B.C. HYDRO AND POWER AUTHORITY

Report on
at

1976 Geothermal Investigation Meager Creek

North and Northeast Flanks of the

Volcanic Complex

Alternative Energy Studies

Stage Three of Geological and Geophysical Work toward Discovery of Geothermal Steam in the Lower Mainland of British Columbia.

February 7, 1977

REPORT ON 1976 GEOTHERMAL INVESTIGATIONS AT MEAGER CREEK: NORTH AND NORTHEAST FLANKS OF THE VOLCANIC COMPLEX

Prepared on behalf of

THE BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

Alternative Energy Studies

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SUMMARY

During 1976 two important projects added to the accumulated information on the Meager Creek geothermal prospect.

Reconnaissance geophysics on the north and northeast flanks of the Meager Mountain volcanic complex defined several areas of anomalous self-potentials thought to be caused by the subsurface movement of geothermal fluids. Coincident with two previously measured resistivity lows, the new data favour the presence of one or more near-surface reservoirs of unknown lateral and vertical extent.

The core of the volcanic complex was mapped in detail by Dr. P.B. Read for the Geological Survey of Canada, providing basic information which will enable cross sections of the complex to be constructed and structures analyzed. Dr. Read's studies have confirmed earlier hypotheses that the latest volcanic events have occurred in the north, lending support to the possibility of a volcanic heat source in the vicinity of the geophysical anomalies discovered there.

Studies in 1974 and 1975 concentrated on the east and south flanks of the volcanic complex and acquired detailed data on the first reservoir identified. The 1976 data imply that the northern parts of the complex and its thermal and groundwater domains should be thoroughly understood before choosing a site for a deep exploratory well.

It is possible that the geophysical measurements to date have detected near-surface components of an arc-shaped reservoir wrapping around the south, east, and north flanks of the Meager Mountain volcanic complex for a length of, say, twelve miles.

The new information increases the probabilities that the Meager Creek geothermal system is several times larger than previous surveys indicated. We can start thinking in terms of an ultimate reservoir capacity approaching or exceeding 1000 Mw.

We recommend that the northern anomalies be investigated further by temperature probing of the Lillooet River bed and by dipole-dipole and Schlumberger resistivity surveys. A draft of a comprehensive long range programme is in preparation.

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REPORT ON 1976 GEOTHERMAL INVESTIGATIONS AT MEAGER CREEK: NORTH AND NORTHEAST FLANKS OF THE VOLCANIC COMPLEX

1.0 INTRODUCTION

1.1 Terms of Reference

In 1973, as part of a study of alternative sources of energy, British Columbia and Power Authority instructed Nevin Sadlier-Brown Goodbrand Ltd. to conduct a reconnaissance geological and geophysical investigation of the Lillooet River valley and surrounding region for the purpose of determining the potential for geothermal steam and identifying areas of significant promise. This initial exploratory phase was completed in June of 1974. From October 1974 through November 1975, the firm proceeded with a detailed investigation of the Meager Creek geothermal prospect on the southern side of the Meager Mountain volcanic complex.

A proposal by the firm, dated 27 August 1976, recommended a reconnaissance geophysical survey of the eastern and northern parts of the Meager Mountain volcanic complex and ancillary work. This work was performed under British Columbia Hydro and Power Authority purchase Order No. 653 072. The objective of this work was to test rapidly and cheaply for the presence of subsurface thermal fluids using the electrical self potential profiling method followed up with several vertical resistivity soundings.

1.2 Scope of this Report

This report describes the work done and data acquired by this firm from September through November 1976. Other studies in the area are summarized.

1.3 Location and Access

The Meager Mountain volcanic complex is located on the southwest side of the Lillooet River, about 35 miles northwest of Pemberton, British Columbia. Meager Creek drains the southern and eastern sides of the complex.

During 1976 a logging road was advanced along the northeast bank of the Lillooet River, past the mouth of Meager Creek, to within 3/4 of a mile of Pebble Creek. While tracked equipment could now be walked into the valleys, helicopter is still the only practical access into most of the area.

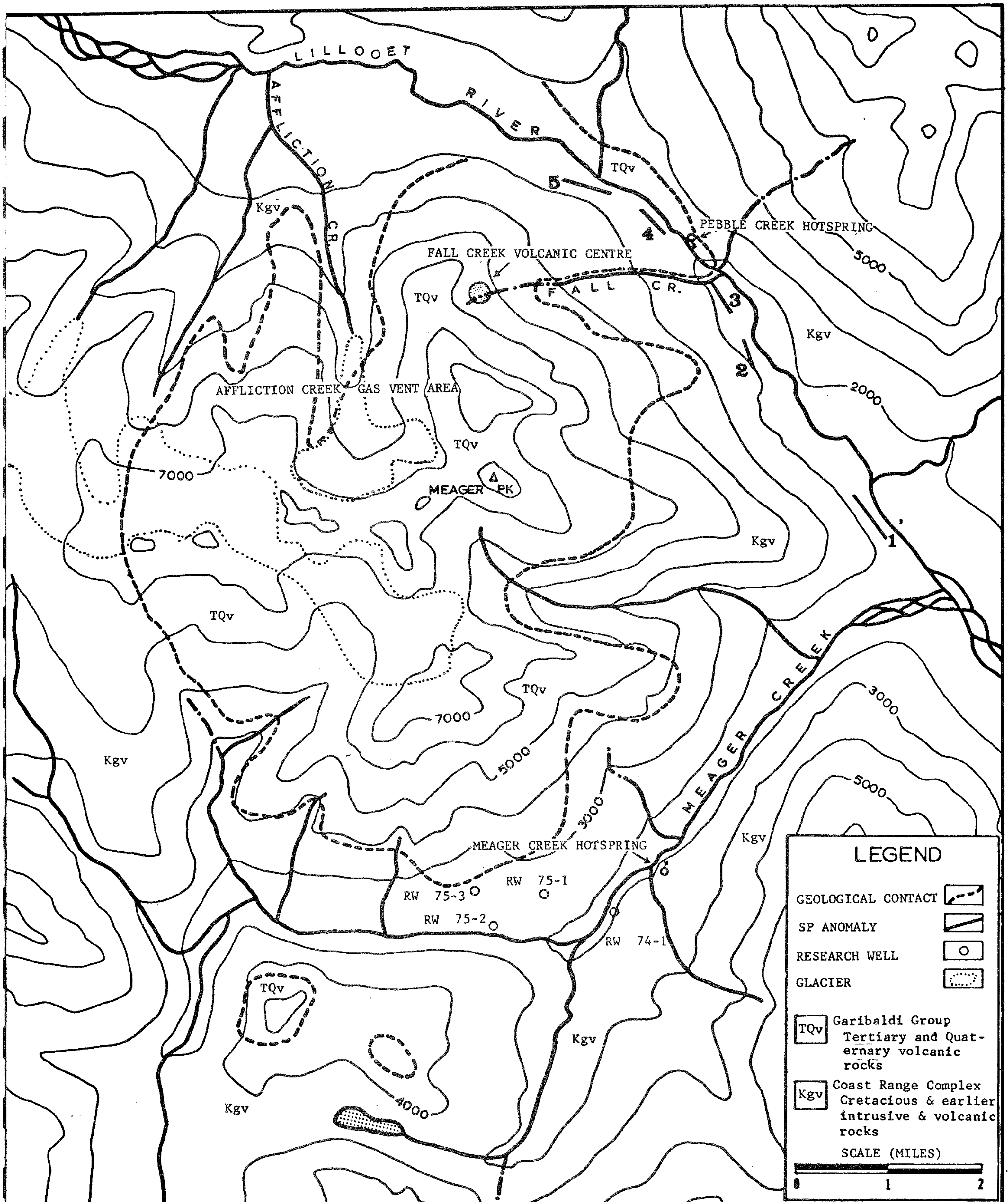

Fig 1. MEAGER MOUNTAIN GEOTHERMAL AREA

During 1977 the logging road will be advanced to Pebble Creek, and a spur will bridge the Lillooet River immediately upstream from the mouth of Meager Creek and continue about four miles along its left bank.

2.0 WORK COMPLETED UNDER CONTRACT

Deep Grid Analysis Ltd., was engaged to carry out geophysical surveys of the Lillooet River Valley north and northeast of the Meager Mountain volcanic complex. A total of 32.1 line miles of electrical self-potential profiling on both sides of the valley was completed. In addition seven vertical electrical resistivity soundings were conducted. The report on this work is contained in Appendix 'A'.

Geological examinations were made in the valley of Affliction Creek and elsewhere along the northeast slope of the Meager complex in the general area covered by the geophysical survey.

A water sample was taken for analysis from Affliction Creek after the pronounced odour of hydrogen sulfide gas was traced to this stream. Its origin was found to be in the valley at the toe of the Affliction Glacier.

Work carried out in the Meager Mountain area during the summer and fall of 1976 by the Federal Department of Energy, Mines & Resources was monitored. This included detailed geological mapping, a magneto-telluric survey, and a geochemical study of spring waters.

3.0 WORK COMPLETED BY ENERGY, MINES & RESOURCES

Dr. P.B. Read, on contract to the Geological Survey of Canada, completed a detailed geological map of the core of the volcanic complex. The base map was supplied, on a scale of 1:10,000, by the British Columbia Hydro and Power Authority through Nevin Sadlier-Brown Goodbrand Ltd. Dr. Read's initial report on the work is excerpted from the Geological Survey of Canada's Report of Activities and appears in Appendix 'B'.

During the summer of 1976 the Mineral Exploration Research Institute of Montreal, Quebec, under contract to Dr. L.K. Law, Earth Physics Branch, Victoria, British Columbia conducted a magnetotelluric survey in the Lillooet Valley. Measurements were taken at three test sites between Pemberton Meadows and Meager Creek. A summary of the survey is in

Appendix 'C' under "Magnetotellurics: 1976". Results of magnetotelluric field studies conducted by Dr. Law in 1975 over the Meager Creek geothermal prospect as well as in the Alta Lake-Pemberton-D'Arcy area have not been fully analyzed to date. Brief descriptions by Dr. Law appear in Appendix 'C' under "Magnetotellurics: 1975".

Hammerstrom and Brown of the University of British Columbia, under contract to the Geological Survey of Canada, initiated a geochemical study of the thermal spring waters and surficial fresh waters of the Meager Creek area during the latter half of 1976. A statement of their project is taken from the GSC Report of Activities and is contained in Appendix 'D'.

A proposed test of "Geoprobe", a deep penetrating multi-frequency EM unit being developed under contract from Energy, Mines and Resources, was not conducted in 1976.

4.0 GEOLOGY AND GEOCHEMISTRY

The area investigated lies along the Lillooet River between Meager and Affliction Creeks. It is underlain by two distinct groups of rocks. The oldest of these are the Mesozoic metamorphic and intrusive rocks of the Coast Crystalline Belt. For purposes of this report they are termed "Basement". They are overlain by extrusive rocks of the Garibaldi Group, a sequence of flows, tuffs and agglomerates ranging in age from Miocene to Recent. These rocks are distributed over a linear belt trending north from Howe Sound to beyond the head of the Bridge River.

The peaks which form the Meager Mountain volcanic complex are all composed of Garibaldi Group rocks which are particularly abundant in this area While other centres of Garibaldi volcanic activity exist both to the north and south, the Meager complex is of particular interest for a number of reasons. It is, for instance, the only locality within the Garibaldi Volcanic Belt where hotsprings are known. The north side of the Complex adjacent the Lillooet River is the source for the Bridge River Ash and the Fall Creek lava flow, which may be the most recent volcanic event in southern British Columbia. The Pebble Creek hotspring also occurs in this area as does the undiscovered source of the hydrogen sulfide gas in the Affliction Creek Valley.

Line A is the principal control for the present survey. It extends northwest from Meager Creek for 37,500 feet to a point on the southwest bank of the Lillooet one mile above Salal Creek. (See Appendix 'A', Drawing 3, in pocket, for a map showing Line A.)

From Stn 0+00 to Stn 245+00 NW at Fall Creek, Line A traverses Basement. In the vicinity of Fall Creek, it crosses the Fall Creek Stock, a biotite quartz monzonite (Read, 1977, Appendix 'B') locally mineralized with pyrite, molybdenite, and chalcopyrite.

On the northeast bank of the Lillooet River, opposite Stn 244+00, is a hotspring which, although located some three miles from Pebble Creek, is known as the Pebble Creek hotspring. It issues from a fractured intrusive rock, probably part of the Fall Creek Stock, a medium-grained quartz monzonite showing some alteration (albitization and sericitization) of the feldspars. The surface temperature of the spring is 60°C and sampling conducted during the initial regional reconnaissance program in 1974 established the water to be sodium bicarbonate in character. Analytical results are reproduced in Table 1.

From Stn 245+00 NW to Stn 375+00 NW, the end of Line A, the rocks are Garibaldi Group flows, tuffs and agglomerates. Immediately north of Fall Creek is a dacitic lava flow of Quaternary, possibly Recent age which originates in a cirque at the head of the creek. It is reported (Read, 1977) to be the product of the latest volcanic event in the Meager Mountain complex. The lava flowed down the creek valley to spread out over the older sequence of flat lying tuffs and flows which partially occupy the Lillooet Valley at this point. Blocks of pumice found in this area originate from a vent on the north slope of Plinth Peak. This vent may coincide with the source of the Fall Creek flow.

