Report on E-SCAN multiple pole-pole resistivity survey
at Mt. Cayley, British Columbia

by

Greg A. Shore

June 1, 1983

Survey conducted in August 1982 by Premier Geophysics Inc., Richmond, B.C.
under contract serial # OSB82-00218: Geological Survey of Canada, client;
Dr. J.G. Souther, scientific authority; Supply and Services Canada, administrators.

PREMIER GEOPHYSICS INC.

#4 - 11220 VOYAGEUR WAY, RICHMOND, B.C., CANADA V6X 3E1 • (604) 270-6885

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1.0 Summary of results

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

Additional data analysis and subsequent continuation of field resistivity coverage are recommended to define the vertical geometry and western extent of the anomalous zone.

2.0 Introduction

The Mt. Cayley area of southwestern B.C. has been the subject of investigations by the Geological Survey of Canada to determine the potential for geothermal energy development. Since 1979, geological mapping, geochemical studies, thermal gradient drilling and geophysical surveys have been undertaken. In 1980, a reconnaisssance resistivity survey through a selected area near Mt. Cayley (Shore, 1981) produced a resistivity anomaly in upper Shovelnose Creek valley.

In August of 1982, Premier Geophysics Inc. of Vancouver, B.C. undertook a program of E-SCAN multiple pole-pole resistivity survey in the same area, covering the route occupied by the 1980 survey line and extending exploration coverage into the rugged terrain nearby.

The survey was conducted under contract serial # OSB82-00218, for the Geological Survey of Canada, client; Dr. J.G. Souther, Scientific Authority; Supply and Services Canada, administrators.

This survey marked the first field exploration use of E-SCAN multiple pole-pole resistivity hardware and methods. A substantial amount of the field operational time was occupied in conducting hardware system performance checks, and verification of analog signal performance. The author is pleased to acknowledge the funding assistance of Energy, Mines and Resources in the construction of the present system hardware, and the support and encouragement of Dr. J. G. Souther of the Geological Survey of Canada in the development of this exploration system.

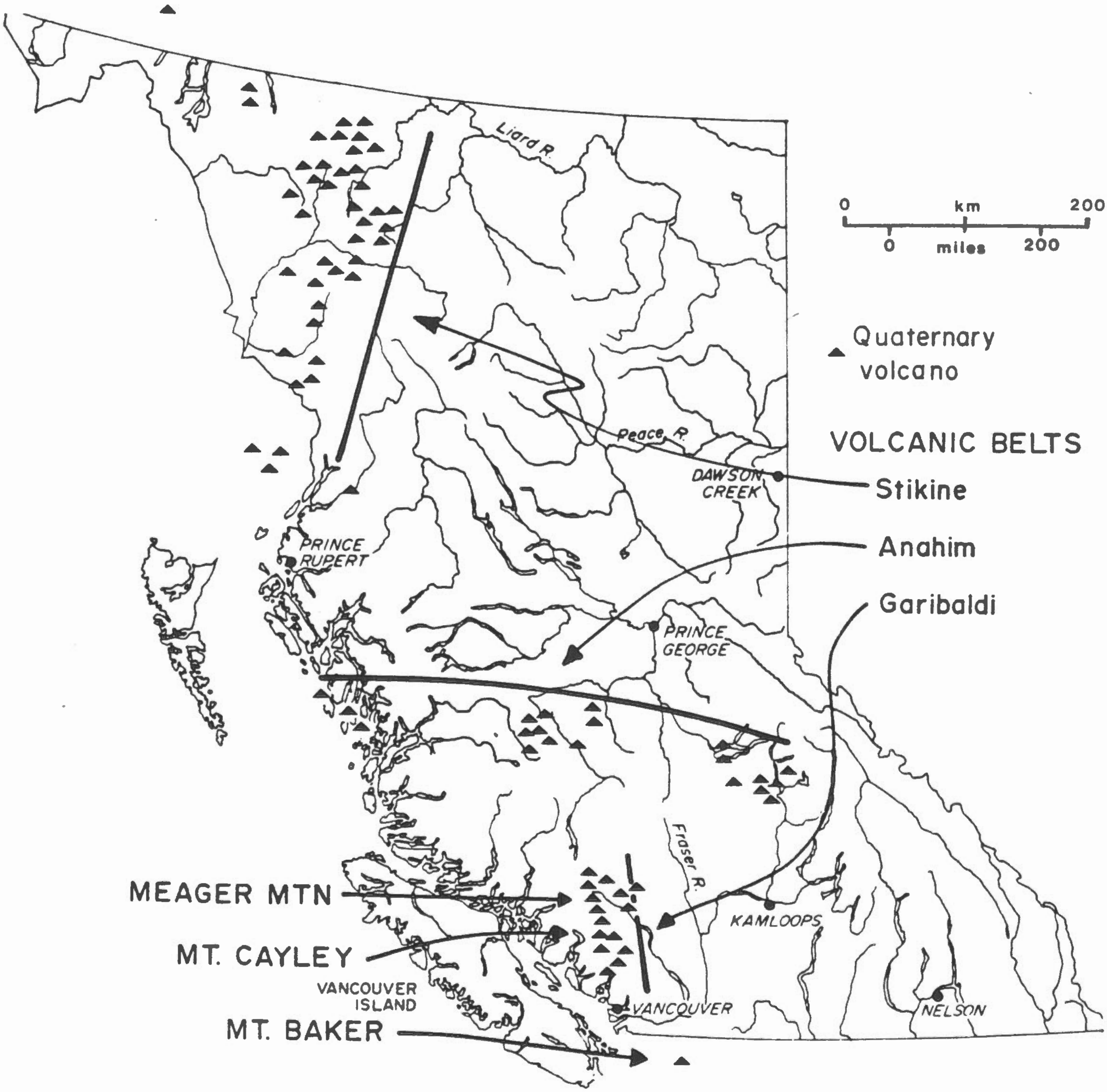

Figure 1 Location of Mt. Cayley in the Garibaldi volcanic belt.

