Report on Analysis of Dipole-Dipole Resistivity Data,

Meager Creek, British Columbia

for

Premier Geophysics Inc.

by

Stanley H. Ward

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1.0 Introduction

1.1 The Assignment and Data Base

At the request of Greg A. Shore, President, Premier Geophysics Inc., a one day analysis was made (May 6, 1981) of the dipole-dipole resistivity data accomulated at Meager Creek during the interval 1974-80. The results of three Schlumberger soundings were taken into account in interpreting the dipole-dipole data, but the Schlumberger data was not separately interpreted in a rigorous manner. No study was made of available pole-pole resistivity data since such would have been beyond the scope of the request for consultation.

In interpreting the dipole-dipole resistivity data I benefitted from extensive discussions with Greg A. Shore and from brief discussions with Brian Fairbank of Nevin Sadlier-Brown Goodbrand Ltd. Account was taken of current knowledge of topography, geology, drill hole information, brine chemistry, tectonic history, ages of extrusive rocks, and preliminary quantitative interpretation of a single profile of dipole-dipole data (interpretation of Line K by Claron Makelprang of the Earth Science Laboratory of the University of Utah Research Institute). My previous knowledge of the Meager Creek geothermal prospect was acquired through discussions with personnel of Nevin Sadlier-Brown Goodbrand Ltd., through a one day visit to the property, courtesy of the latter firm, and through study of the literature referenced herein.

1.2 Presentation of Analysis

A plan map at a scale of 1:20,000 to be overlayed on the geologic map (GSC Open File 603) of Peter B. Read, is used herein to present the significant resistivity lows found in the analysis. The correlation between geology, geophysics, and thermal springs is thereby afforded.

2.0 Pertinent Geologic Features

2.1 Regional and Local Trends of Eruptive Centres

Figure 1 (Lewis and Souther, 1978) illustrates the NNW trend of the Garibaldi belt of Quaternary volcanism. Locally, between Meager Creek and the Lillooet River and possibly beyond to the Bridge River, the trend lies almost due north as shown in Figure 2 (from Roddick and Woodsworth, 1975). These authors state that "This belt thus appears to be the locus of a major fracture system that persisted from at least Miocene to Recent time." Potassium-Argon dates of extrusives are shown to the right of this figure. Figure 3 (from Read, 1978) shows the locations and ages of volcanic vents between Meager Creek and the Lillooet River. The axis of the vent system and the eastern and western bounds of it are superposed on this latter figure.

2.2 Mapped Local Faults

Souther (1980), in reporting on the Central Garibaldi Belt, notes that "The only basement structures that appear to be related to the volcanic belt are north-northwesterly trending, gouge-filled fractures." Read (1978) observes that "Springs and volcanic vents trend northerly and are spatially associated, particularly if the estimated position of the subcrop of Meager hot springs is considered." ...."Fracturing during rhyodacite volcanism in these vent areas probably produced the necessary permeability to depth in the basement, which permits deep circulation of the spring waters in this area of abnormally high heat flow." Fairbank (personal communication)