Line SP-1 begins at the base of a pumice slide about 600 feet west of Stn 375+00 on Line A. The line trends northwesterly along the river bank to Stn 170+00 NW. Lines SP-2, -3, -4, and -5 tie into it covering the alluvial fan formed by the lower portion of Affliction Creek. This area is underlain mainly by basement metamorphic rocks (greenstones and amphibolites). Immediately south of the survey area these rocks are covered by flows of the volcanic complex.

Line SP-6 is a closed traverse on the northeast bank of the Lillooet, beginning opposite Stn 310+00 on Line A and looping above the Pebble Creek hotspring. The terrain is steep and underlain by Basement rocks. Line SP-7 is 17,000 feet long, centered on Pebble Creek opposite Line A. It traverses unconsolidated overburden lying on Basement.

In the valley of Affliction Creek and on some of the surrounding ridges the strong odour of hydrogen sulfide gas was reported by Geological

Survey of Canada field personnel during the summer of 1976. This was subsequently traced to the waters of Affliction Creek, a turbid, fast flowing glacial stream. The odour was most intense about 100 to 500 feet downstream from the toe of Affliction Glacier, which occupies the upper portion of the creek valley. In the vicinity of the high gas concentration the creek deposits black, elemental sulfur on submerged boulders and sediments.

A water sample was taken from Affliction Creek and analyzed by Chemex Labs Ltd., North Vancouver, B.C. Results are tabulated in Table 1. Composition indicates a different thermal history for waters mixing with Affliction Creek than for the Pebble Creek hotspring waters.

5.0 GEOPHYSICS

5.1 General Statement

Self-Potential is one of the earliest geophysical methods used in exploration for near-surface metal deposits. Although generally supplanted by more advanced techniques for this purpose, it has been applied, with some success, as a reconnaissance tool in geothermal exploration. Self-Potential measurements were read concurrently with a resistivity survey at Meager Creek in 1975 and located a large area of anomalous response of the order of +250 to +350 millivolts spatially associated with a portion of the very low resistivity zone discovered. The method is inexpensive and rapid and has been confirmed as a non-exclusive rapid reconnaissance tool in the type of ground water regime found at Meager Creek.

Vertical electrical resistivity soundings provide basic data for the calculation of resistivity variation with depth.

5.2 Discussion of Results

SP gradients range from strong and widely variable in outcrop and shallow overburden conditions (Line A between stations 0+00 and 320 +00 NW) to weak and unclear in relatively deep overburden conditions (Lines SP-1, -2, -3, -4, -5).

Significant anomalies were measured on Line A. A broad sinusoidal response in excess of 1 volt extends from Stn 0+00 to Stn 320+00. Superimposed on this regional inflection are five local

TABLE 1

QUANTITATIVE (ppm in sample)	Affliction Creek at toe of Affliction Glacier (Oct 1976)	Pebble Creek Hot Spring (Jan 1974)
T°C	0.0	60.0
pH	6.38	7.9 - 8.1
SiO2 (ppm)	22.0	75.5
Na	7.9	425.0
K	2.9	14.5
Ca	26.0	30.0
Mg	6.0	4.7
HCO3	41.0	757.0
CO3	-0.1	n.d
SO4	44.0	-1.0
Cl	0.3	100.0
STANDARDIZED SEMI-QUANTITATIVE ANALYSIS (ppm in sample)		
Sb	- *	-
As	-	
Ba	40	10
Be	-	-
Bi	-	-
Bo	-	1000 **
Cd	-	-
Cr	-	-
Co	-	-
Cu	2	-
Ga	-	-
Ge	-	-
Fe	1000	n.d
Pb	10	-
Mn	300	10
Mo	-	100
Ni	-	-
Nb	-	-
Ag	-	-
Sr	40	-
Ta	n.d	-
Te	-	-
Th	-	-
Sn	140	-
Ti	20	-
V	-	-
Zn	-	-
Zr	-	-

'n.d' stands for no determination

* '-' below detection limit

** borosilicate glassware used in procedure positive filtered anomalies. They are potentials in excess of 100 mV over distances ranging from 1600 to 3200 feet and are labelled 1 through 5 on **Figure 1.**- Meager Mountain Geothermal Area Map, page 2.

The positive component of the regional anomaly lies between Stn 0+00 and Stn 200+00 NW and can best be attributed to streaming potentials (see Appendix 'A') set up by the subsurface movement of thermal fluids. Local anomalies 1 and 2 peak near Stns 52+00 NW and 198+00 NW respectively.

Anomaly 1 coincides with a low resistivity zone (R-1) discovered by McPhar Geophysics in the course of reconnaissance resistivity survey of the Meager Creek area in 1974. Four electrical resistivity soundings (S-1 through S-4) conducted during the present survey in the vicinity of Anomaly 1 indicate that apparent resistivities of the order of 1 to 3 ohm-metres extend from near surface to beyond array penetration at 1000 feet. Sounding S-5 did not encounter the very low resistivities found to the south-east and may reflect a northwestern limit to the conductive zone in the vicinity of Pebble Creek. These soundings roughly delineate a possible reservoir covering an area of about 1.5 by 0.7 miles (2.4 by 1.1 km) with boundaries open to the north, east and south.

Anomaly 2 is near McPhar anomaly R-2, a deep seated res-isitivity low centred on Stn 155+00 NW. Soundings S-6 and S-7, operated several thousands of feet to the northeast, across the Lillooet, did not detect any zones of decreased resistivity.

The negative component of the regional SP anomaly lies between Stns 200+00 NW and 320+00 NW. It may be due, in part, to oxidation-reduction potentials related to the interaction of thermal and meteoric waters and perhaps metallic sulfide grains within the Fall Creek Stock. Anomalies 3, 4, and 5 are centered on 230+00 NW, 270+00 NW and 310+00 NW respectively. These positive manifestations are underlain by the Fall Creek Stock (3) and Meager Mountain Volcanics (4 and 5) and may be caused by thermal fluids circulating in fractured basement at depth. McPhar anomaly R-3 is between and overlapping slightly on 3 and 4. R-3 has been ascribed to conductive gravels overlain by a post glacial volcanic flow.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The self-potential method is a useful exploration tool in the Meager Creek environment. Convergence of self potential and resistivity (soundings and dipole-dipole) data has demonstrated the possibility of a reservoir underlying the Lillooet Valley between Meager and Pebble Creeks. Self potential and dipole-dipole resistivity anomalies upstream to the northwest may reflect subsurface thermal fluid activity as well.

Five SP anomalies have been located. Of these, the most important is No. 1 which is centered immediately downstream from the mouth of Pebble Creek. Anomalies 2 and 3 are considered to be second order while numbers 4 and 5 are minor anomalous zones.

Geologic mapping of the volcanic complex has confirmed the hypothesis that the most recent eruptions took place on the north side of the volcanic complex and moreover, that eruptions systematically marched north as the volcanic complex grew. This implies that the driving source of heat for the geothermal reservoirs might be closer to the north slopes than the south.

The data which have been accumulated on the Meager Creek geothermal system continue to display commercial-class characteristics. The two lines of evidence in the northern part of the complex extend the prospective area of the reservoir system to the point where we may begin to think in terms of potential capacity on the order of 1000 Mw.

It would be consistent with the depth characteristics of productive geothermal reservoirs, and with the limitations of geophysical methods to postulate that surveys to date have detected only cupolas, or near-surface extensions, of a large underlying reservoir which wraps around the south, east and north sides of the volcanic complex.

Immediate measures to obtain additional information are:

1) Closely spaced temperature probe traverses across the bed of the Lillooet River adjacent to the new SP anomalies

2) Compilation of ten 1:10,000 scale geologic profiles from existing geologic and geophysical data

3) Detailed dipole-dipole resistivity surveys and several Schlumberger vertical resistivity soundings to define the lateral limits of the new anomalous readings

4) Two or more shallow research wells of the type drilled in 1975 near the No. 1 anomaly at Pebble Creek.

A draft of a work programme required for siting a deep exploratory well is in preparation.

Respectfully submitted,

NEVIN SADLIER-BROWN GOODBRAND LTD.

T.L. Sadlier-Brown, Geologist

Andrew E. Nevin, P.Eng.

February 7, 1977

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Appendix 'A' : Report on Geophysical Survey Operations on the North and Northeast Flanks of the Meager Mountain Volcanic Complex, Meager Creek Selected Area, B.C. October - November 1976

G.A. Shore, Deep Grid Analysis, Limited, Vancouver, B.C.

SUMMARY

Reconnaissance self-potential (SP) survey traverses on the north and northeast flanks of the Meager Mountain volcanic complex have defined several areas of anomalous potentials interpreted as being caused by the subsurface movement of geothermal fluids. The coincidence of some of the largest of these anomalies with previously located resistivity anomalies lends support to a model describing one or more active geothermal convection cells of potentially large areal and volumetric dimensions.

INTRODUCTION

Geothermal areas are usually characterized by the presence of hot, circulating saline solutions carrying a dissolved-solids load from a few thousand parts per million (ppm), as at the Dunes geothermal anomaly in California, to several hundred thousand ppm as at Cesano, Italy (Calami et al., 1975). Both the physical movement of the fluid through pore spaces and the interaction of geothermal waters with less-saline regional meteoric waters may contribute to the establishment of an electrical potential field (a self-potential anomaly) at the earth's surface. Three such processes are described below; numerous other mechanisms are known to exist, but require such elaborate sets of conditions as to limit their occurrence to rare cases.

1. STREAMING POTENTIALS occur as a result of fluid movement within the pore spaces of the rock. In the typical mode, anions are selectively adsorbed by the rock surfaces, leaving a relative excess of cations in the moving fluid. In an upward flow of water, these surplus cations tend to accumulate near the top of the flow causing a positive self-potential anomaly. (In the less typical mode, involving some clays and carbonate rocks in basic solutions, the process is reversed, with cation adsorption and negative potentials in the direction of streaming). Examples are given in the following table:

TABLE: Examples of Positive Anomalies caused by Streaming Potentials

AREA	POTENTIAL	REFERENCE
Mud Volcano geothermal reservoir, Yellowstone National Part	+45 millivolts	Zohdy et al., 1973
Dunes geothermal anomaly, Imperial Valley, California	110-250 millivolts	Combs and Wilt, 1975
Grass Valley, Nevada	70 millivolts	Corwin, 1975
Southeast Meager Mountain, B.C.	250-350 millivolts	Shore, 1975
Kilauea Volcano, Hawaii	+2000 millivolts	Zablocki, 1975
Long Valley caldera, California	1100 millivolts	Anderson & Johnson,1976

Negative SP anomalies have been reported adjacent positive anomalies at Yellowstone, the Dunes anomaly, Grass Valley, and occasionally on Kilauea; in each case the investigators have suggested streaming potentials from descending waters as the source mechanism. At Long Valley, Anderson and Johnson (1975) suggest that while downward percolation of meteoric waters may be responsible for part of the broad negative anomaly, suitable conditions probably exist for the production of diffusion potentials and/or oxidation-reduction potentials which may account for some or all of the observed negative anomaly.

2. DIFFUSION POTENTIALS may occur when relatively pure meteoric waters interface with saline thermal fluids. Ions from the saline solution will migrate into the less concentrated solution, at rates dependent on the difference in salinities, the mobility of the ions, and the temperature difference between the solutions. The presence of clays will also tend to accelerate the transfer. The more mobile ions will typically be of one polarity; therefore an electrical potential will develop across the solution interface as a result of the net current flow. Potentials of up to 100 millivolts may be expected (Nourbehecht, 1963).

3. OXIDATION-REDUCTION POTENTIALS may be established at the interface between dissimilar fluids provided certain conditions are met:

1. a difference in Eh or redox potential between the solutions is required to provide the driving force for the transfer of electrons from one solution to the other.

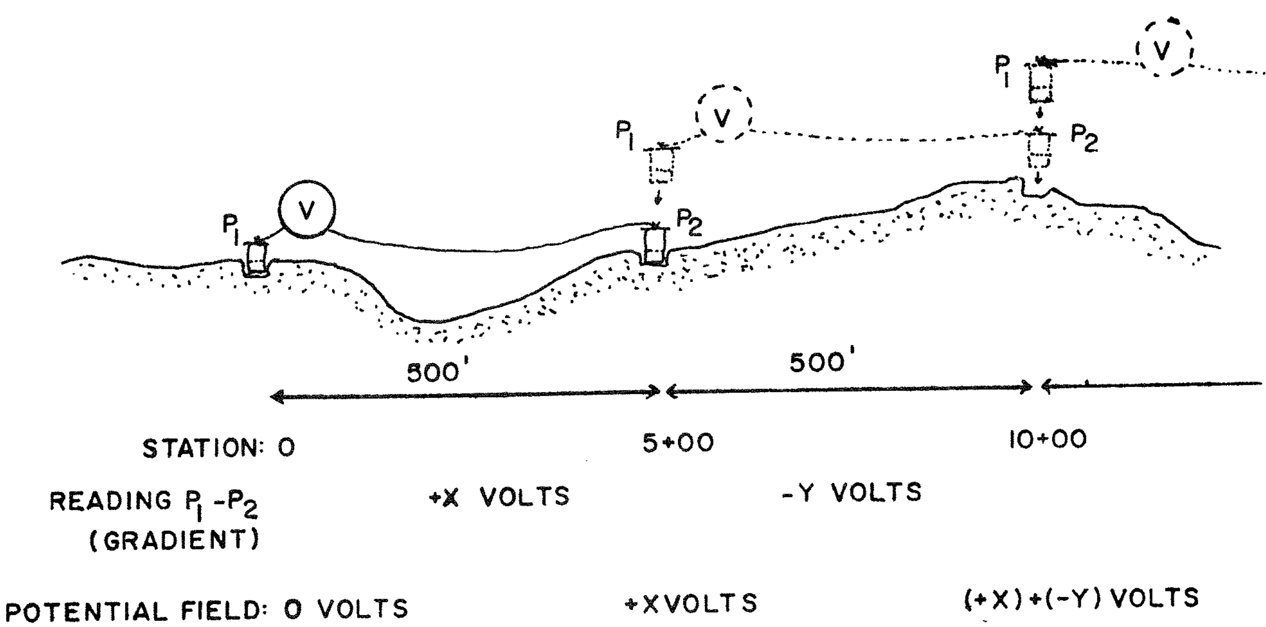
2. the presence of a conductive body across the interface is required to facilitate the transfer of electrons.