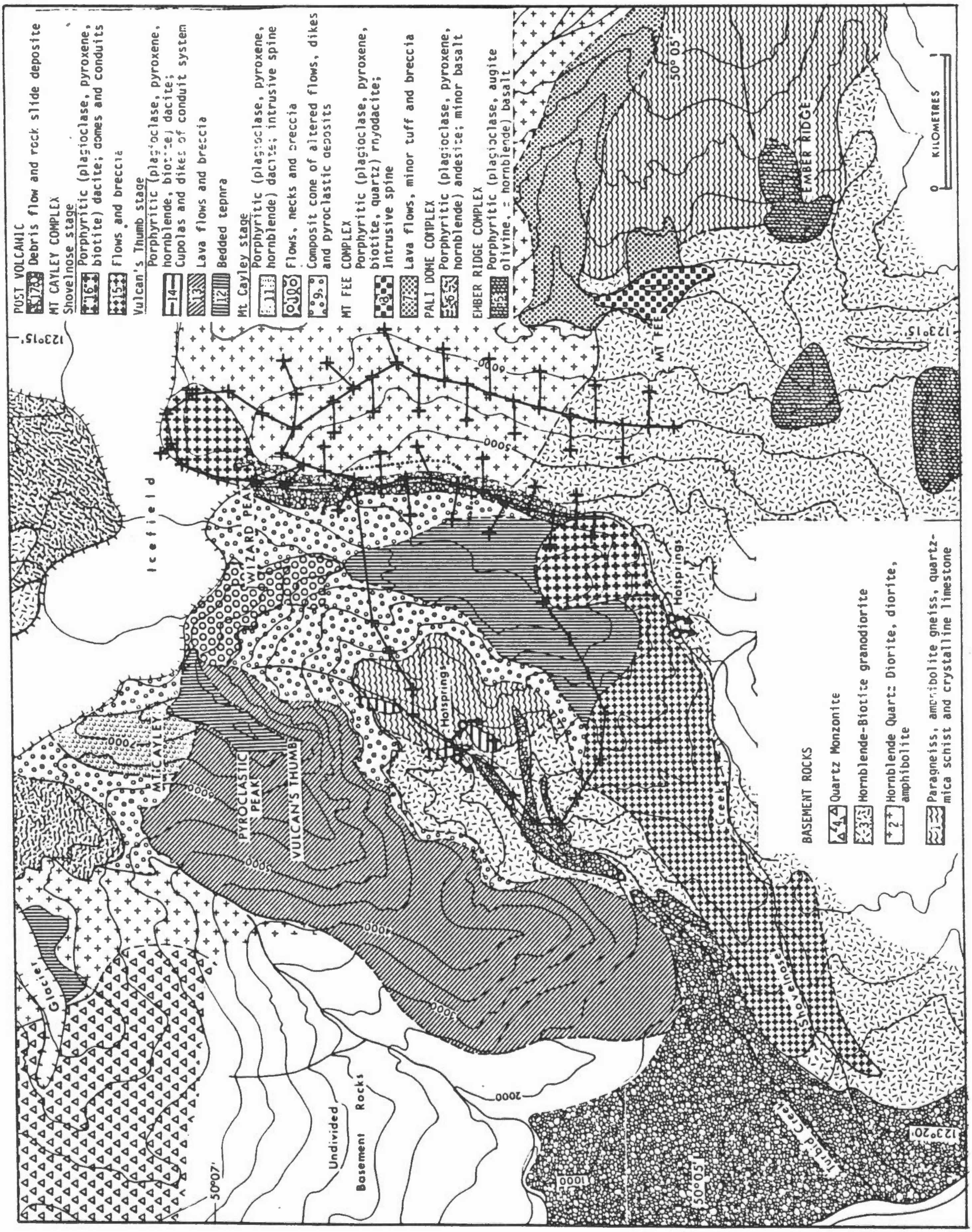

Figure 2 Geology of the Mt. Cayley area (from Souther, 1980), showing E-SCAN array layout and 1982 anomaly area.

150 ohm-metre contour: ....

3.0 Geology

3.1 Central Garibaldi volcanic belt

The vulcanism of the central Garibaldi belt (figure 1) is described by Souther (1980). Mt. Cayley is a composite volcano, one of seven eruptive complexes extending south from Meager Mountain. Souther observes, "The north-northwesterly trend of the belt reflects young structures in the underlying Mesozoic to Tertiary plutonic and metamorphic rocks of the Coast Plutonic Complex. Hydrothermal alteration associated with these structures plus the discovery of thermal springs near Mt. Cayley suggest that reservoirs of residual heat, similar to those being developed at Meager Mountain, may also be present in the central Garibaldi belt."

3.2 Survey area geology

Detailed mapping of the Mt. Cayley area by Souther (1980) is shown in figure 2. Most of the 1982 resistivity survey area is underlain by granitic basement rocks. A zone of metamorphic rocks occurs in upper Turbid Creek; its eastern contact with granitic rocks is obscured by a ridge of volcanics, principally tephra and older cone remnants.

The location of the 1982 survey array is shown on the geology map. The intensive array coverage is in the Shovelnose Creek drainage, where anomalous (but ambiguous) resistivity results were obtained in 1980. The electrode array encircles the northern of two young dacite domes (unit 16), and approaches the east side of the southern one. A series of electrodes placed in the ridge of volcanics west of Shovelnose Creek were installed to test its resistivity signature, in anticipation of its possible responsibility for the 1980 anomaly pattern. The quartz diorite and granodiorite basement prevalent in this area is heavily sampled by this array.

In Turbid Creek an array loop passes over the volcanic ridge, through the metamorphic unit and into granodiorite before looping back up on volcanics toward the lower dacite dome. Intended high density sampling of this area was not accomplished, however.

4.0 1980 dipole-dipole resistivity results

A reconnaissance dipole-dipole resistivity line was conducted through the upper Shovenose Creek drainage area in 1980 (figure 5). The significant anomaly system (A-2, A-3, B-2, B-3) clearly marked the surrounding area as containing a zone of very low resistivity. Even with the establishment of detail line B, it was not possible to obtain sufficient data to unambiguously define either the magnitude of the anomalous zone, or its location relative to the survey line. The main dipole-dipole line used the only available linear and accessible route through the area; even line B was established by running wires downslope from line A to each station, and switching wires along line A to obtain dipole data along the route of line B.

It was anticipated that a multiple pole-pole survey could operate effectively in this terrain, and provide data for the unambiguous identification of the anomaly responsible for the 1980 survey results.

5.0 E-SCAN multiple pole-pole array resistivity survey

5.1 Principle of operation

Where steep or irregular terrain prevents the use of conventional dipole-dipole or other arrays, a multiple pole-pole array can usually be established. Even in the roughest terrain, skilled crew workers can get to most points on a proposed grid, provided that a roundabout access route is acceptable, and that time is available for safe progress. Trailing a two-conductor communication and analog signal wire, the crew teams installs remote controlled switch boxes and electrodes in a best-efforts approximation of the proposed grid (figure 3). Each box is capable of being independently instructed by the central controller to hook up an electrode to the wire, completing a signal path from the electrode back to the resistivity receiver circuitry at the controller. During a period of current waveform transmission from a current input site (figure 4), the potential electrodes in the network are connected one at a time to allow individual pole-pole measurements to be made. Reference (infinite) electrodes for both current and potential circuits are located in fixed positions well away from the survey area. For the duration of the entire survey operation, the only electrode which must be moved about is the current input electrode. From each current input site, pole-pole measurements equal in number to the number of potential electrodes in the network can be measured.

Results are obtained rapidly, at about 3 per minute during scanning of potential electrodes as current is transmitted. At Mt. Cayley, a total of 2288 resistivity measurements were obtained and stored in a 2 1/2 day measurement period.

