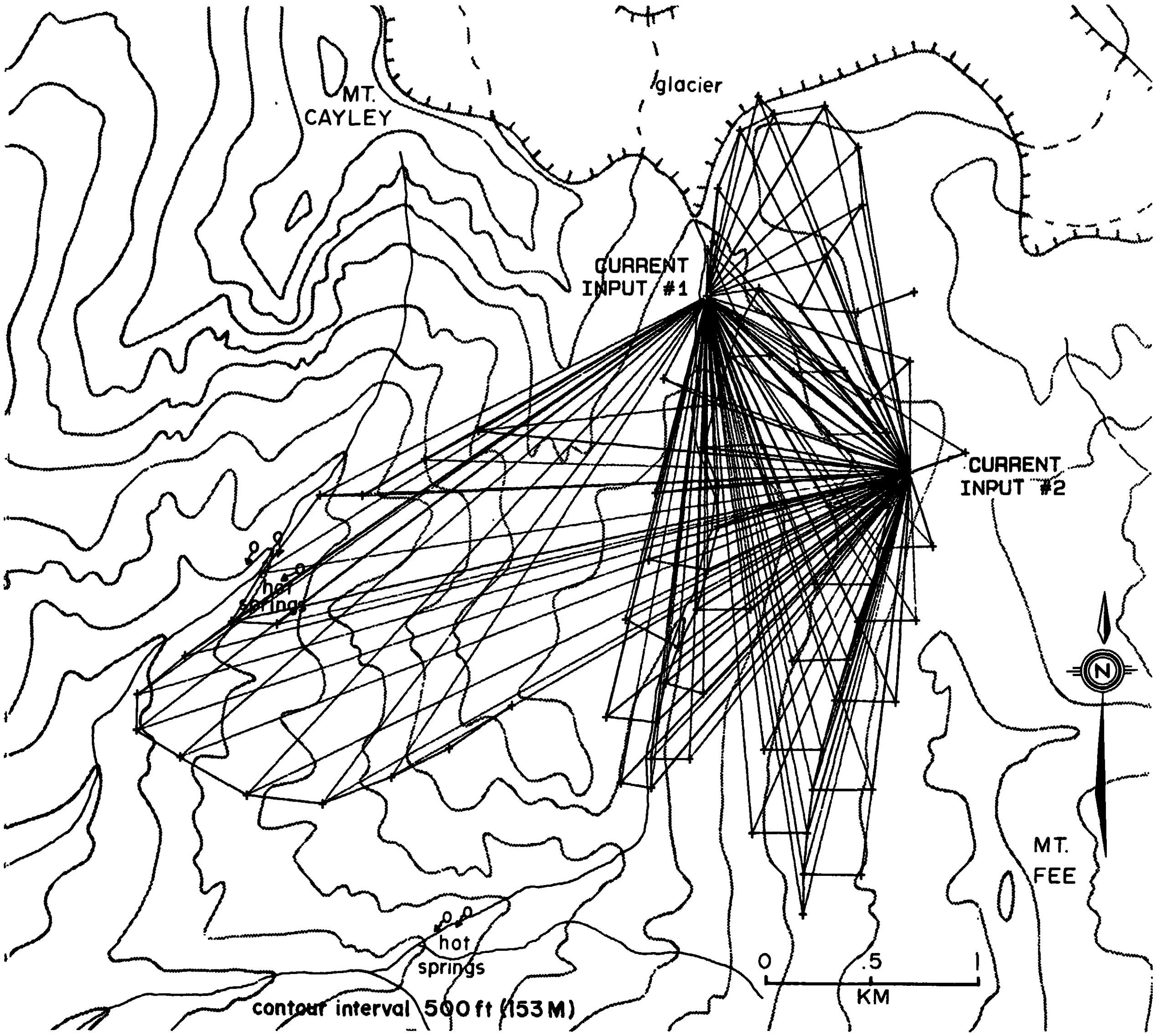

Figure 3 The rays connect current input sites to various potentials comprising individual pole-pole array measurements. Two of the 36 current input sites occupied during the survey are shown. The data set builds rapidly; above can be seen some pole-pole array measurements sampling the same volume of earth, but from varying azimuths. Other groups of data share azimuth, current source, array length (therefore sampling the same nominal volume of earth), the single variable of these groups being the differences in near-surface conditions at their potential electrodes. Single-variable subsets provide the basis for logical and statistical development and testing of detailed surface resistivity maps.

ohm metre regional background for crystalline basement rocks. The anomaly remains open to the west, but has north and south boundaries firmly identified within the present array area.