3. the electron mobility rate must exceed the mobility of the upward moving positive ions in the surrounding solution in order to establish a net charge.

Conditions meeting these requirements could be described in terms of thermal waters with some dissolved iron content to provide the reducing environment, regional meteoric waters carrying substantial free oxygen to provide the oxidizing environment, and disseminated metallic sulfides in the area of the solution interface to provide a vehicle for electron transfer. Sato and Mooney (1960) indicate that potentials of 400 to 500 millivolts may be expected; Anderson and Johnson (1976) report observation of substantially higher potentials, most often negative in polarity at the earth's surface.

FIELD PROCEDURE

Self-potential traverses were made using a 500 foot measurement dipole, as illustrated below:



Copper - copper sulphate porous porcelain electrodes were employed, with a Hewlett-Packard 970A digital voltmeter with 10 megohms input impedance as the measurement instrument. Electrodes were placed in holes dug into the damp "C" soil horizon, and no additional watering or other contact-improving mechanisms were required. The pot holes also served to assure recovery of the exact lead pot position by the following pot with each move.

Operational logistics prevented the use of a common error-reducing mechanism in which the relative positions of the pots are reversed on each successive move (leapfrogging) to balance out electrode polarization effects. Careful handling of balanced pots is thought to have minimized accumulated polarization error; the observation of a closure error of less than 80 millivolts in 19,000 feet of traverse in closed loop SP-6 (drawing 3) indicates success in these efforts, and lends confidence in dealing with the data from open-ended lines such as Line A (drawing 3,4) where determination of closure error is impossible.

The vertical electrical resistivity soundings were undertaken using an expanding 3-array with "a" spacings of 10, 20, 40, 80, 160, 320, 640, 1280, 2560 feet.

DATA PROCESSING

Potential field data was developed by algebraic addition of measured gradient data, in the direction of original data accumulation. Drawing 4, figures 1 and 2 illustrate gradient and potential data for line A; potential field data is preferred for use in evaluation of anomalies and inflections.

A low-pass filtering program was applied to the data, and the results appear in drawings 4 and 5 labelled as "Deviation from locally averaged background". A simple running average of eight data points was calculated to filter out very large spatial wavelength trends. Then a simple two-point running average was calculated, to reduce the significance of single-point excursions, many of which appeared to be related to topographic features of extreme dimensions. The sum of these two data curves is thus represented as the deviation from locally averaged background.

DISCUSSION OF RESULTS

Drawing 3 is a plan of the survey area on the north and northeast flanks of the Meager Mountain volcanic complex. Survey line locations are shown, with station locations at usually 1000 foot intervals. The positions of anomalous SP responses are shown, as are the centre points and array directions for the seven vertical electrical resistivity soundings. For reference purposes, the locations of resistivity anomalies reported by McPhar Geophysics (Hallof and Bell, 1974) are shown. Graphic presentation of SP results is found in drawings 4 and 5; resistivity soundings are plotted in drawings 1 and 2, in the text.

Regional Overview. A consistent, inverse relationship between SP gradients and the depth of overburden in the survey path is clearly discernable. SP responses in the (apparently) very deep overburden in the area of Affliction Creek (Lines SP-1, -2, -3, -4, -5) are very weak, the peak potential difference over the whole set of lines being less than 100 millivolts. On the near-outcrop conditions of most of line A (35+00 to 320+00 NW) and line SP-6, steep and widely variable SP gradients are recorded. On line SP-7, in the narrower Lillooet valley opposite line A near Meager Creek where the depth of overburden is not expected to be as great as that near Affliction Creek, an intermediate type of response, characterized by moderate to strong SP gradients with an apparent rounding of peak values, is observed.

A wide variety of hydrological, electrochemical and electrokinetic mechanisms may be contributing to the apparent suppression or dispersion of anticipated regionally "normal" responses in the areas of exceptionally deep overburden. It is beyond the scope of the present report to delve further into these mechanisms and their possible effects, as any insights that might be gained will be of largely academic interest and will in no forseeable way provide additional practical assistance in interpreting the available data. It must be concluded that due to the lack of interpretable surface SP expression, the area covered by line A from 320+00 to 375+00 NW and lines SP-1, SP-2, SP-3, SP-4, and SP-5 remains essentially untested.

In the remaining major portion of the data, steep and widely variable SP gradients are common, and numerous anomalies are identified.

Line A (Location Dwg 3, SP data dwg 4, resistivity soundings dwg 1,2)

Line A traverses apparently very deep overburden from 320+00 to 375+00 NW and shows very little SP relief. From 0+00 to 320+00 NW overburden is shallow to non-existent and SP gradients are strong and widely variable. SP anomalies of two spatial wavelengths are identified, a single large sinusoidal curve which spans a distance of six miles, and numerous shorter inflections of 1600 to 3200 feet in width.

The large sinusoidally shaped curve (fig 2. dwg 4) has a broad positive component peaking between 120+00 and 200+00 NW, and a large negative component peaking between 240+00 and 260+00 NW, with a total potential difference of 1100 millivolts. The positive component is located entirely within the granodiorite and may be caused by streaming potentials within a major fluid convection cell or series of cells. The negative portion is located in an area of a geologically recent dacite flow which is inferred to overlie pre-existing valley sediments. Part or most of the negative expression could be caused by streaming potentials originating in the downward flow of cooled waters in a convection cell or in the downward percolation of meteoric waters through the dacite and underlying gravels, or a combination of both. However, the complex layering of the area, in which the porous gravels are contained by the overlying, less porous dacite, suggests the possibility for channelling meteoric waters into contact with geothermal brines, resulting in the establishment of diffusion potentials and/or oxidation-reduction potentials. Metallic sulfides are known in the area, and the vigorous meteoric water regime suggests a plentiful supply of free oxygen, thus satisfying some of the major conditions for oxidation-reduction potentials to develop. While the precise combination of mechanisms responsible for the negative voltage cannot be determined from the data presently available, those mechanisms suggested as being involved indicate cold water/thermal water interfacing or the downward flow of cooled convective cell water, neither of which conditions is of economic interest except as a guide to the potentially productive zones of maximum heat and maximum porosity.

The shorter wavelength anomalies which can be observed superimposed on the broad dipolar anomaly curve in fig. 2 (dwg 4) are more clearly observed in the filtered data profile of fig 3. Five positive SP anomalies (numbered 1 through 5) may represent individual convective cells or sub-cells in a major system. Each has associated negative inflections which may indicate areas of downward flow of cooled convective waters.

Anomaly 1, centered at 50+00 NW, stands out as the best defined anomaly, particularly when presented against the normalized SE slope of the broad positive curve on which it occurs (fig 4, dwg 4). This anomaly occurs at the start of a resistivity low discovered by McPhar Geophysics (Hallof and Bell, 1974) in the final few measurements of their line A coverage to the SE. Vertical resistivity soundings were conducted as part of the current program to further define the dimensions of the resistivity low. Soundings 1 (28+00 NW) and 2 (54+00 NW) indicate a continuation of the zone to the SE, and soundings S-3 and S-4, on the opposite side of the river, encounter low resistivities and indicate considerable width to the zone. An area 1.5 miles long and 0.7 miles wide has been delineated, with boundaries to the north, east and south open at present (see outline dwg 3). Apparent resistivities of the order of 1 to 3 ohm-metres extend from near-surface to beyond array penetration at 1000 feet, and indicate very high porosity with a probability of clays and/or thermal precipitates contributing to the conductivity. These are the lowest apparent resistivities yet measured in the Meager complex, and, allowing for data distortions of even 100% due to the proximity of the river and possible current streaming in near-surface layers, the resistivity values will still hold major interest as an indicator of possible geothermal activity.

Anomaly 2 is of interest for its magnitude and breadth (3200 feet) and its proximity to deep-seated resistivity low R-2 centered at 150+00 NW. Vertical resistivity soundings S-7 and S-6 (locations dwg 3, data dwg 2) were operated on the north side of the river opposite 165+00 and 115+00 NW respectively in an attempt to intersect a near-surface projection of resistivity low R-2. No such intersection was achieved; if R-2 does extend out into the valley, it does so at a depth greater than 1000 feet S-7 and S-6 encountered increased resistivities at about 50 and 450 feet respectively; this may or may not represent bedrock.

Anomaly 3 is located in the area of the Fall Creek biotite quartz monzonite stock. Fracturing and fissuring in the perimeter granodiorites could provide a porous environment amenable to the establishment of convective water circulation, provided a heat source was available. The Pebble Creek hot spring, located 2000 feet north of the anomaly, may be controlled by such a structural feature, and by its 60°C outflow indicates that some local heat may be available.

Anomalies 4 and 5 occur over the Fall Creek lava flow, and are not presently known to be associated with the geological or geophysical features which could enhance their description or potential.

Vertical resistivity sounding S-5 was measured opposite 85+00 NW on the north side of the river, upstream from Pebble Creek. Its purpose was to determine the NW boundary of the conductive zone being outlined by resistivity low R-1 and by soundings S-1 through 4. S-5 ended apparently in overburden, without encountering the extremely low resistivities found to the SE. It may be postulated then that the NW boundary of the very conductive zone lies between S-5 and S-4, possibly controlled by a structural feature in the valley of Pebble Creek.

Line SP-1 east half (location dwg 3, data dwg 5)

This line is a continuation of line A, beyond a physical barrier formed by a large pumice deposit at 375+00 NW on line A. The east half of the line shows a gradual negative trend to the NW, with subdued gradients. No anomalous values are observed.

Lines SP-1 west half, SP-2, SP-3, SP-4, SP-5 (location dwg 3, data dwg 5)

These lines were operated as closed electrical loops, permitting the observation of closure error and distribution of the error over the length of each loop in linear manner. Accumulated error was very minor.

The density of coverage in this area was required to effectively search for the source of reported (and observed during survey) H2S gas. A vent located within the Affliction Creek fan should have been identifiable from a distance by a positive SP anomaly. No anomalies were discovered; the SP relief over the entire area does not exceed 100 millivolts.

These lines represent some of the area in which the anticipated SP response appears to have been affected by very deep overburden.

Line SP-6 (location dwg 3, data dwg 5)

This line was operated from a crossing point in the gorge of the Lillooet River above the falls, up the north slopes of the valley to cross above Pebble Creek hotsprings. The line turned uphill for 700 vertical feet and recrossed above the hotsprings at a higher level. No anomalies were observed, and most of the gradients of any consequence appeared spatially tied to extremes of topography (e.g. measurement dipole across a steep valley slope).

Line SP-7 (location dwg 3, data dwg 5)

This line lies on the north side of the river, paralleling line A from opposite the mouth of Meager Creek, NW across Pebble Creek, to a point opposite 150+00 NW of line A. Gradients appear somewhat subdued and the potential profile shows rounded inflections, the probable influence of a moderate to large depth of overburden. The overall gradient is positive to the NW, as it is on line A, but at about one half the gradient. Short wavelength positive peaks may be indicative of streaming potentials in underlying convection cells, but with no quantitative data on the masking effects of the overburden, it is difficult to evaluate the inflections and relate them to SP activity on adjacent line A.

CONCLUSIONS AND RECOMMENDATIONS

Self-potential survey at Meager Mountain appears to be a useful reconnaissance tool. It should be limited in future to areas of minimal overburden to obtain readily-interpreted data, except in cases where a specific target, such as an active vent, may be expected to provide a recognizable signature.

One SP anomaly of long spatial wavelength and five anomalies of shorter wavelength are located on line A between 0+00 and 300+00 NW. These appear to be caused by streaming potentials generated in the upward flow of water in convective fluid cells. Anomaly 1 (at 50+00 NW) and anomaly 2 (at 190+00 NW) are associated with known zones of increased porosity, and require further detailed geological and geophysical investigation to determine the lateral boundaries of the porous zones, and their resistivity characteristics at greater depths. The very large porous zone associated with SP anomaly 1 and partially delineated with vertical resistivity soundings S-1 through 5 requires additional dipole-dipole traverses at a=1000' and a=2000', with one or more Schlumberger soundings near its center to determine its resistivity variation with depth.