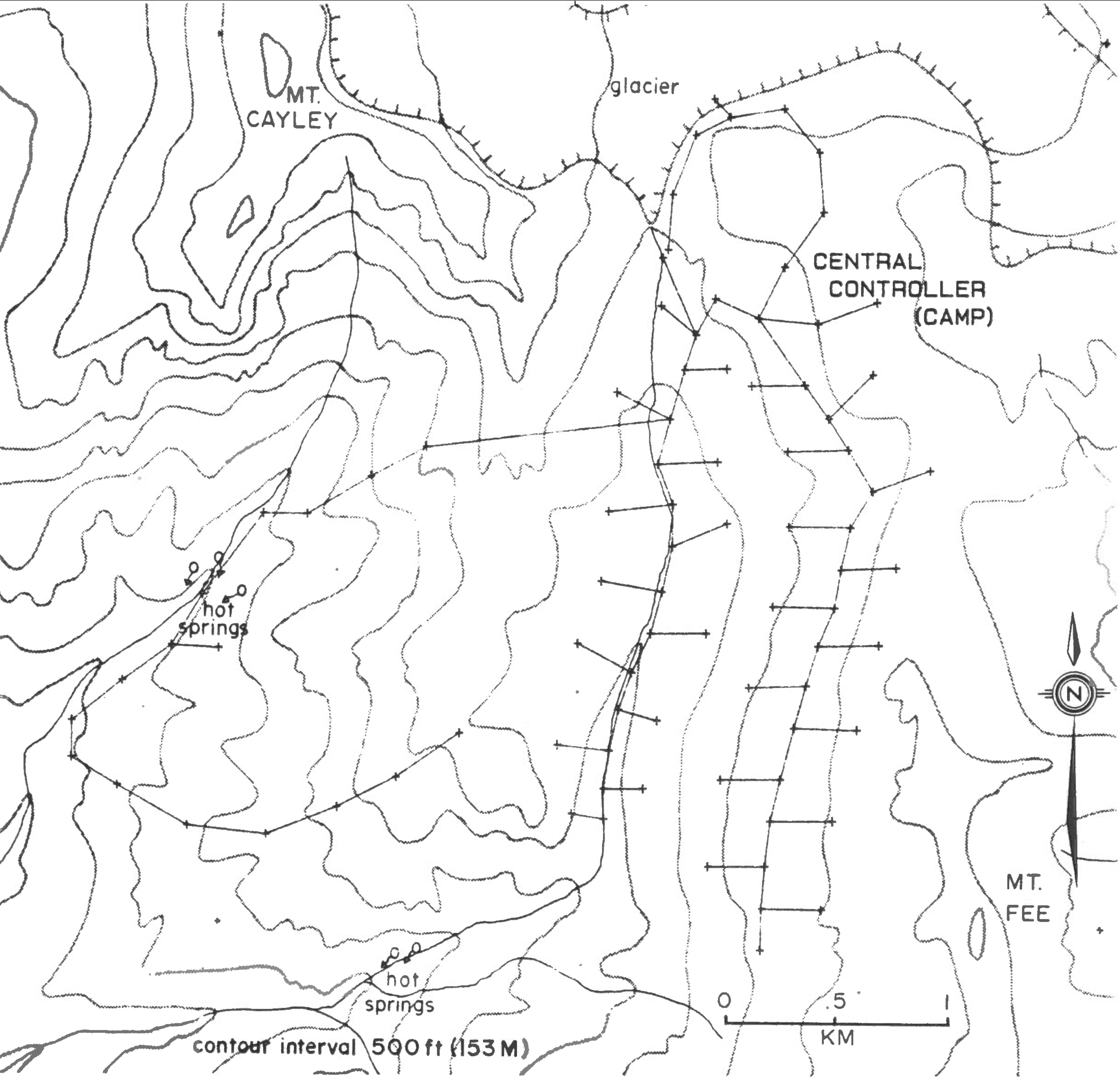

Figure 3 E-SCAN multiple pole-pole electrode layout. + indicates a potential electrode accessible through the network from the central controller at the camp.

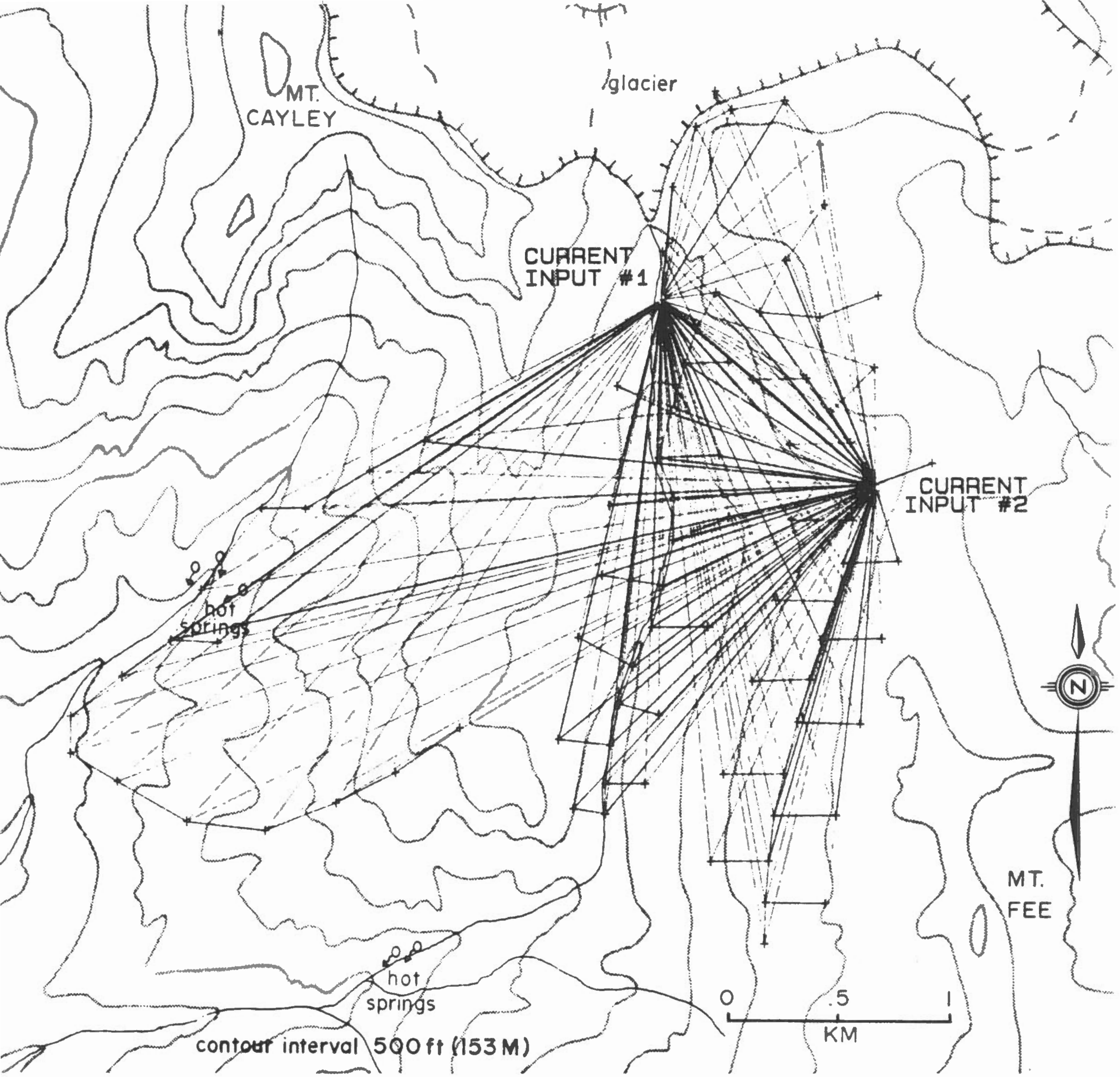

Figure 4 The rays connect current input sites to various potentials comprising individual pole-pole array measurements. Rays from two of the 36 current input sites occupied during the survey are shown.

5.2 E-SCAN data set characteristics

Several observations can be made about the E-SCAN 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 procedure and the ability to measure pole-pole array segments across impassible barriers or terrain, there is a high degree of spatial continuity to data set coverage.

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

4. Data element simplicity: Pole-pole data are the simplest of all resistivity array data. Other types of array data such as dipole-dipole can be constructed directly from pole-pole data elements within acceptable noise limits; 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 pseudo-sections constructed from the raw data set.

The ability to assemble large numbers of data subsets in which measurements vary only in a single characteristic provides unique opportunities to develop and test earth models in the presence of geological or structural complexity. Sensitivity to vertical resistivity boundaries is particularly good with these methods. When the near-surface resistivity distribution is completely mapped, the electrode source conditions for deeper measurement arrays and whole constructed pseudo-sections can be evaluated prior to selection of data for deep modelling. Analysis or modelling assumptions can be checked for compliance of the proposed data set; sections best accomodating such assumptions will obviously provide the most useful results.

From the present knowledge of upper 300 metre resistivity distribution throughout the Shovelnose Creek watershed, it is apparent that an attempt to model the source of the 1980 dipole-dipole data in two dimensions (or in one dimension) would yield either no acceptable result, or a misleading coincidental fit to the data. The earth under the dipole line is clearly neither two dimensional nor one dimensional in terms of position of the anomaly source material. From the contours of figure 6, however, it can be seen that a reasonable approximation of a two dimensional earth exists for a section east from the centre of the anomaly. It is not ideal, in that the anomaly does not extend to infinity to the north and south, but it is close enough to use as a good starting point for modelling.