Although many long-spacing measurements were obtained from potential electrodes in the western array loop into Turbid Creek valley, circumstances in the field denied the opportunity to place current electrodes in that area. The consequent lack of shorter-spacing (0-1000 metres) data at this time prevents detailing of the western extent of the anomaly.

DATA SET CHARACTERISTICS

Several observations can be made about the multiple pole-pole data set:

1. Density. The data set is very dense, with much overlapping of data, but little actual redundancy.

2. Continuity. Because of the operational flexibility of the physical array setup, there is less likelihood of gaps in coverage caused by difficult terrain than is the case with conventional arrays.

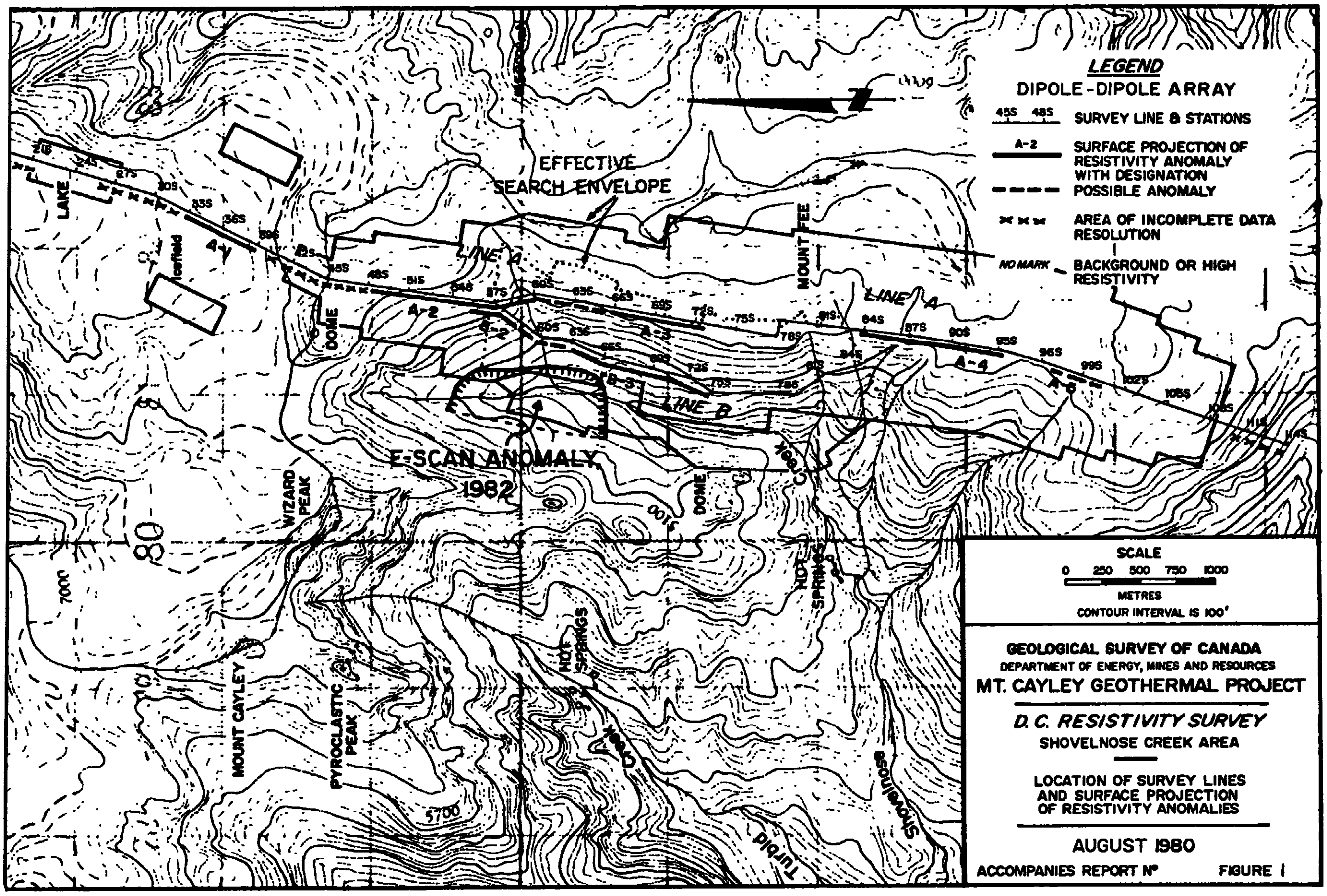

Figure 4 The 1982 multiple pole-pole anomaly is compared to the plan view of 1980 dipole-dipole results. The dipole-dipole reconnaissance line successfully identified the area of interest, but the limited data set could not provide an unambiguous causative model. The 1982 anomaly shows that the dipole-dipole arrays were influenced by a "side-look" to the west. The effective search radius noted in the drawing indicates the radial distance sampled from each line at its largest array separations. The suggestion of "double-peaking" in the above spatial pattern is supported in the pseudosection detail of the 1980 data, (Above figure after Shore, 1981)