Anomaly 3 may be associated with convective circulation in fractures or fissures around the perimeter of the Fall Creek Stock. Further geological and geophysical investigations should be undertaken in this area.

Anomalies 4 and 5 are not associated with supportive geological or geophysical anomalies at present.

At Pebble Creek hotsprings, no SP anomaly was located. However, since the SP approach is non-exclusive, interest in this manifestation remains high, particularly in view of the location of the spring in relation to the Fall Creek Stock. A resistivity traverse or deep gradient survey in this area would provide some firm information on local rock porosities, and permit a further evaluation.

In the area of very deep overburden in the valley NW of the mouth of Salal Creek, a single deep Schlumberger sounding might provide a firm estimate of overburden depth to test the assumption of deep sediments. Resistivity profiling should be used to test this area, keeping the traverse line close to bedrock near the sides of the valley in a continuation of line A resistivity up to and beyond Affliction Creek, unless sounding data indicates that bedrock can be effectively sampled further out into the valley.

On-going geological and geophysical investigations along the length of line A should be periodically reviewed to assess their usefulness in building or modifying the two model possibilities suggested by the SP, a series of discrete or interrelated smaller convection cells as indicated by anomalies 1 through 5, or a major deep-lying convective system underlying the SE half of line A as suggested by the broad dipolar anomaly curve.

Original signed by
G.A. Shore
Deep Grid Analysis, Limited
December 31, 1976

<u>Attached</u>:

References Cited
Drawing 1. - Vertical Resistivity Soundings S-5 to S-7
Drawing 2. - Vertical Resistivity Soundings S-1 to S-4
Drawing 4. - Line A
Drawing 5. - Lines SP-1 to SP-7

<u>In pocket</u>

Drawing 3. - SP Survey, Area Plan

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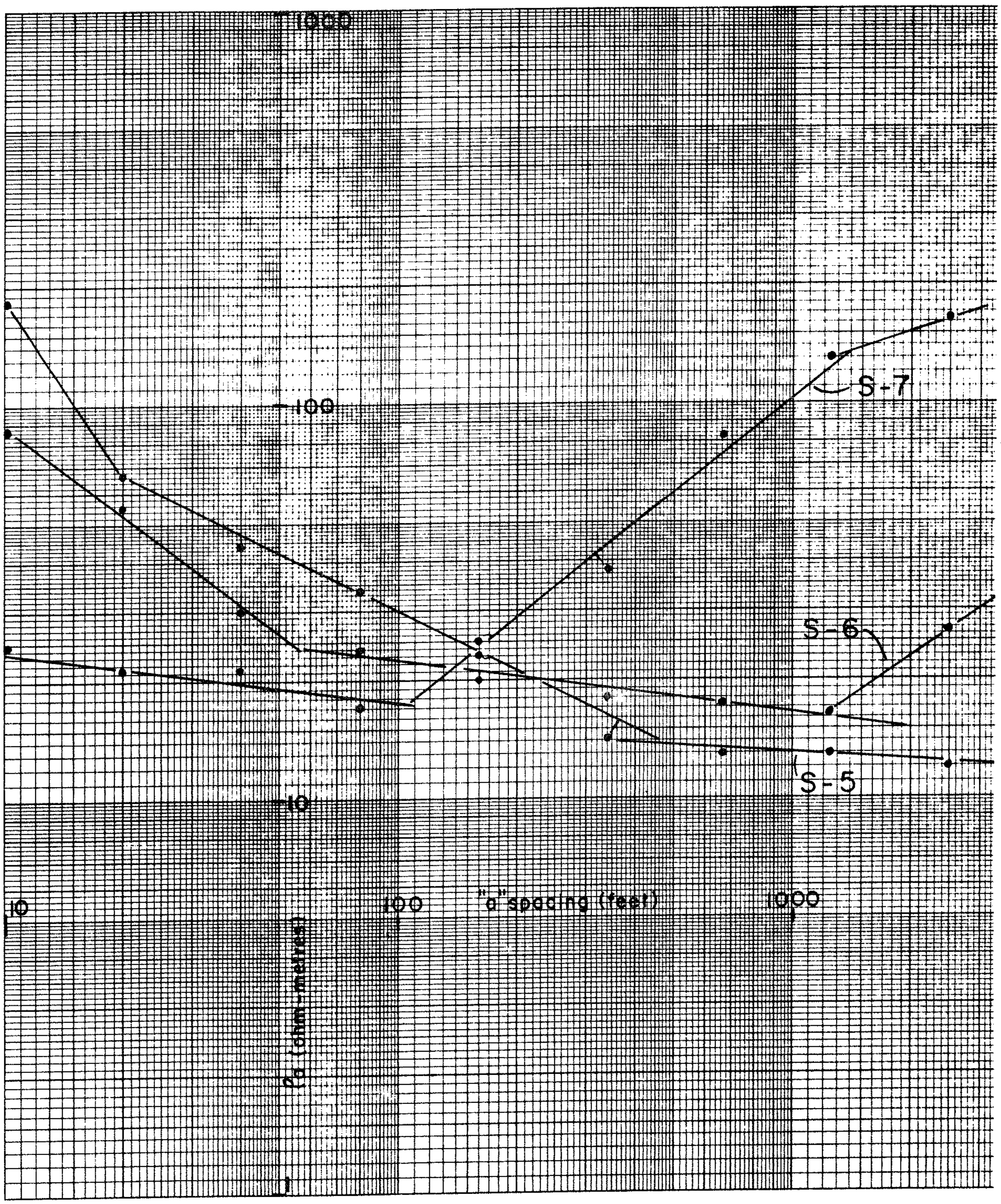
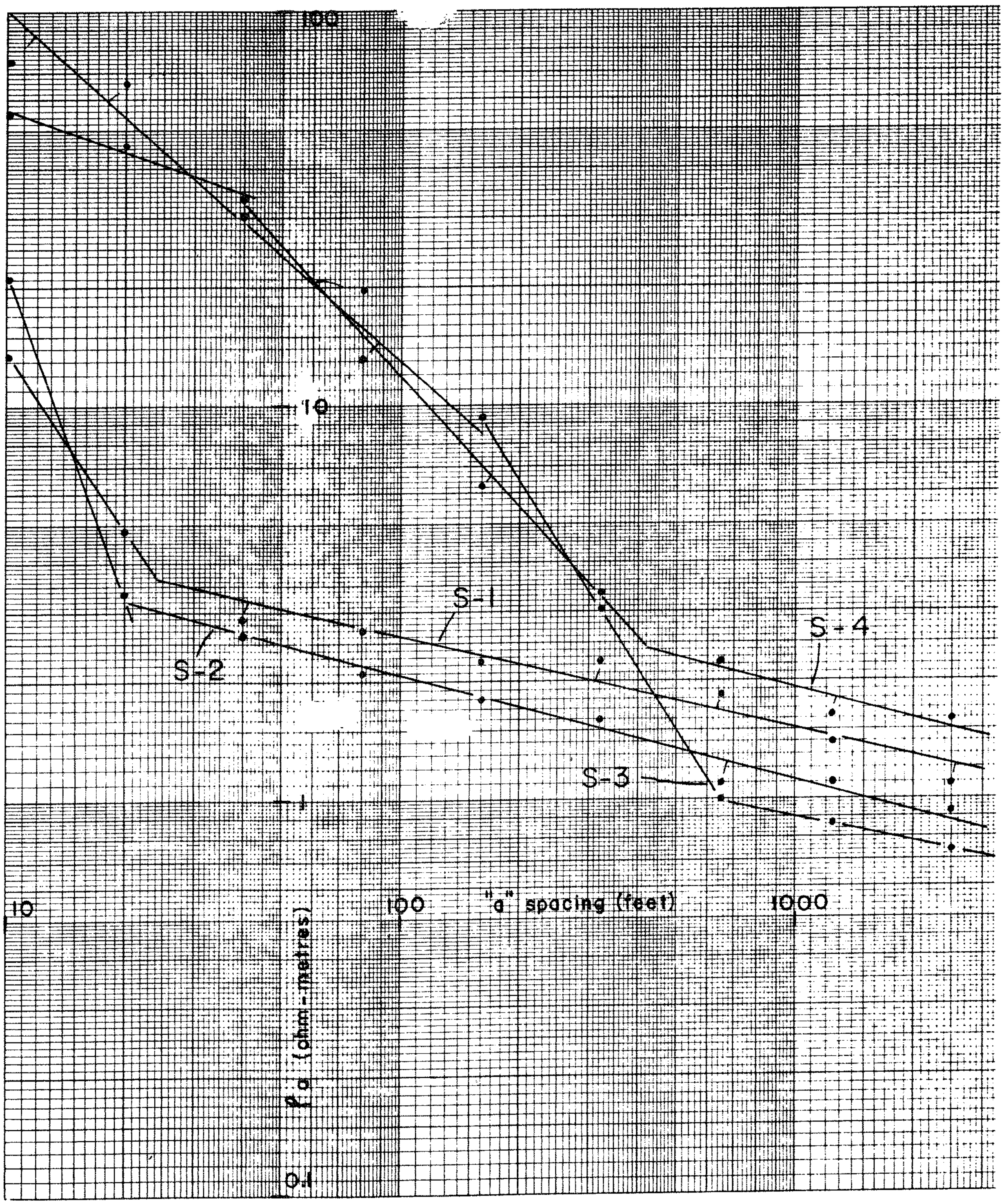
Dwg. 1