6.0 Survey results and interpretation

6.1 Shovelnose Creek area

A single low resistivity anomaly has been identified, lying west of Shovelnose Creek about halfway between the two young dacite domes (figures 2, 5 and 6). It contains apparent resistivities of less than 70 ohm-metres, and lies within granitic basement rocks of normal background resistivity of 700 to several thousand ohm-metres. The rocks of the overlying volcanic ridge are not suspected of causing the anomaly directly, since array testing of the same ridge materials north and south of the anomaly reveal 200 to 400 ohm-metre signatures. The overlying volcanics may have been altered in the area of the anomaly, but such alteration would probably originate from beneath, implying a basement hydrothermal regime.

The anomaly is 1 kilometre in north-south extent, the array data positively indicating these limits. Its westerly extent is unknown at present, but the intensity of the available anomalous measurements suggests that the presently defined width of a few hundred metres is likely to continue under the volcanic cover to the west. Until additional direct resistivity testing is done over a westward projection, the full extent and conductivity of the anomaly will not be known. Modelling of existing resistivity results could provide some indications of possible extent, both vertical and westward lateral.

The metamorphic unit mapped in upper Turbid Creek contacts the granitic basement under the ridge volcanics somewhere west of Shovelnose Creek. Since its resistivity signature is not known, this unit remains a possible candidate for a non-thermal cause of the anomaly.

Elsewhere in the Shovelnose Creek drainage area, high resistivities prevail. Testing of both young dacite dome areas yields no indication of anomalous conductivity. The expanse of granitic basement on the east side of Shovelnose Creek shows typical signatures of 700 to several thousand ohm-metres.

The 1980 dipole-dipole results are fully explained by the single anomaly west of Shovelnose Creek (Figure 5). Prior to the unambiguous establishment of the anomaly character and location by the 1982 survey, several possible models could be proposed, involving one or more conductors of various intensities and geometries, located anywhere within the "effective search envelope" beside or below the line. The resolution of the location of the anomaly confirms the utility of dipole-dipole array reconnaissance where it can be applied, in that a significant anomaly was indeed noted, and an anomaly cause has been confirmed within the "effective search envelope". The ambiguity inherent in single-line dipole-dipole results is familiar and well-understood; it is an acceptable cost encountered in the obtaining of the rapid, valley-wide sweeps provided by dipole-dipole reconnaissance. The demonstrated ability of multiple pole-pole array data to resolve the details of anomalies picked up in dipole-dipole reconnaissance suggests that the two approaches should be considered as complementary.

The 1980 dipole-dipole pseudosection data shows a "double-peak" pattern typical of the response caused by the passing of large-array dipoles near a smaller size anomalous zone. The zone is off to one side,- the array is said to be "side-looking", providing a response generally indistinguishable from a deep anomaly response from under the line.

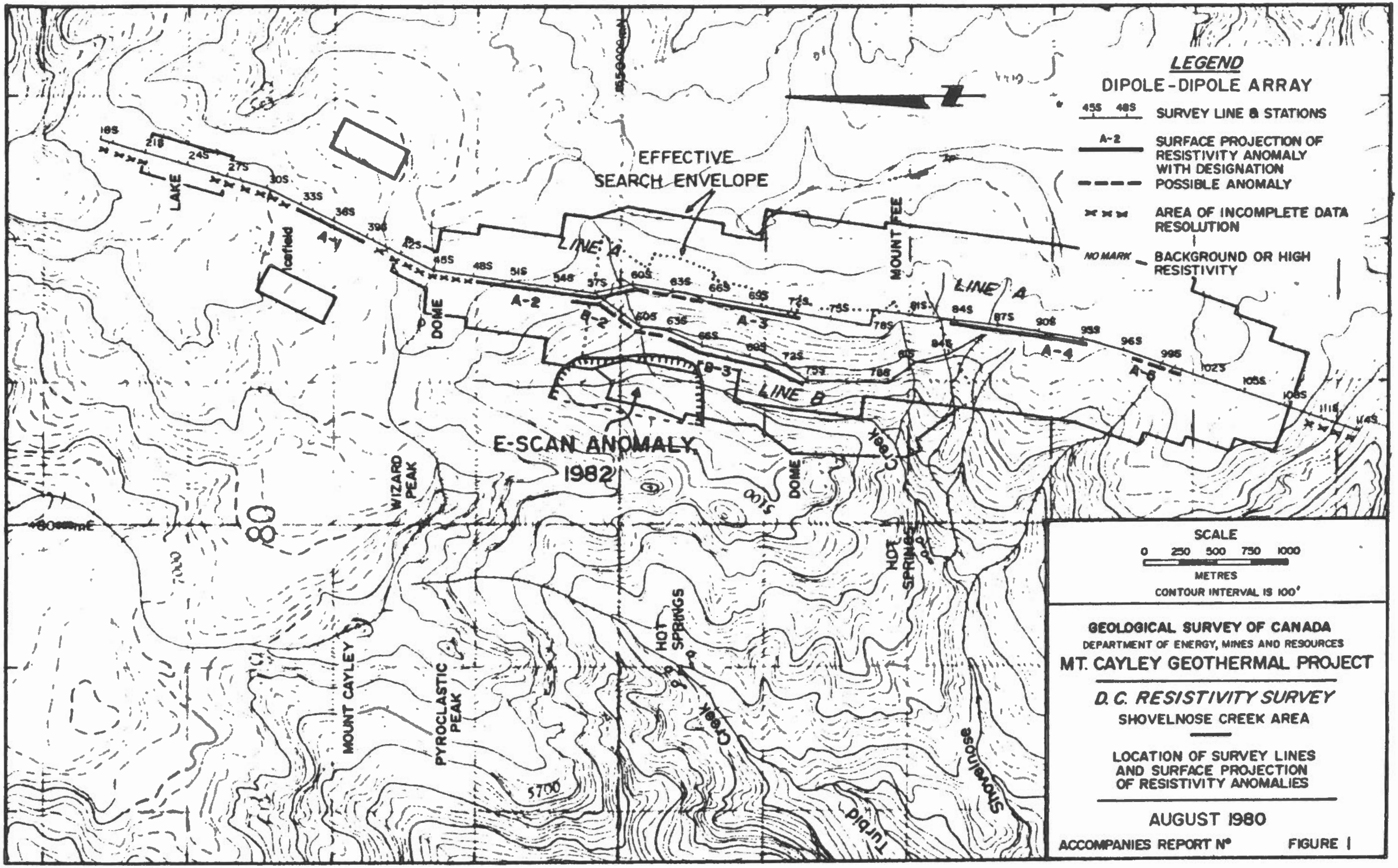

Figure 5 Location of E-SCAN anomaly relative to 1980 dipole-dipole lines and results. (figure after Shore, 1981)