3. Orientation. The data set is inherently multi-directional.

4. Element simplicity. Pole-pole data are the simplest of all resistivity array data, originating from only two electrodes within the active survey area. Other types of array data such as dipole-dipole can be constructed from pole-pole data within acceptable noise limits, but the converse is not true in practical terms.

These data set characteristics are used in combination for a number of interpretation processes involving logical tests, statistical tests, and conventional analysis of pole-pole and dipole-dipole pseudosections constructed from the raw data set.

The ability to assemble large numbers of data subsets in which measurements share common electrodes and other characteristics except for a single variable provides unique opportunities to develop and test earth models in the presence of geological or structural complexity.

For example, the location of the resistivity anomaly (Figure 4) was initially spotted from a simple plot of unfiltered field data (Figure 5), using pole-pole apparent resistivity values with a maximum nominal penetration of 300 metres. The eye is drawn immediately to the anomaly area, and equally important, the area surrounding the anomaly is seen to be resistive, near background levels. A "side look" of 1980 dipole-dipole array data is apparently indicated. This initial concept is supported throughout a series of overlapping and interlocking logical and statistical tests, leading to a conclusion that the near-surface (0 to 300 metres or so) resistivity distribution is indeed as indicated in Figure 5.

At no point in this testing has there been more than a single step from observed data; no assumptions have been required, and all aspects of the placement of model constraints have been tested logically and with regard to the laws of potential field behaviour. It is precisely because these methods deal in logical (1 or 0) tests, without overriding assumptions,