Vertical Resistivity Soundings



Dwg. 2

Vertical Resistivity Soundings



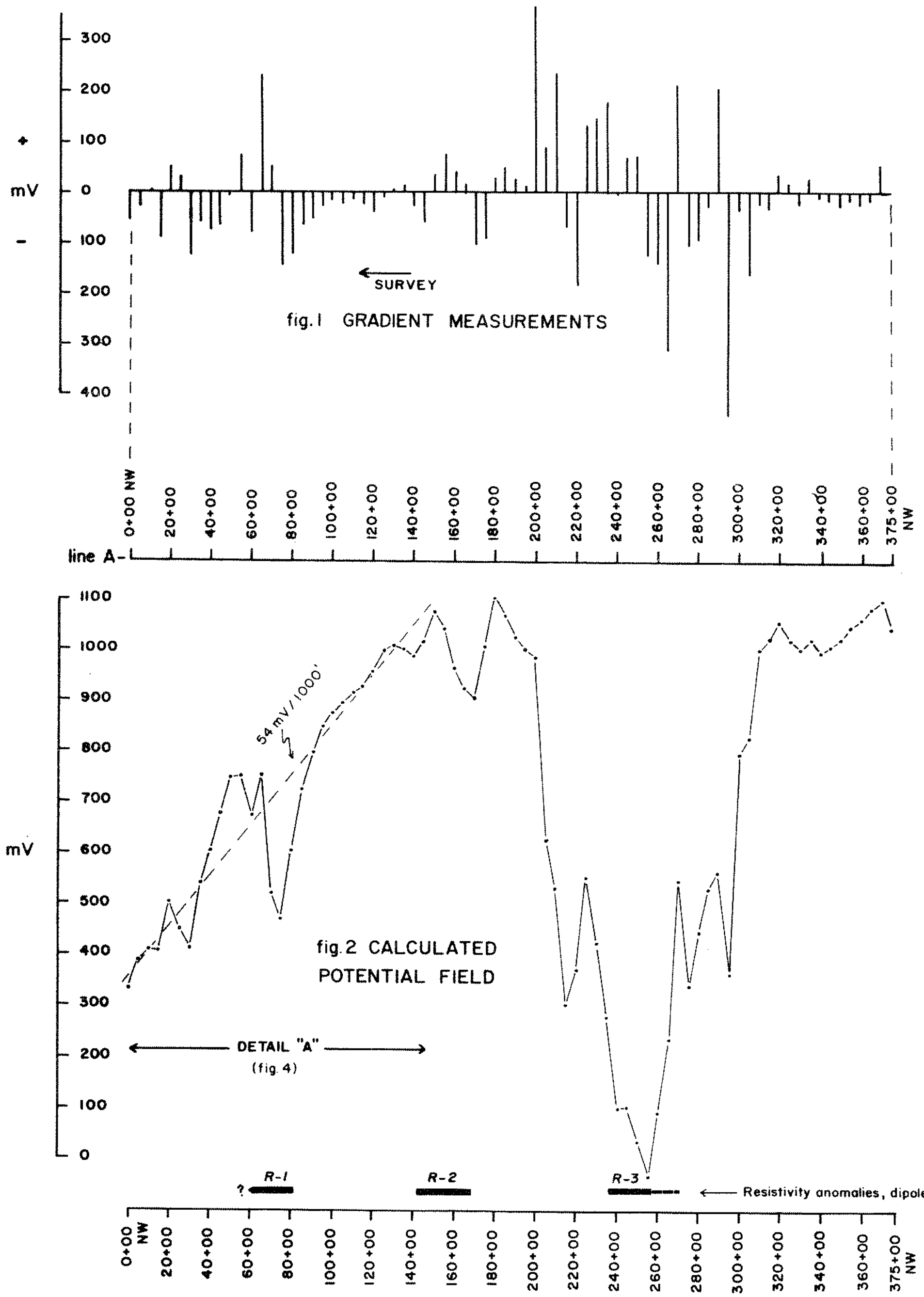


fig. 3 FILTERED DATA

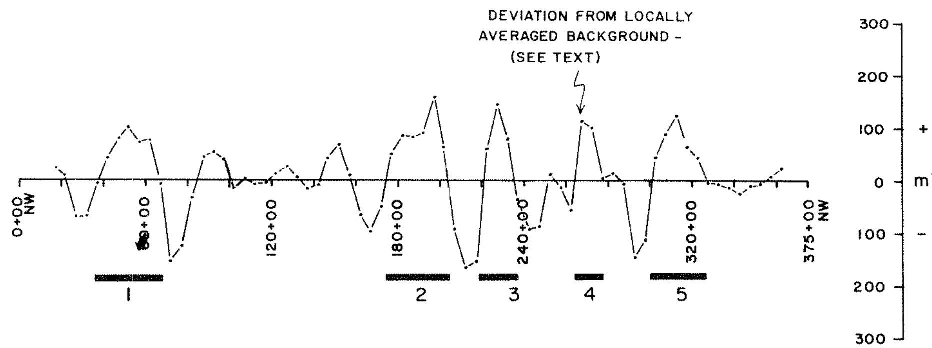
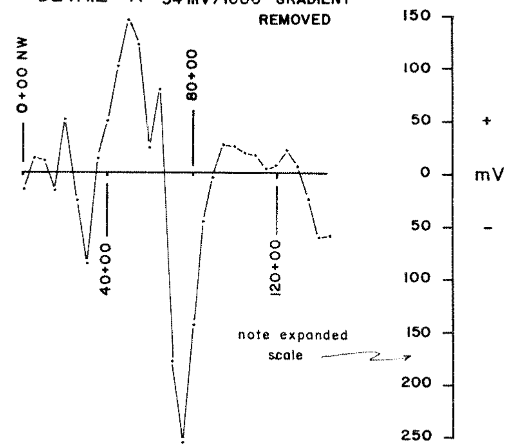


fig. 4 FILTERED DATA
DETAIL "A" 54 mV/1000' GRADIENT REMOVED



LINE A

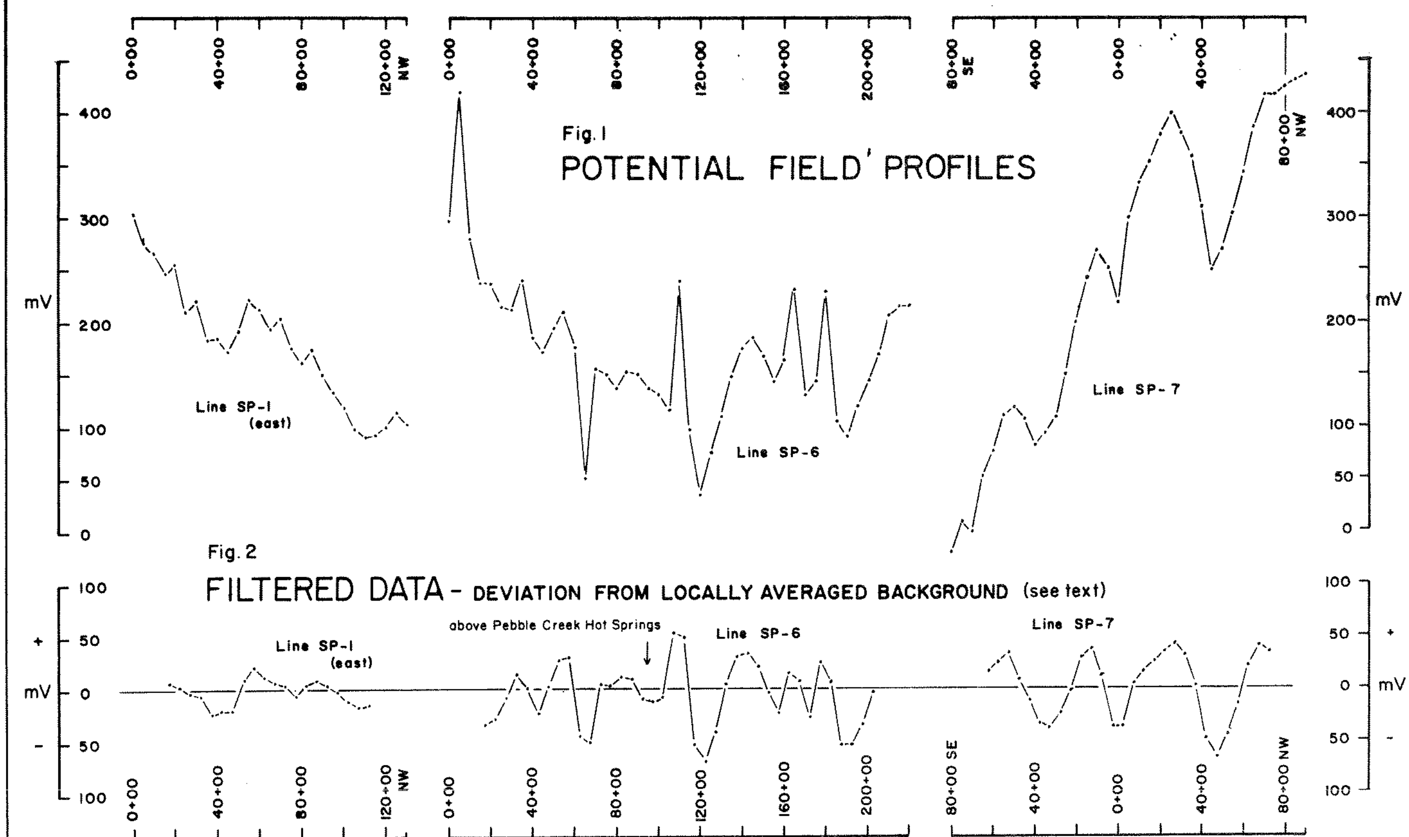
B.C. HYDRO AND POWER AUTHORITY	LINE A
GEOTHERMAL INVESTIGATION SELF-POTENTIAL (SP) SURVEY	
GEOPHYSICS - NE MEAGER MOUNTAIN VOLCANIC COMPLEX	
MEAGER CREEK SELECTED AREA, B.C.	
To accompany report TO NSBG UNDER BCH P.O. 653 072	
Date DEC, 1976 / Horiz Scale as shown	
DGA Project no 0476	Dwg no 4
DEEP GRID ANALYSIS, LTD. EXPLORATION GEOPHYSICS - VANCOUVER, B.C., CANADA	

Fig. 1

POTENTIAL FIELD PROFILES

Fig. 2

FILTERED DATA - DEVIATION FROM LOCALLY AVERAGED BACKGROUND (see text)



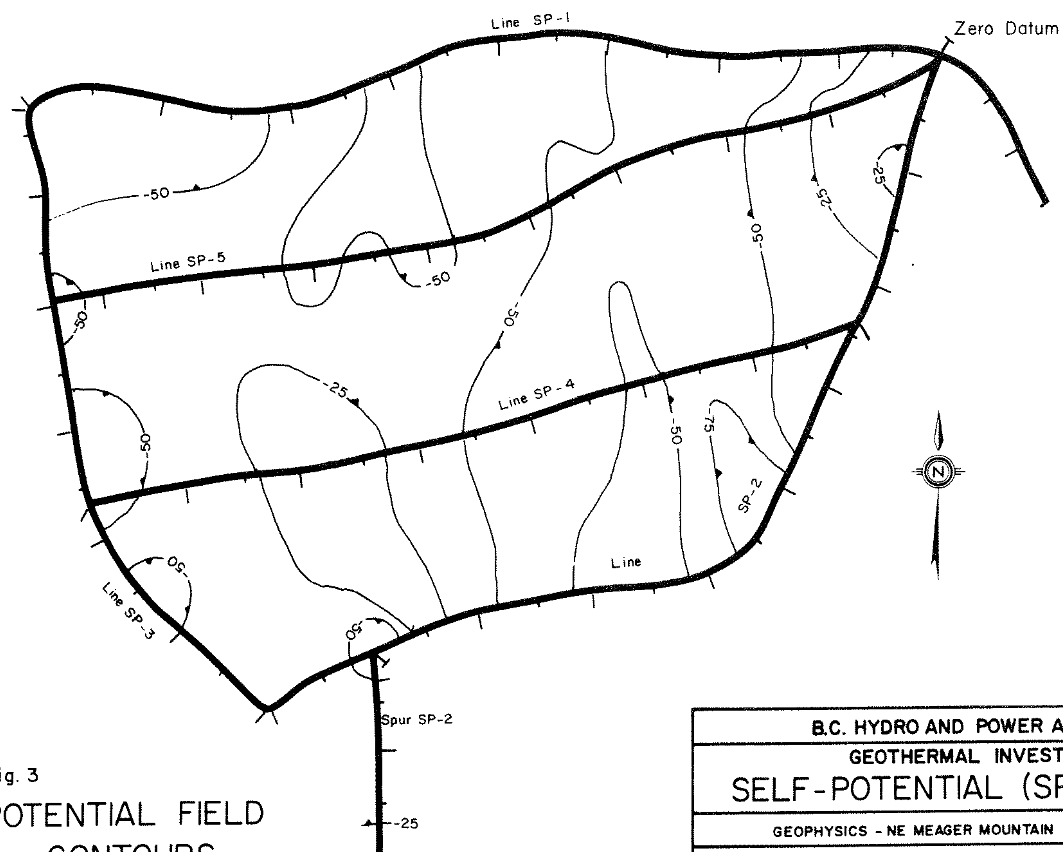


Fig. 3

POTENTIAL FIELD CONTOURS

in MILLIVOLTS

Lines SP-1 (west half), SP-2, SP-3, SP-4, SP-5

B.C. HYDRO AND POWER AUTHORITY

GEOTHERMAL INVESTIGATION

SELF-POTENTIAL (SP) SURVEY

GEOPHYSICS - NE MEAGER MOUNTAIN VOLCANIC COMPLEX

MEAGER CREEK SELECTED AREA, B.C.

To accompany report TO NSBG UNDER BCH P.O. 653 072

Date DEC 1976 | Horiz Scale as shown

DGA Project no 0476

DEEP GRID ANALYSIS, LTD.

EXPLORATION GEOPHYSICS - VANCOUVER, B.C., CANADA

LINES SP-1 to SP-7

5

57. MEAGER CREEK VOLCANIC COMPLEX, SOUTHWESTERN BRITISH COLUMBIA

Project 730067

Peter B. Read[1]
Regional and Economic Geology Division

Nearly 65 years ago hot springs were discovered along Meager Creek and Lillooet River west of their confluence in the west half of map-sheet 92 J (Robertson, 1911). During 1974 and 1975 a program consisting of water geochemistry, resistivity and self potential surveys, and diamond drilling totalling 2523 feet has contributed data for an assessment of the geothermal potential of the area. In the summer of 1976, nearly two months were devoted to mapping of the Pliocene and Recent volcanic rocks outcropping west of the junction of Meager Creek and Lillooet River. L. Hammerstrom, Department of Geological Sciences, University of British Columbia, is engaged in a detailed study of spring water geochemistry.

Nine volcanic assemblages of the Garibaldi Group form the Meager Creek Volcanic Complex. Andesite and dacite flows predominate and range in age from Pliocene and(?) Miocene to postglacial. The complex overlies a basement composed of Mesozoic plutonic and metamorphic rocks which are unconformably overlain by low grade metavolcanic rocks all of which are intruded locally by quartz monzonite stocks of presumed Miocene age. The hot springs issue from basement.

Meager Creek Volcanic Complex

In the complex, widespread andesite constitutes most of the older part which is best exposed in the south. In the northern half of the complex, younger dacite flows and lava domes overlie and intrude remnants of the formerly more extensive andesite flows. Approximately one third of the complex, most of it dacite, is postglacial in age. Nine volcanic assemblages comprising the complex and depicted in Figure 57.1 will be described in order of decreasing age.

1. Basal Breccia: Locally preserved remnants of breccia up to 300 m thick overlie basement on the south side of the complex. Clasts of granitic, grey or green aphanitic volcanic, and minor metamorphic rocks lie in a tuffaceous matrix. South of Pylon Peak, where the breccia is thickest, clasts less than 0.5 m long increase in size downwards to jumbled blocks of quartz diorite up to 20 m long with less than 10 per cent matrix. This area, where basement is lowest, may represent a partly exhumed vent and its southern edge apparently coincides in part with the northern margin of an area of anomalously low resistivity (Shore, 1975).

2. Porphyritic Quartz Dacite: In the southwest corner of the map-area, a grey-green dacite with sparse phenocrysts of quartz, plagioclase and hornblende forms a remnant of subhorizontal flows up to 200 m thick. Gently dipping acid tuff and breccia overlap the older dacite along a subvertical eastern contact.

3. Acid Tuff and Breccia: On the south and west flanks of Pylon Peak and The Devastator is a cream to yellow ochre weathering assemblage up to 500 m thick of acid volcanic rocks. They are hydrothermally altered quartz latite with locally preserved quartz, plagioclase and biotite phenocrysts. Silicification, pyritization and the development of ubiquitous clay minerals and sporadic carbonates characterize this unit. Crudely layered tuff and breccia, dipping gently northeastward, compose all but the eastern end of the unit. Here the quartz latite is massive and may represent either flows and/or hypabyssal intrusions of a partly preserved vent.