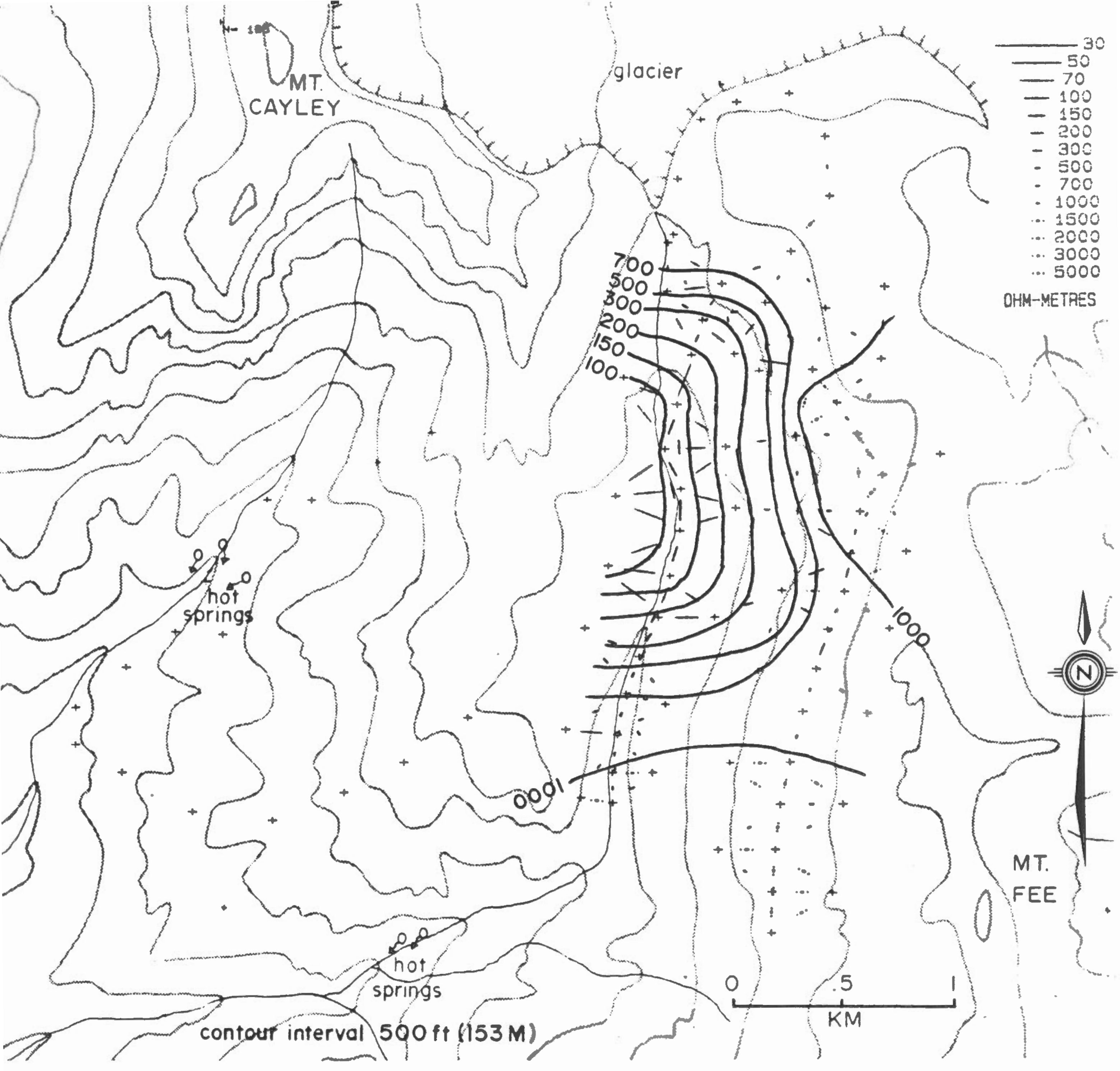

Figure 6 Apparent resistivity contours derived from 0-300 metres nominal penetration data only. The 150 ohm-metre contour is considered to be the conductive unit boundary. The plot marks are inversely proportional to apparent resistivity, are plotted at the mid-point between the electrode pair responsible for the measurement, and indicate the azimuth of the pole-pole array orientation.

6.2 Turbid Creek area

The lack of short-spacing resistivity data from Turbid Creek area precludes meaningful analysis of resistivity distributions in the area. The single-variable subset analysis of long-spacing data originating from electrodes spanning the granodiorite-metamorphic contact in Turbid Creek suggests that the metamorphic unit resistivity is only slightly lower than that of the adjacent granodiorite. This does not resolve anything, however, unless it can be assumed that the granodiorite is non-anomalous and of high (typical) resistivity. Since the local granodiorite has not been specifically sampled, and since there are occurrences of intense fracturing, fracture alteration and production of warm brines from fractures in the area, no assumptions of normality should be made for the area.

The failure to obtain detailed data from Turbid Creek was not due to physical inability to do so, but rather other factors of time, cost and air logistics. Resolution of the westward extent of the anomaly and of the resistivity character of the upper Turbid Creek drainage would be facilitated by proper 300 metre grid spacing multiple pole-pole survey, operated from a camp established in the area.

7.0 Conclusions and recommendations

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

The Shovelnose Creek area data set contains array elements which can be used for the construction of vertical data pseudosections along various azimuths through the area. It is recommended that an evaluation be made of the possibility of conducting two-dimensional modelling on a data section extending eastward from the centre of the anomaly. The information to be tested for is as follows:

a. examine the compatibility of the available data with three possible anomaly geometries:
   1. conductive volcanic cover only
   2. basement conductor, extending to depth
   3. combination of above.

b. while testing for (a), determine possibility of various westward extensions to the present anomaly outline.

c. depending on (a) and (b), note the range of permissible internal true resistivities, and possible dip angles on any eastward boundary indicated at depth.

Subject to information available in the above modelling exercises, an extension of 300 metre grid spacing throughout Turbid Creek from its upper accessible limit to lower outwash area should be conducted to investigate the following specific aspects:

a. westward extension and nature of the present resistivity anomaly

b. measurement of metamorphic rock resistivity signature

c. detailed coverage of the intensive fracture/alteration and hot spring area of upper Turbid Creek

d. identification and description of any outflow plume below the above-noted areas.

Respectfully submitted,

Greg A. Shore

June 1, 1983

References cited

Shore, Greg A.,1981, Report on resistivity survey in the vicinity of Mt. Cayley: Geological Survey of Canada open file.

Souther, J.G., 1980, Geothermal reconnaissance in the central Garibaldi belt, British Columbia: in Current Research, Part A, Geological Survey of Canada, paper 80-1A, p. 1-11.

APPENDIX

Data plots, figures 7 through 12.

The plots of data show a line marking the nominal plot position of each pole-pole array measurement, at the mid-point between the two electrodes from which the reading was derived. A straightedge placed on the line will pass through the electrodes, located at a separation equal to 4/3 of the nominal measurement penetration. For example, the electrodes responsible for a reading on the 300-500 metre nominal penetration plot (figure 8) will bracket the plotted line at a separation of 4/3x300 to 4/3x500 scale metres.

The line length is inversely proportional to resistivity value; the plot scale shows the length or type of line for a range of values.

The distance separating the electrodes may not always appear to match the plot depth constraints. This is because the separations and nominal depth penetrations have been calculated based on local slope angles, while these plots are flat plans which artificially compress slope distances. The length of the lines indicating resistivity are however calculated in the plane of the paper and may be digitized directly.