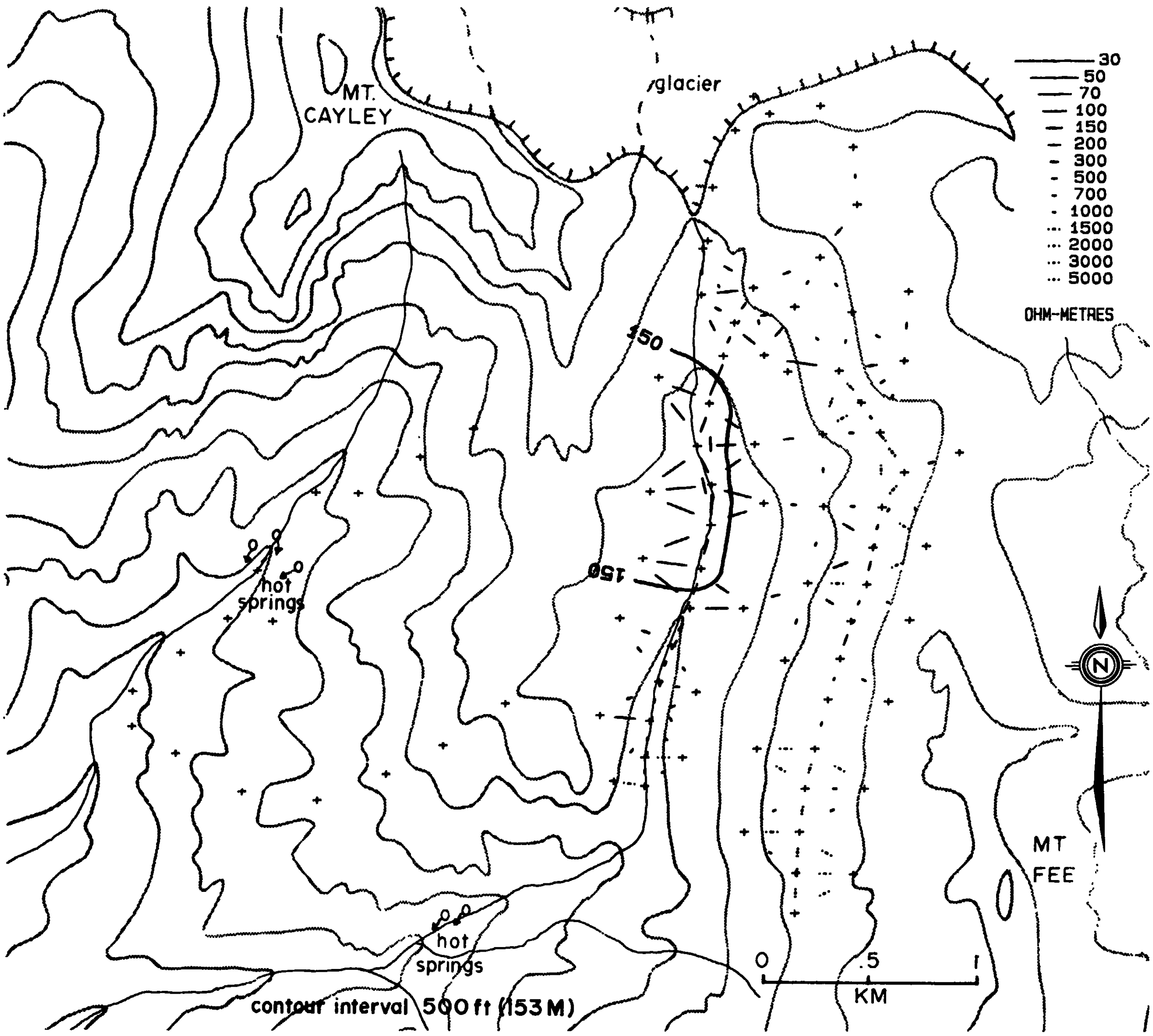

Figure 5 Plot of unfiltered pole-pole array apparent resistivity data, limited to 300 metres nominal penetration or less. The 185 data provide an immediate overview of upper earth resistivities in general. A logical deduction test applied to the data radiating from each electrode position determines whether the electrode is situated within a nominal resistivity unit, or near a lateral resistivity boundary or change. This and other single-variable subset tests provide high sensitivity to lateral variation, and help to generate documentation of near-surface resistivities near each electrode and to the outer edge of the array grid itself. This first-level description of near-surface resistivity distribution will be useful in evaluating true causes for deeper penetrating measurement data.

that this first-level data processing is amenable to both computer implementation, and to simple field evaluation with a pencil and short checklist.

The availability of first-level results (Figure 5) assists the worker in selecting vertical data sections for computer modelling of deeper structure. Obvious near-surface variation and other disruptive features can be avoided, and sections can be selected to best fit the assumptions demanded by the various one- and two-dimensional modelling routines.

As an example, experience and field sense may have suggested that conducting a two-dimensional modelling evaluation of the 1980 dipole-dipole data would yield poor or ambiguous results at best, due to a lack of evidence for the necessary assumption of a two-dimensional earth. No such evaluation was undertaken, and the 1982 results (Figure 4) show that any model based on a two-dimensional earth assumption would indeed have been incorrect.

The 1982 multiple pole-pole first-level results (Figure 5) show that a reasonable approximation of a two dimensional earth could be assumed for a section running east from the middle of the anomaly. This is by no means a perfect two-dimensional case, but it is a reasonable one, with the nature of its limitations (the anomaly does not extend as far north and south as we would like) clearly evident for consideration in evaluating the results.

Data originating between electrodes lying along the proposed section can be formatted as a pole-pole or dipole-dipole pseudosection, to suit the worker's preferred modelling routine.

A two-dimensional model might be expected to provide information to determine:

1. whether the anomaly is a superficial cap of weathered volcanics, or whether it extends to depth in the crystalline basement,
2. the nature (dip) of the eastern boundary of such a deep structure,
3. indications of true resistivity values within the anomaly,
4. possibilities for a model which extends various distances to the west being compatible with present data.

These are questions which have importance in determining if and how the anomaly is to be further delineated or drill tested. In this rugged terrain, guidance of directional drilling from the nearest accessible point will demand the fullest possible description of the location of the target.

SUMMARY

The multiple pole-pole method has yielded data in terrain conditions which precluded continued use of conventional survey arrays.

An anomaly of potential geothermal significance has been found, providing an unambiguous explanation for 1980 dipole-dipole array data, and providing a specific target for further evaluation.

In the course of achieving measurements in the rough terrain areas, a data set of substantial depth and utility was obtained, leading to the development of logical and statistical tools which enhance existing modelling and interpretation methods.

ACKNOWLEDGMENTS

The author is grateful to Messrs. Nevin, Sadlier-Brown and Goodbrand, and to B.C.Hydro and Energy, Mines and Resources Canada (EMR) for supporting initial experimentation during 1977 and 1978 exploration programs at Meager Creek geothermal area. Special thanks go to Dr. Jack Souther of the Geological Survey of Canada for his early and continuing support and encouragement, and to the Geological Survey (EMR) for hardware development funding assistance in 1981-82.

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