4. Aphanitic Flows and Minor Intrusions: Medium to dark grey aphanitic flows here and there overlie the basal breccia and acid volcanic units and a few dykes less than 50 m thick cut both units. On the south-southeast ridge of The Devastator a lens of conglomerate composed of subrounded pebbles and cobbles of this lithology overlies the acid volcanic unit.

5. Porphyritic Plagioclase Andesite: Porphyritic plagioclase andesite, the most extensive unit of the complex, forms most of the southern and western parts of the complex. Best outcrops are on Pylon Peak and The Devastator. Gently dipping flows are more extensive than basal and intercalated breccia and tuff, and dykes and plugs are restricted to The Devastator and possibly Peak 7927' at the head of Job Glacier. The maximum thickness may exceed 1200 m of flows south of Capricorn Creek. Flows are commonly flow-layered or have a subparallel platy jointing and thin reddened breccia and tuff lenses may separate flows up to 20 m thick. Monomictic breccias up to a few hundred metres thick of porphyritic plagioclase andesite clasts lie at or within a hundred metres of the base of this sequence. The monomictic composition and differential weathering of the clasts distinguish this breccia from the basal breccia unit. Close to The Devastator, angular clasts up to several metres long are common in breccia. The concentration of hypabyssal intrusions and coarse volcanic breccia in the vicinity of The Devastator favour it as a major andesite vent. Potassium argon dates of 4.2 ± 0.3 m.y. and 2.1 ± 0.2 m.y. (Anderson, 1975) indicate a long period of andesite volcanism spanned by this unit.

6. Hornblende-Biotite Rhyodacite: Surrounding Mount Job in the centre of the complex, are ochre-yellow weathering flows of porphyritic hornblende-biotite quartz rhyodacite. They are prominently flow-layered and locally have columnar jointing. At the head of

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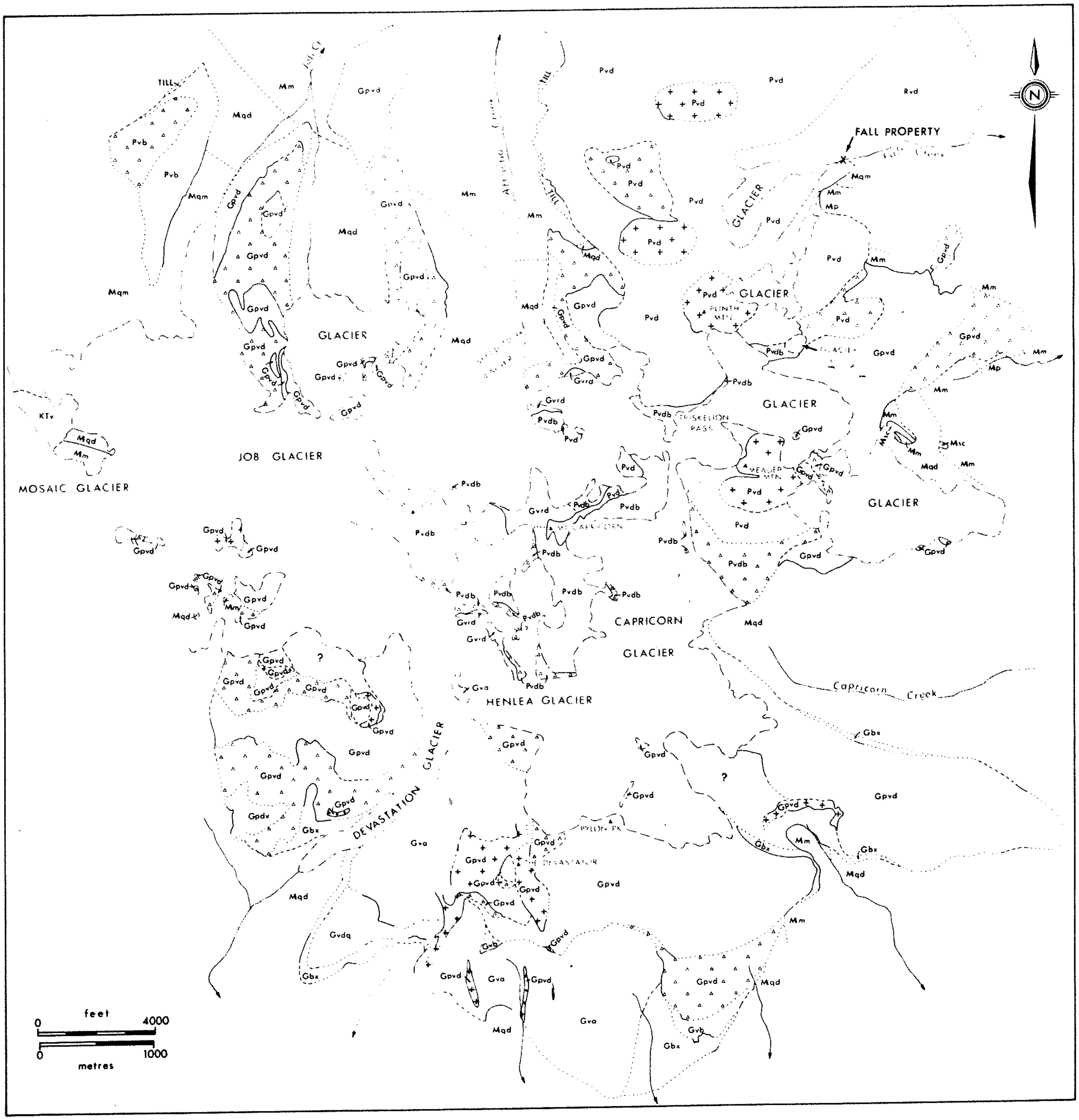
From: Report of Activities, Part A;
Geol. Surv. Can., Paper 77-1A (1977).



VOLCANIC COMPLEX

- Rvd Scoriaceous dacite
- Pvd Porphyritic dacite
  - breccia and tuff
  - hypabyssal intrusion
- Pvb Porphyritic (plagioclase, olivine) basalt
  - scoriaceous bombs, breccia and tuff
- Pvdb Porphyritic (biotite) dacite
  - breccia and tuff
- Gvrd Porphyritic (hornblende, biotite) rhyodacite
- Gpvd Porphyritic (plagioclase) andesite
  - breccia and tuff
  - hypabyssal intrusion
- Gvb Aphanitic flows
- Gva Acid tuff and breccia
- Gvdq Porphyritic (quartz) dacite
- Gbx Basal volcanic breccia

BASEMENT

- Mqm Biotite or biotite-hornblende quartz monzonite
- KTv Aphanitic flows and breccia
- Mqd Quartz diorite, diorite and quartz monzonite
- Mm Amphibolite
- Mp Phyllite and rusty schist
- Msc Marble

Figure 57.1. Simplified geological map of the Meager Creek Volcanic Complex.

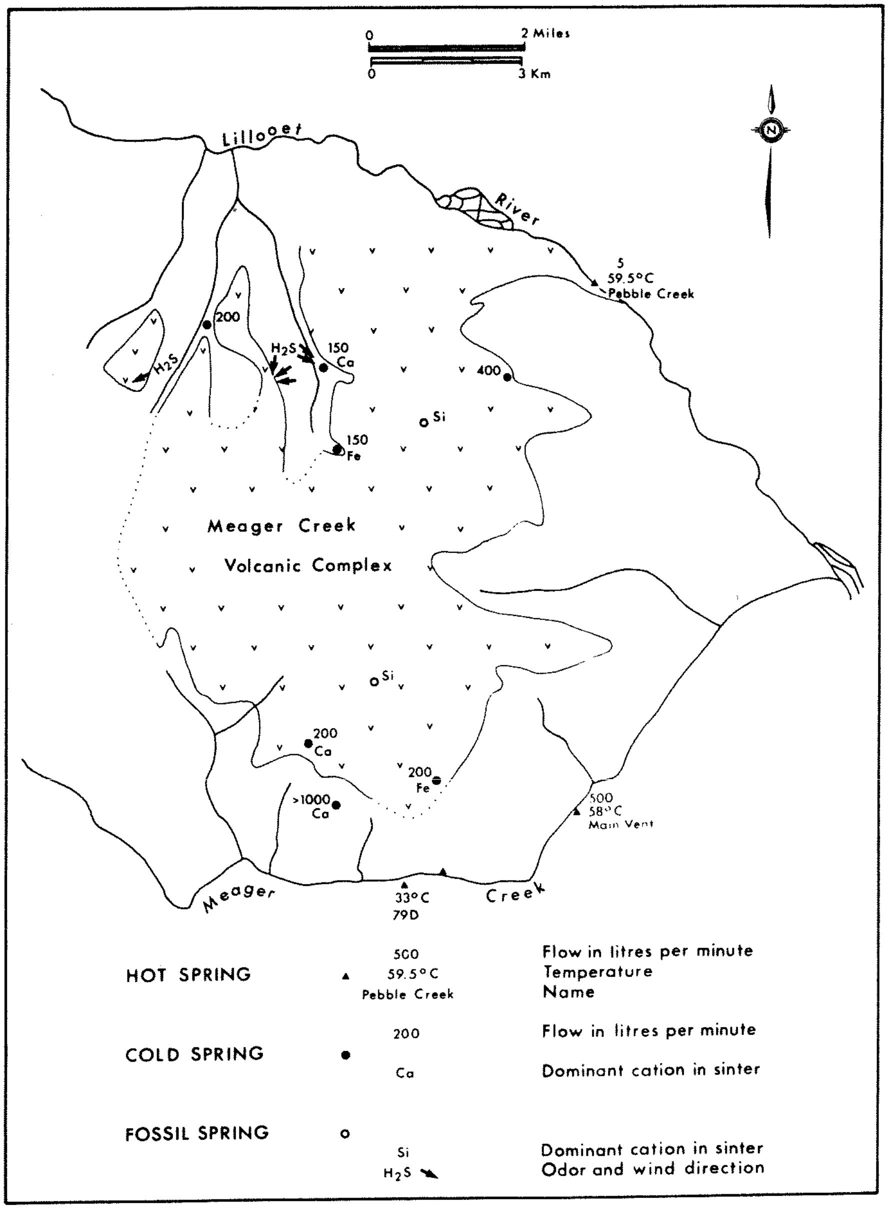


Figure 57. 2. Springs of the Meager Creek Volcanic Complex.

Affliction Glacier, the unit attains a maximum thickness of 500 m. On the east side of the glacier, it unconformably overlies porphyritic andesite and at the head of Affliction and Capricorn glaciers it is truncated by porphyritic biotite dacite of Mount Capricorn.

7. Porphyritic Biotite Dacite of Mounts Capricorn and Job: The final 600 vertical m of mounts Capricorn and Job are brick red to maroon-grey weathering dacite. Coarse phenocrysts (5 mm) of plagioclase, quartz, and biotite characterize this vesicular dacite. Angular clasts of dacite up to 2 m long form a basal breccia up to 100 m thick. Similar breccia is interspersed throughout the dacite. On Mount Job local platy and columnar jointing and layering suggest that flows form the bulk of the massif, but their absence on Mount Capricorn may favour this as a source of the eruptive rocks.

8. Porphyritic Dacite of Plinth and Meager Mountains: The top 600 m of Meager Mountain and the bulk of Plinth consists of a light grey porphyritic dacite with medium grained (2 - 4 mm) phenocrysts of plagioclase, quartz, minor biotite, and rare hornblende. The dacite is commonly vesicular, has a glassy matrix, and is distinguished from other dacites by scattered, rounded inclusions of fine grained hornblende andesite. On Meager Mountain, the absence of flows or breccia, and development of steeply inclined flow layering suggest that it is a plug or lava dome. In contrast, Plinth Mountain consists of prominent columnar- or platy-jointed flows and widespread breccia and ash on its northern flank. Only three areas on the north ridge and the flat-topped summit show steep to vertical flow layering and subhorizontal columnar jointing of possible plugs or lavas domes. On Plinth, attitudes of flows commonly are subparallel to topography and dips range from 30 to 60 degrees. East of Affliction Glacier and Creek, basal flows overlie a probable till.

The Bridge River ash incompletely blankets the area between the north and east ridges of Plinth. Within this area, crudely stratified breccia and ash deposits are up to 20 m deep on some ridges. Over 90 per cent of the clasts are cream-weathering, porphyritic (plagioclase, hornblende, pyroxene) dacite pumice. They range in maximum size from 10 cm on the summit of Plinth Mountain (Nasmith *et al.*, 1967) through 1 m at the 6500 foot level on the north ridge crest to 4 m blocks on the north side of the creek crossing the Fall Property at 4965'. Two per cent of the clasts are subrounded pebbles and cobbles of a porphyritic quartz monzonite exposed along the creek. These data strongly indicate the lower part of the valley as the source of the Bridge River ash.

The creek flows down the southern margin of a scoriaceous dacite flow which floors the present valley. Because Bridge River ash, which should thickly blanket this flow is absent, the flow must be younger than the ash (2440 ± 140 years B. P.) and probably covers the ash vent. Much of the edifice of Plinth Mountain is probably postglacial and that of Meager Mountain may be as well.