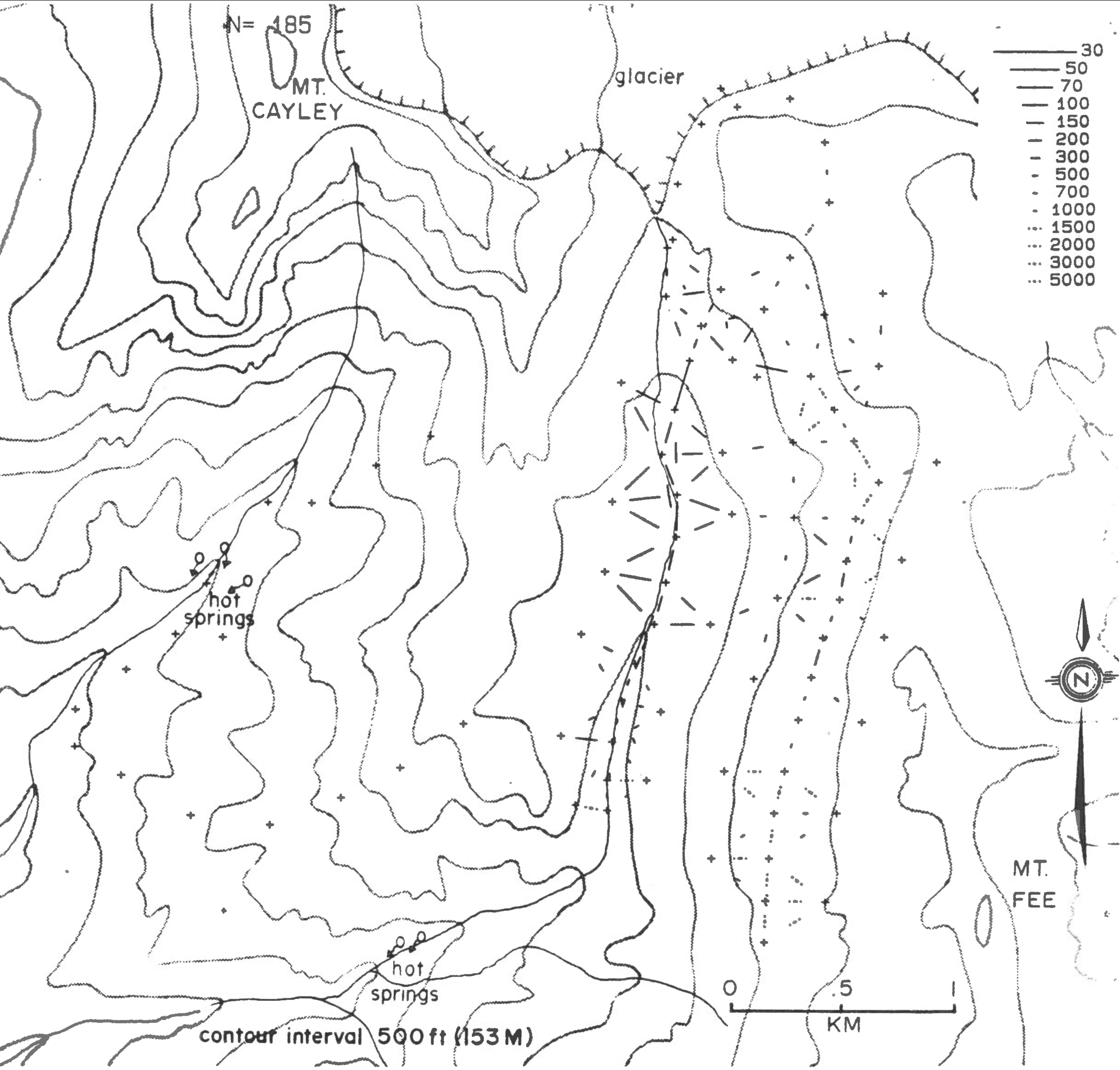

Figure 7 Apparent resistivity data, pole-pole array, nominal penetration of 0-300 metres. (P1-C1 separation 0-400 metres)

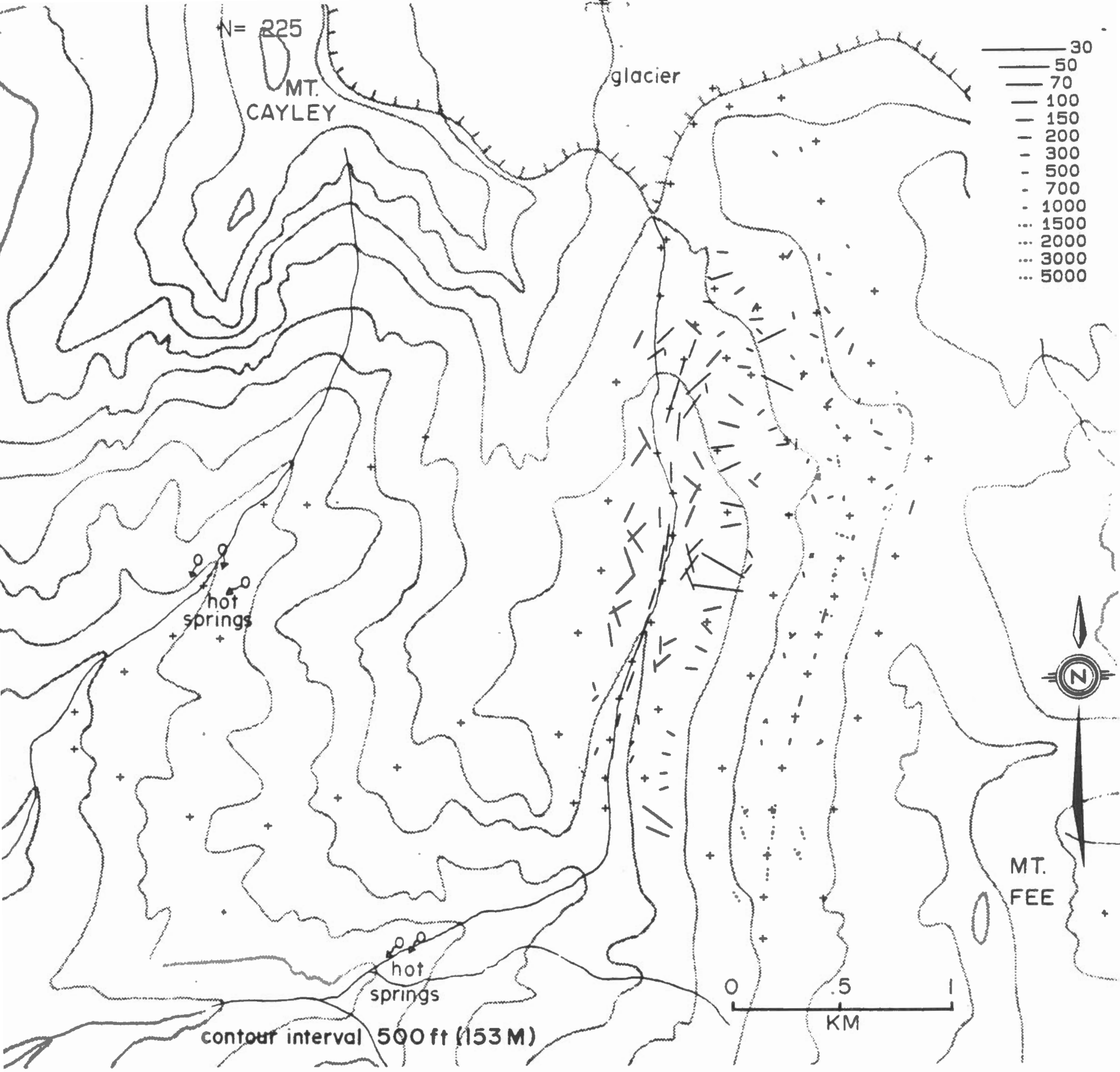

Figure 8 Apparent resistivity data, pole-pole array, nominal penetration of 300-500 metres (P1-C1 separation 400-666 metres)

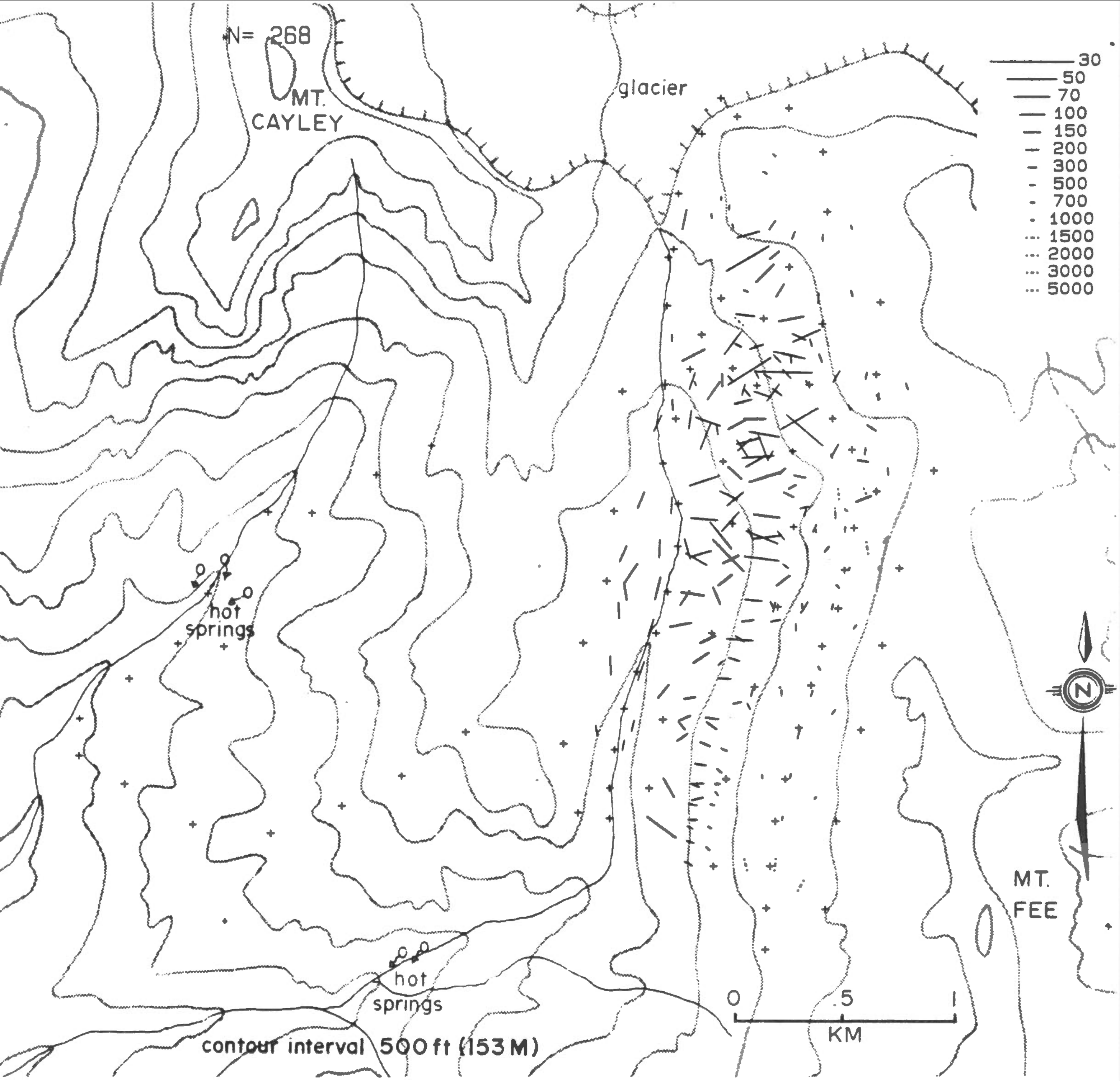

Figure 9 Apparent resistivity data, pole-pole array, nominal penetration of 500-700 metres (P1-C1 separation 666-933 metres)

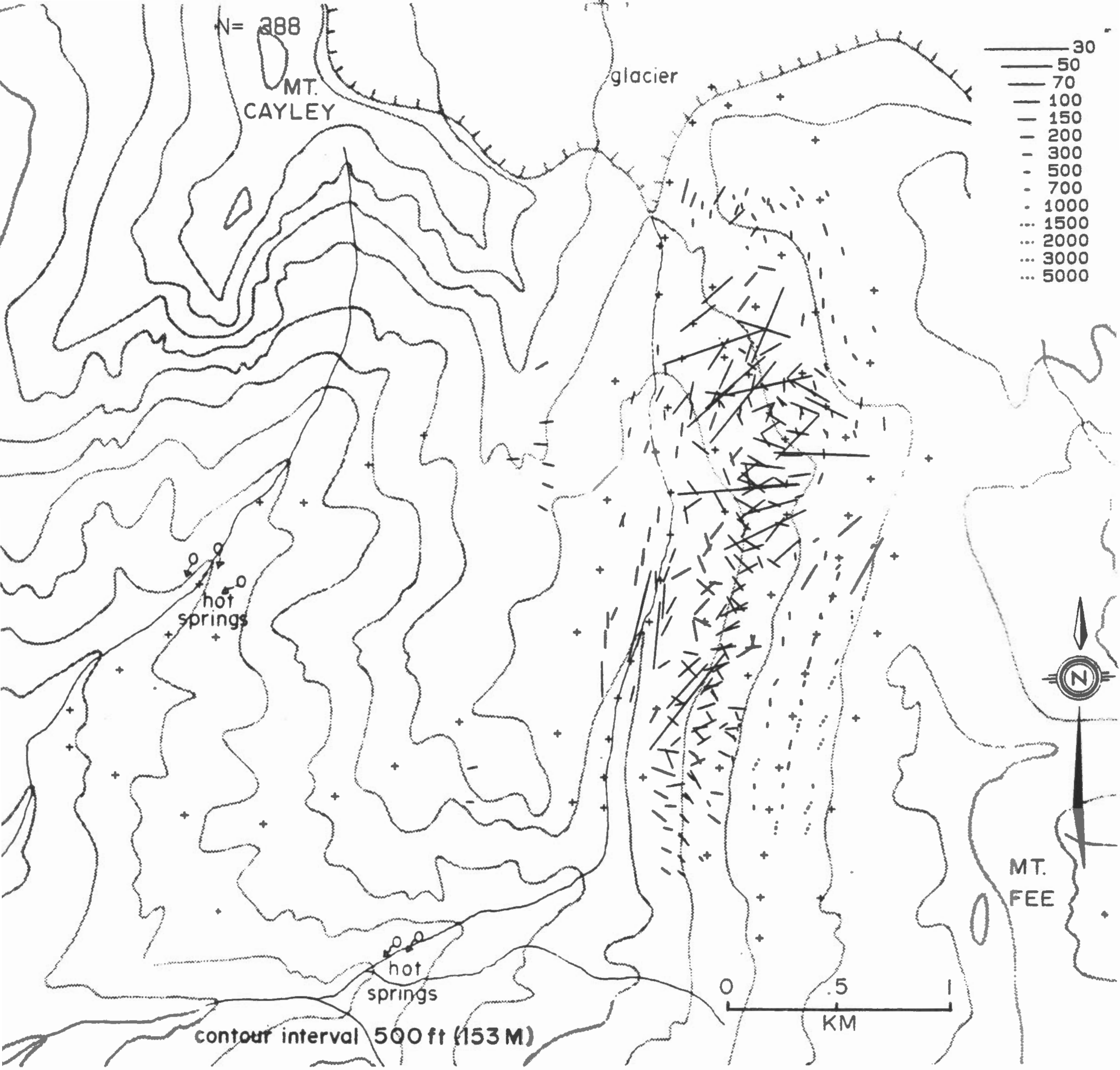

Figure 10 Apparent resistivity data, pole-pole array, nominal penetration 700-1000 metres (P1-C1 separation 933-1333 metres)