9. Olivine Basalt: A sparsely porphyritic plagioclase and olivine basalt underlies part of the ridge separating Job and Mosaic creeks. Flat-lying to southeasterly dipping flows parallel the present topography. On the northwest side of the ridge, basalt scoria and bombs comprise a breccia which overlies the flows and till.

Basement of the Meager Creek Volcanic Complex

Metamorphic and plutonic rocks form a highly irregular base to the complex with up to 1200 m of relief. Four units ranging in age from Mesozoic to Miocene are described in order of decreasing age.

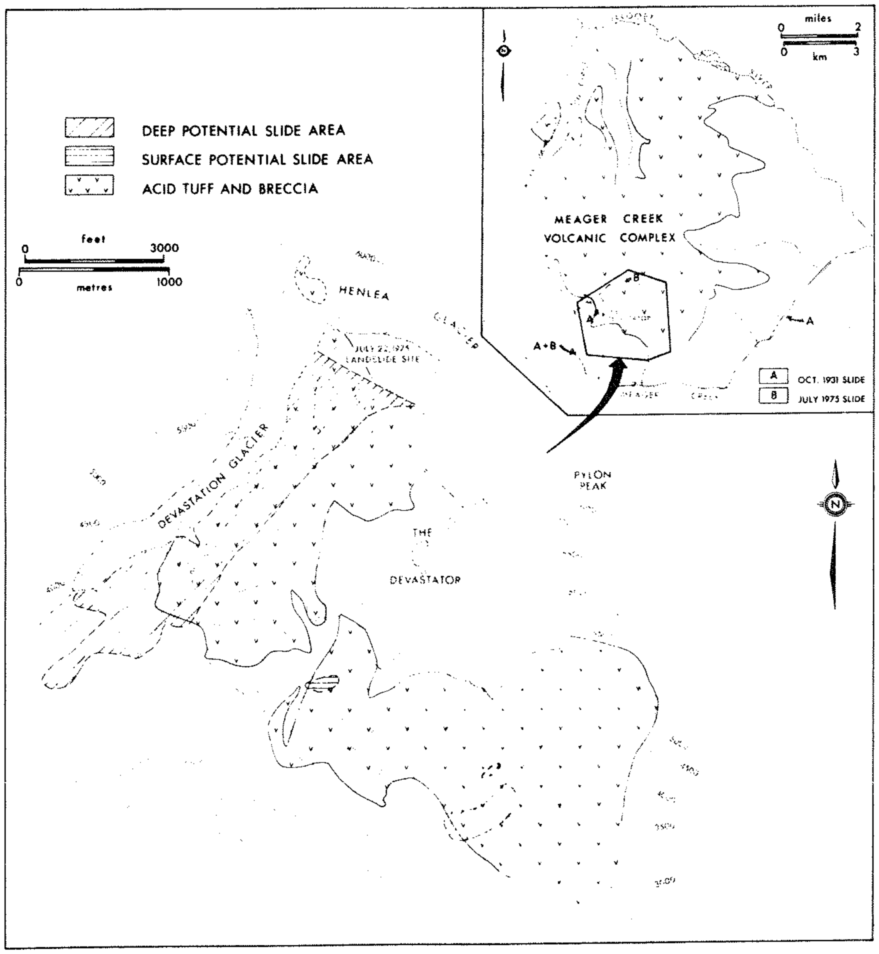


Figure 57. 3. Landslide potential of the Meager Creek Volcanic Complex.

1. Amphibolite, Grey Phyllite, and Marble: Mainly amphibolite, some grey phyllite, and rare marble underlie the northern part of the complex. Plutonic sills and dykes extensively intrude the strongly deformed and steeply dipping succession. The metamorphic rocks are part of a large septum of Upper Triassic to Lower Cretaceous rocks which extends 75 km along the Lillooet River from Lillooet Lake (Roddick and Hutchison, 1973) to Lillooet Glacier (Roddick and Woodsworth, 1976).

2. Quartz Diorite, Diorite, and Quartz Monzonite: Biotite-bearing hornblende quartz diorite and diorite and biotite quartz monzonite underlie most of the complex. Sporadically developed foliation strikes west-northwesterly with a steep dip and parallels trends of the older metamorphic rocks.

3. Volcanic Breccia and Flows: Weakly deformed and metamorphosed flows and breccia underlie the west side of the complex. A basal breccia composed of plutonic, metamorphic and volcanic detritus ranges in thickness from a few tens to hundreds of metres. Dark grey to light grey-green aphanitic flows with intercalated volcanic breccias containing plutonic clasts comprise a sequence over 500 m thick. The rocks are unfoliated and metamorphosed in the subgreenschist facies. Because the sequence nonconformably overlies the previously described plutonic rocks and rocks of possible Miocene age intrude it, a Cretaceous or Early Tertiary age is likely.

4. Miocene(?) Stocks: From the east end of the complex, Fall Creek stock extends eastward to and beyond the limits of the map-area. The biotite (3%) leuco-quartz monzonite stock has fine grained and pegmatite phases. Locally, sulphides including molybdenite fill closely spaced fractures as on the Fall Property.

From Job Glacier to beyond the western limit of the map-area is the yellow to ochre weathering quartz monzonite of Job Glacier stock. On the west side of Job Glacier, the medium grained (1 to 2 mm) hornblende biotite (8%) leucoquartz monzonite stock has closely spaced fractures filled with pyrite. Adjacent to the fractures, intense hydrothermal alteration produces a porous rock from the quartz monzonite, and elsewhere propylitic alteration is common.

Because these stocks are lithologically similar to Salal Creek stock of Miocene age and because Job Glacier stock is the youngest of the basement units, Job Glacier and Fall Creek stocks are probably of Miocene age.

Springs

Included within springs are hot springs which issue from basement, cold springs flowing from basement or the complex, and fossil spring areas found only in the complex (Figure 57. 2). Of the several odorless cold springs found, most have flows in the 50 to 250 litres per minute range and deposit carbonate or hydrated iron oxide sinters. No new hot springs were discovered, but during calm, dull days a strong H_2S odor drifts up the valley of Affliction Creek. Because known hot springs in the area are nearly odorless (Nevin, pers. comm., 1976), the odor may indicate an undiscovered hot spring within the lower course of Affliction Creek or the immediately adjacent Lillooet River. Fossil spring areas are characterized by opaline sinter encrusting joint surfaces over areas less than a 100 m square.

Landslide Potential

Within the last 45 years, three slides of rock, mud, water and ice mixtures have flowed down Meager Creek (Patton, 1976). The earliest one in October 1931 originated on the west flank of The Devastator and flowed down the length of Meager valley (Carter, 1932) (Figure 57. 3). Little is known of a slide which occurred in 1947. The recent slide of July 22, 1975, originated between the 5300 and 6600 foot levels on the southern edge of Henlea Glacier above its confluence with Devastation Glacier. Failure of a water-saturated slope of the acid tuff and breccia unit between the 5300 and 6000 foot levels removed support from the overlying basal breccia of the porphyritic plagiocalse andesite unit. Bedrock of these units plus ground moraine and ice flowed down Devastation Glacier, destabilized the base of slopes underlain by the acid tuff and breccia unit on the east side of Devastation Glacier, and caused massive slumping of this unit which was incorporated in the slide mass. The slide path was 7 km long. The acid tuff and breccia unit underlies most potential slide areas, of which the largest potential slide masses lie on the western flanks of The Devastator overlooking Devastation Glacier which is receding and removing its support from the base of the slopes. On the western valley wall at the head of the west fork of Job Creek is a potential block slide area.

Economic Geology

Because of the proximity of the Salal Creek deposit (Mo) and Fall Property to Job Glacier stock, this locally pyritized and hydrothermally altered stock of possible Miocene age requires additional investigation. The hydrothermally altered and pyritized acid tuff and breccia unit, known to be older than 4.2 m.y., may be an eruptive equivalent of the Miocene stocks and deserves further attention.

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APPENDIX 'C' - Preliminary Reports on Magnetotelluric Studies

Magnetotellurics: 1975, Extracted Comments on EMR - University of British Columbia Studies by Dr. L.K. Law, Division of Geomagnetism, Energy, Mines & Resources, Victoria, British Columbia.

... As a general comment the frequency range from .01 to 100 Hz appears most useful for reconnaissance M.T. projects in geothermal areas. In theory the M.T. method should be very diagnostic, in practice it has not had many successes, but I remain cautiously optimistic....

Meager Creek. A base station was set up at the Nevin Sadlier-Brown Goodbrand Ltd. camp. This station digitally recorded 3 components of the magnetic field at 60 sec. sampling intervals with a pass band of 3×10^4 to 10^2 sec simultaneously with some of the operation in the Pemberton Region. In addition 3 magnetic and 2 telluric components were recorded on slow speed F.M. tape with a pass band of 3×10^2 to 1 sec. A similar instrument recorded the 5 components at each of 3 satellite stations along Meager Creek

Because of the transfer to Ottawa of one of the investigators these data have not been computer analysed to date. Visual inspection of the records indicates some differences between the amplitude of the components at the sites; whether this is related to changes in the conductive valley fill or deeper layers is not known at present.

Pemberton Region. Stations were established at Alta Lake, Pemberton and D'Arcy along a line crossing the Lillooet Valley. Three components of the magnetic field were digitally recorded at 1 minute sampling intervals with a pass band of 3×10^4 to 10^2 sec. Also the telluric and magnetic components (5) were recorded on low speed F.M. tape with a pass band of (3×10^2 to 1 sec.).

Preliminary analysis indicates some structural feature (dipping fault) between Pemberton and D'Arcy. The deep higher conducting layer under Alta and Pemberton appears to be considerably deeper or absent under D'Arcy.

APPENDIX 'C' (Cont'd)

Magnetotellurics: 1976, Report on Reconnaissance Survey in the Lillooet Valley of British Columbia, by Pham Van Ngoc, Mineral Exploration & Resources Institute, Ecole Polytechnique/McGill University, Montreal, P.Q.

A reconnaissance magneto-telluric survey consisting of five sounding stations (frequency range 0.1 hz - 500 Hz) and forty profile stations (frequency range 1 Hz - 1,700 Hz), distributed along four profiles, was carried out in the Lillooet Valley of British Columbia during the summer of 1976. The work was done at three test sites situated along the valley between Pemberton Meadows and Meager Mountain.

The results indicate the presence of two layers in the surficial, unconsolidated, deposits. The first of these which has a thickness range between 45 to 65 meters and a resistivity in the range of 1000 to 3000 ohm-meters corresponds to gravel. The second layer which is quite thin (5 meters), and rather conductive, (2 - 5 ohm-m), reposes directly on the basement rocks and was interpreted to be composed of volcanic ash.

The basement shows the unusual feature of being alternately isotropic and anisotropic from one test site to the next with approximate principal directions along geographic North-South and East-West. The basement resistivity is uniform, at all test sites, along the E-W direction, and, has a value of about 20,000 ohm-m. Along the N-S direction, however, the basement resistivity can be lower than 100 ohm-m at sites 1 and 3 whereas it is about equal to E-W resistivity (20 K ohm-m.) at site 2. This phenomenon could be caused by the presence of large zones of nearly vertical fracturing attributable to a N-S rift system which is related to the Garibaldi volcanic belt.

Finally, the magneto-telluric sounding results indicate that the crust, in the survey area, is relatively thin. A thickness of 20 Km is interpreted for this formation which rests on a deep layer of high conductivity (10 ohm-m). It is possible that sources of intense heat are available at the crustal base in this high conductivity layer.

Attached: Figure 1. - Geographical location of measure sites.