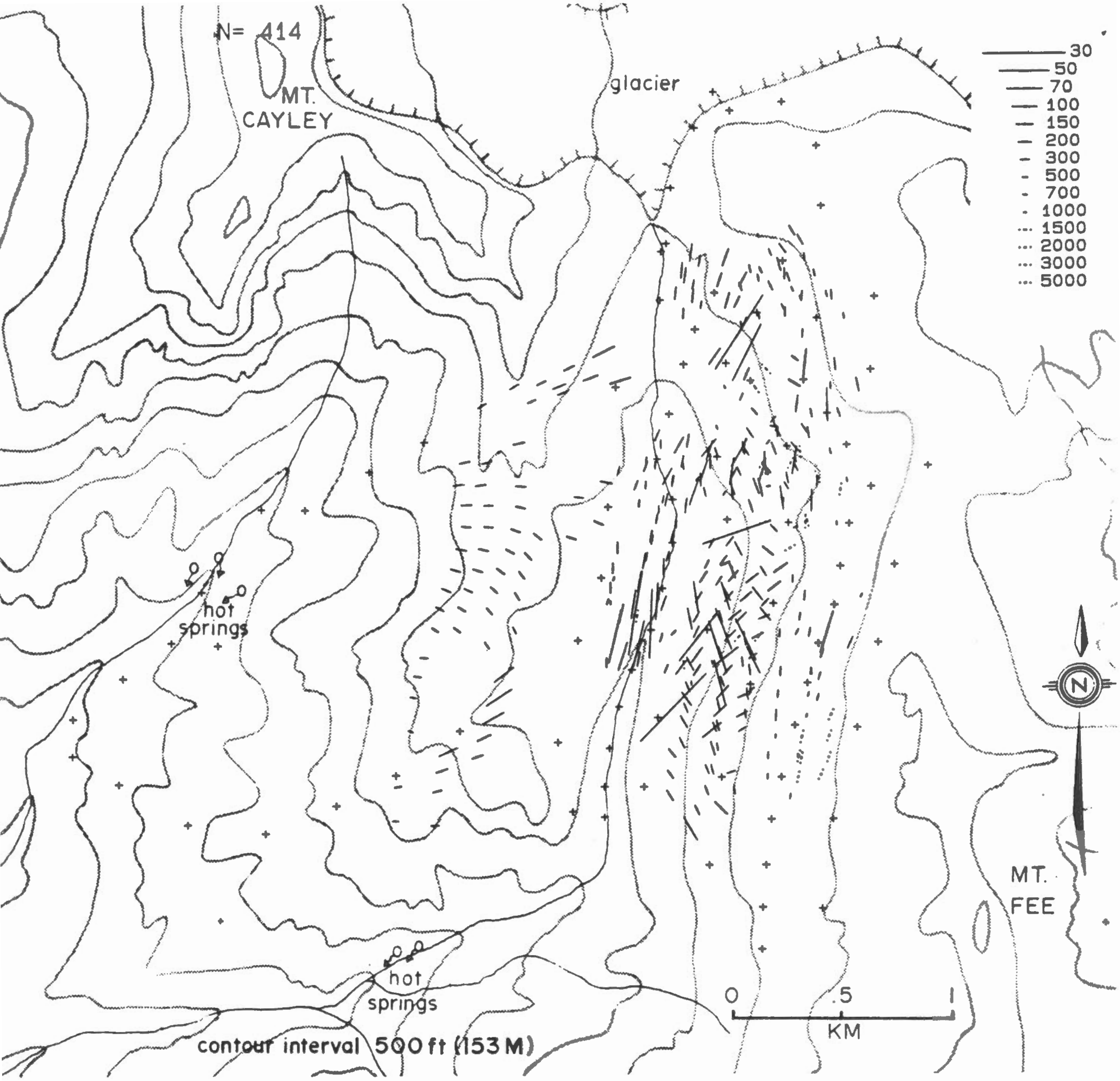

Figure 11 Apparent resistivity, pole-pole array, nominal penetration 1000-1500 metres (P1-C1 separation 1333-2000 metres)

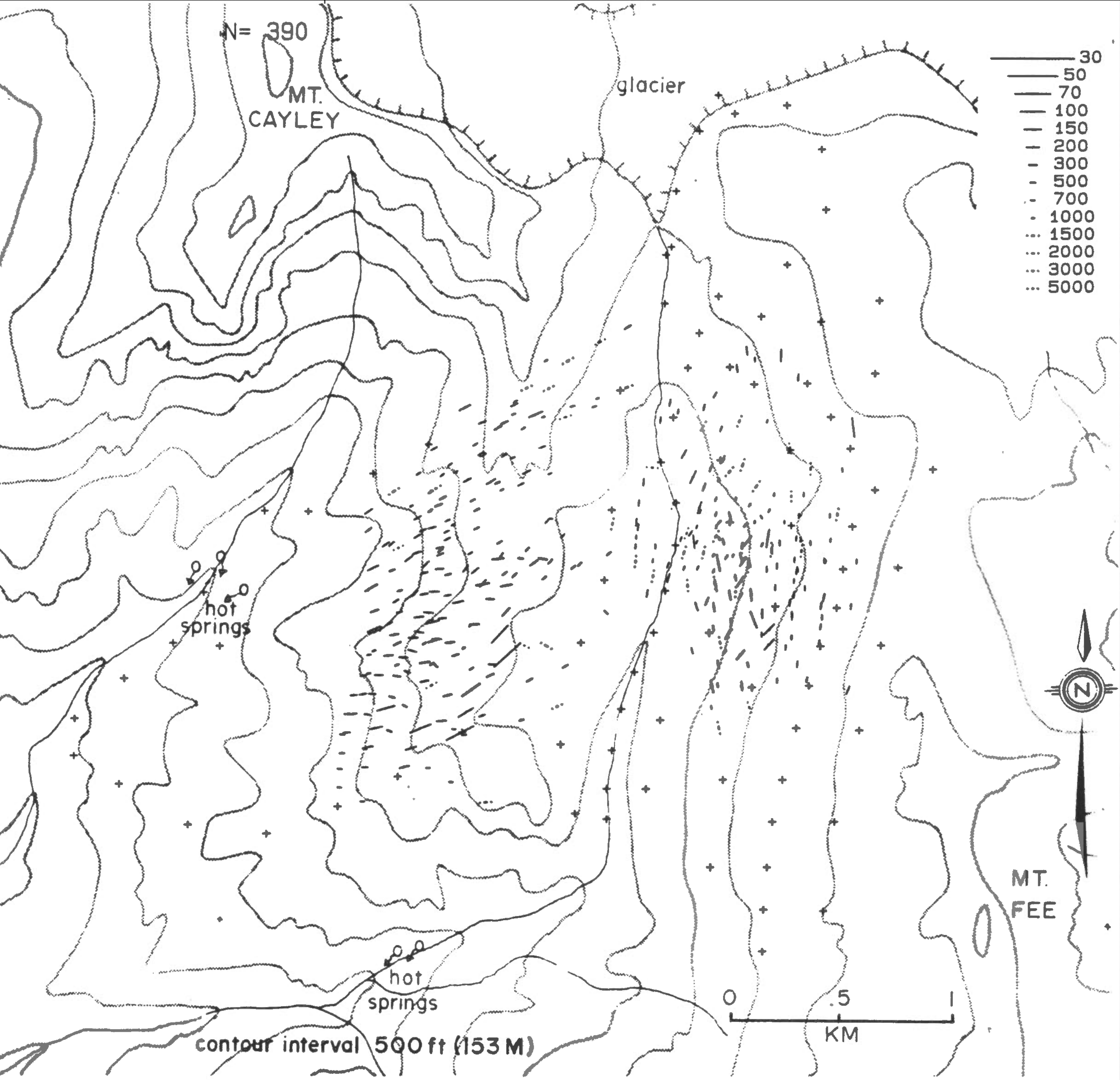

Figure 12 Apparent resistivity, pole-pole array, nominal penetration greater than 1500 metres (P1-C1 separation greater than 2000 metres)