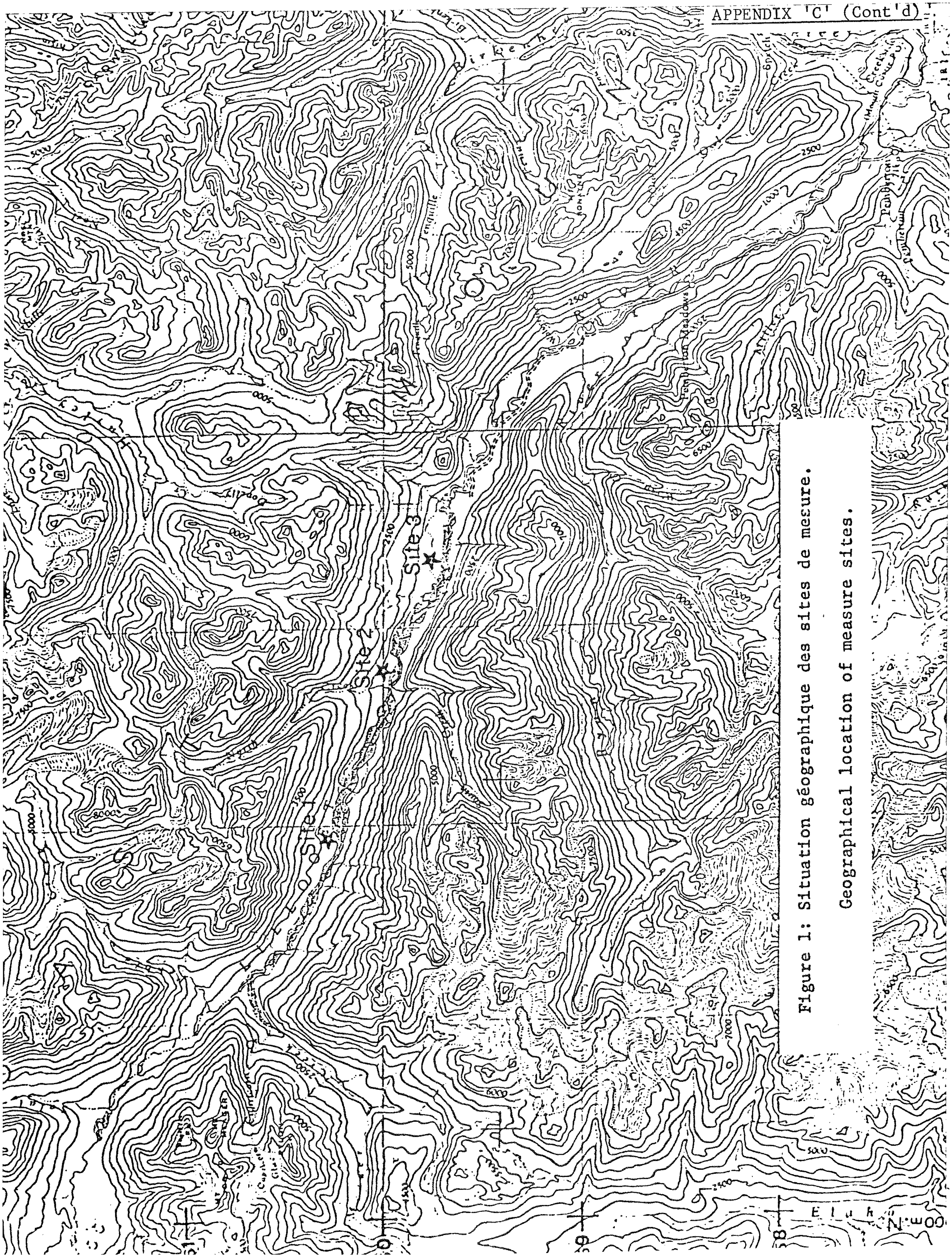

Figure 1: Situation géographique des sites de mesure.

Geographical location of measure sites.

58. GEOCHEMISTRY OF THERMAL WATERS IN THE MOUNT MEAGER HOTSPRINGS AREA, BRITISH COLUMBIA

Project 730067

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Introduction

The Mount Meager hotsprings area, a potential geothermal energy source, has been the object of separate studies for the past three years by the Department of Energy, Mines and Resources (Souther, in press) and by the British Columbia Hydro and Power Authority (Nevin *et al.*). Temperature gradients, water flow, and rock types have been determined from six shallow exploratory wells (maximum depth of 347 m) drilled in the Meager Creek valley. Substantial geophysical work has also been undertaken in an attempt to construct a physical model of the subterranean reservoir.

This project is concerned with the chemistry of the thermal spring waters and surficial fresh waters of the Mount Meager area. Analyses of the waters will provide the data necessary to construct thermodynamic models of the possible reservoir conditions using basic mass transfer principles of water-rock interactions.. These models will be applied to determine if alteration products observed in the well cores are the result of the thermal waters reacting with the host rock. In addition, attempts will be made to estimate the maximum water temperature within the reservoir using existing or new geothermometer principles.

The Mount Meager hotsprings area is 160 km north of Vancouver, British Columbia, near the headwaters of the Lillooet River (Fig. 58.1). The hotsprings outflow ranges from seeps in glacio-fluvial deposits and fractured bedrock to substantial artesian flows from the 4 inch drill stems. The springs are found at an approximate elevation of 730 m a.s.l. along the banks of Meager Creek and the Lillooet River.

Access to the area is usually by helicopter either from a base at Alta Lake, British Columbia approximately 60 km to the southeast, or from a rough helipad on the

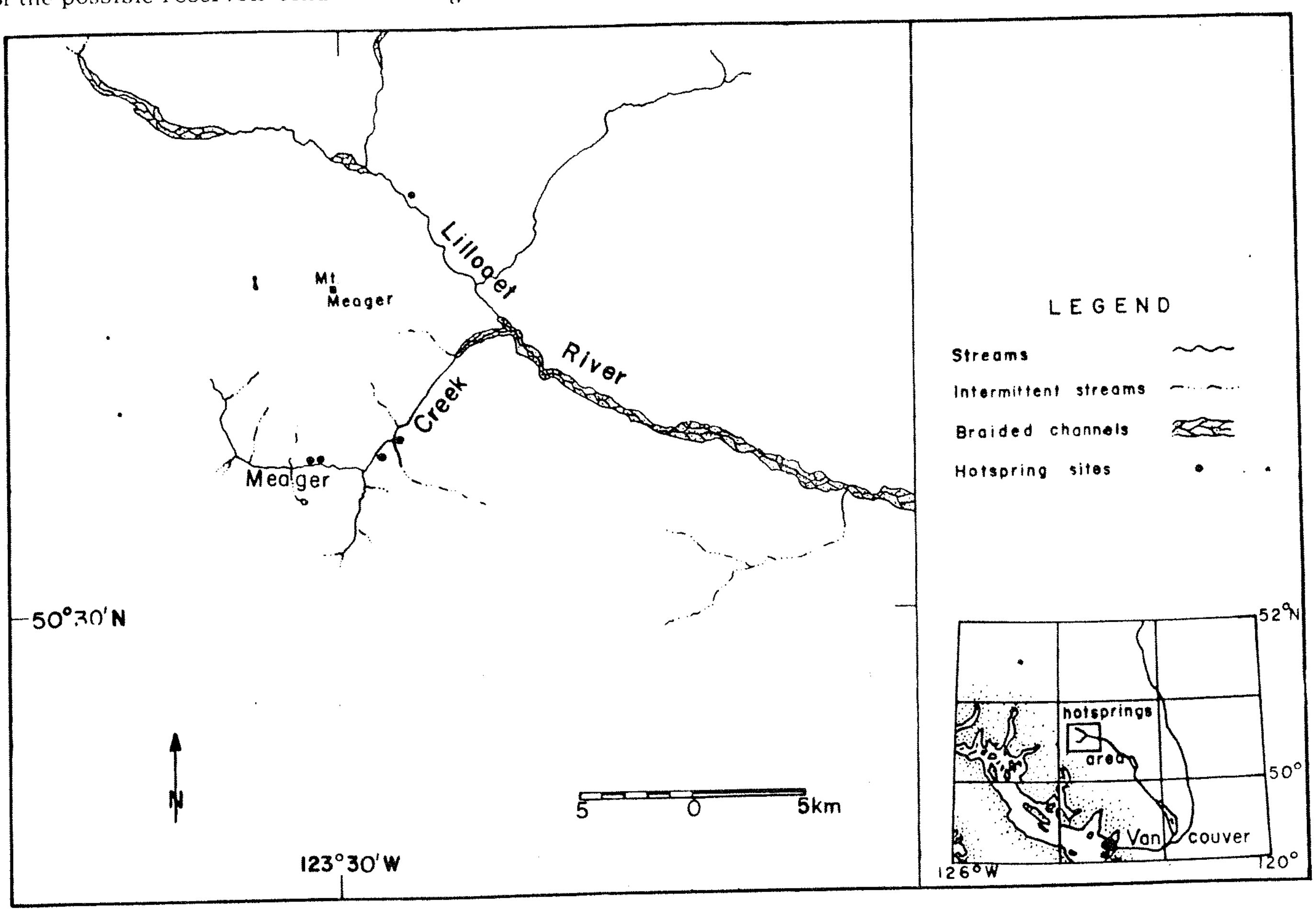

Figure 58.1. Hotsprings locations (•) in the Mount Meager area, British Columbia.

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From: Report of Activities, Part A;
Geol. Surv. Can., Paper 77-1A (1977).

Table 58.1

Analytical results for hotspring waters in ppm.

Site	Location	pH	T°C	SiO_2 ("reactive")	Cl^-	SO_4^{-2}	Na^+	K^+	Ca^{+2}	Mg^{+2}
01	Meager	6.50	31.4	56.0	133	12.5	165	23.7	19.0	15.4
03	Meager	6.80	30.0	54.0	295	12.5	248	27.0	19.5	17.1
05	Meager	6.40	48.0	80.5	428	28.8	347	44.0	5.6	24.8
06	Meager	6.05	56.0	92.0	466	40.0	377	46.2	13.0	34.1
07	Lillooet	7.70	53.5	40.0	72	45.6	410	13.8	6.0	6.6
08	Lillooet	6.85	59.0	43.0	67	45.6	396	18.2	5.4	6.1

southwest bank of the Lillooet River 20 km downstream from the hotsprings area. Access from the nearest private logging road requires a 10 km hike into either the Meager Creek or Lillooet River hotsprings.

The initial reconnaissance and sampling trip into the Meager Creek area occurred July 30 — August 3, 1976. Three hot springs, one drill site, and two freshwater streams were sampled. A second trip was undertaken from September 1 — September 5, 1976, to the hotspring site on the Lillooet River (Fig. 58.1). Samples were taken from two hotsprings and two freshwater streams. Tentative plans call for continued sampling of the Meager Creek area on a monthly basis throughout the winter of 1976-1977, to determine if temporal changes occur in the hotsprings' chemistry.

Sampling Procedure

The sampling procedure used in this study was developed by Presser and Barnes (1974) of the U.S. Geological Survey and requires 3.4 litres of sample water per site. The sample water is stored in polyethylene bottles which have been cleaned previously with a 10 per cent nitric acid solution.

At each site water temperature and pH were recorded. The pH was determined with a meter capable of temperature compensation. On the first trip a portable Hach model 1975 pH meter was used. On the second trip an Orion model 407A specific ion meter was used and this meter will be used for all subsequent analyses. Both meters used an Orion model 90-01 reference electrode and an Orion model 91-01-00 pH electrode.

The water sampling involves initial filtration with Whatman no. 4 filter papers using a hand operated vacuum pump to provide the suction. Three one litre bottles are collected. Two are acidified to approximately pH 2 by the addition of 10 ml of concentrated nitric acid, and the remaining one litre is left untreated. Three 125 ml bottles are filled with 100 ml of sample. One is acidified by the addition of concentrated hydrochloric acid to approximately pH 2 and two are duplicates for sulfide determination. For silica determination a fourth 125 ml bottle is filled with 90 ml of distilled water and 10 ml of sample, which has been filtered through a 0.01 micron Sartorius membrane filter to remove the colloidal silicic acid. For the winter sampling period the total volume of water will be decreased to 2.1 litres because of weight and volume considerations during transport.

Preliminary Results

Analyses have been completed for "reactive" silica, chloride, sulphate, sodium, potassium, calcium, and magnesium ions. The results in parts per million (ppm) for the six hotspring sites are shown in Table 58.1.

The "reactive" silica and sulphate were determined by spectrophotometric analyses, the chloride by a chloride specific ion electrode, and the four major cations by atomic absorption methods. Other species to be analyzed include sulphide, total carbonate, bicarbonate, aluminum, lithium, strontium, trace metals (Mn, Fe, Cu, Pb, Zn), iodide, bromide, fluoride, phosphate, nitrate, and total silica.

From the concentrations given in Table 58.1 there seem to be significant differences between each hotspring site. When the data is converted from parts per million to molalities and with the use of activity coefficients, to activities, it becomes more thermodynamically useful. The activities for the cations can be placed in a ratio with the pH to represent the chemical potential of the oxide components. For example, the chemical potential of the component MgO can be represented as $\ln a_{Mg^{+2}}/a^2_{H^+}$. Tentative results of the activity ratios indicate little variation among the Meager Creek hotspring sites, which suggests they all could originate from the same thermal reservoir system. However, comparing Meager Creek hotsprings' activity ratios to the Lillooet River hotsprings' activity ratios indicates a significant difference in the chemistry of the two hotsprings areas. This could mean that the Lillooet River hotspring, sites may originate from a different thermal reservoir system than the Meager Creek hotsprings. The Lillooet River hotsprings are far from electrical neutrality when the difference between the total molalities of anions and cations for each site are considered. However, the Meager Creek hotsprings, sites are nearly neutral, which indicates that the major solution components have been accounted for. By inspection of the data the Meager Creek hotsprings appear to be a predominantly NaCl solution, but the Lillooet River hotsprings have the highest Na^+ molality and the lowest Cl^- molality of all the hotsprings. The only common anion not presently analyzed for is bicarbonate which will probably be the major anion at the Lillooet River hotsprings. A large amount of bicarbonate at the Lillooet River hotsprings would satisfy the electrical neutrality of the solution and it would provide an anion for the excessive sodium cation. Therefore the Meager Creek hotsprings area may be part of a thermal reservoir system with a characteristic NaCl solution and the Lillooet River hotsprings may be part of a separate thermal reservoir system with a characteristic Na_2CO_3 solution. It must be stressed that this is a tentative conclusion and may not be borne out by further analyses.

Future work will consist of monthly sample collection, chemical analyses, and data processing. It is hoped that this work and the resultant thermodynamic models may lead to a better understanding of the Mount Meager thermal system.

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