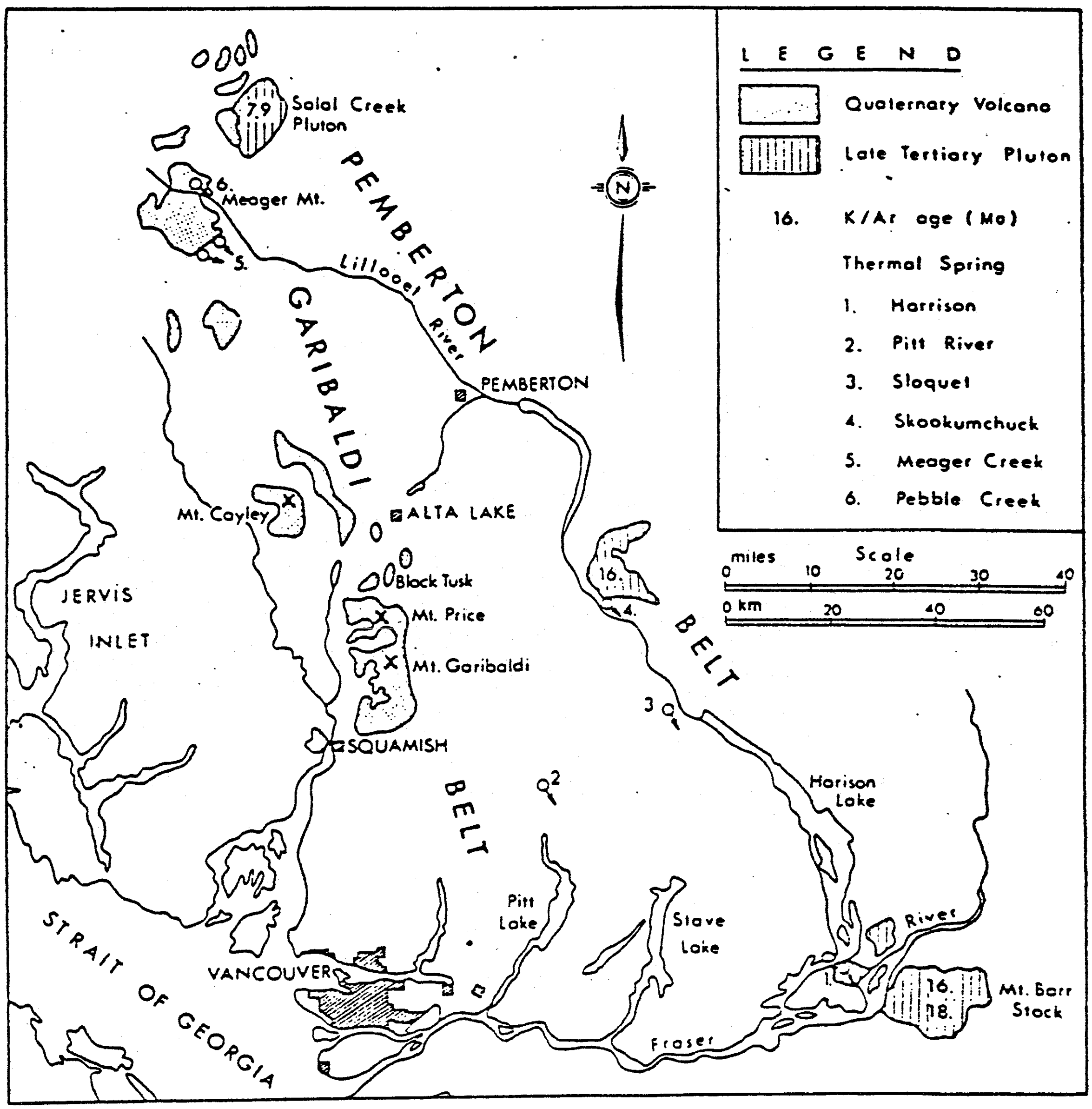

FIG. 1 The Pemberton belt of late Tertiary plutons and the Garibaldi belt of Quaternary volcanoes (from Lewis and Souther 1978).

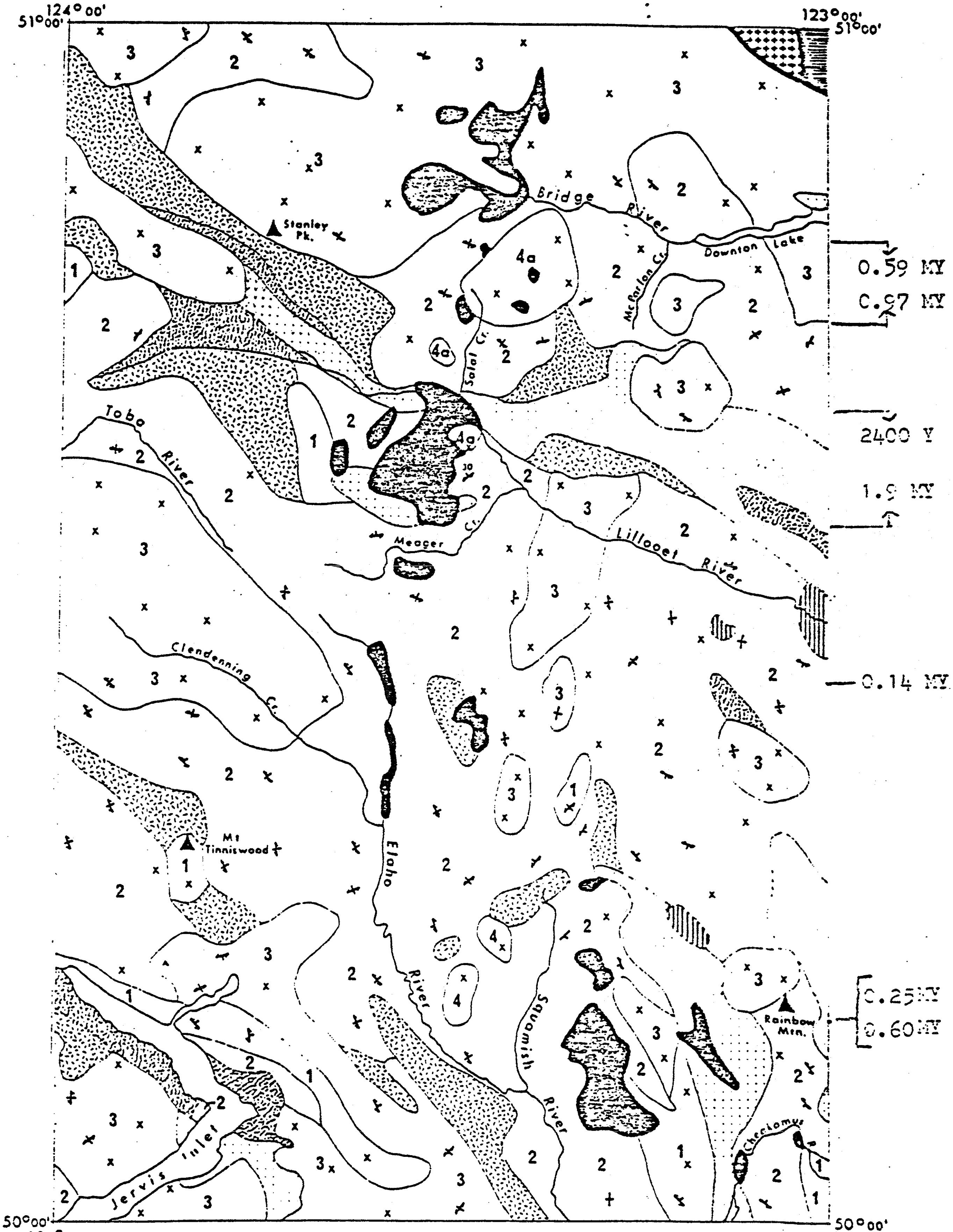

Fig. 2 Distribution of Quaternary rocks (dark areas) and their age distributions. (After Roddick and Woodsworth (1975).

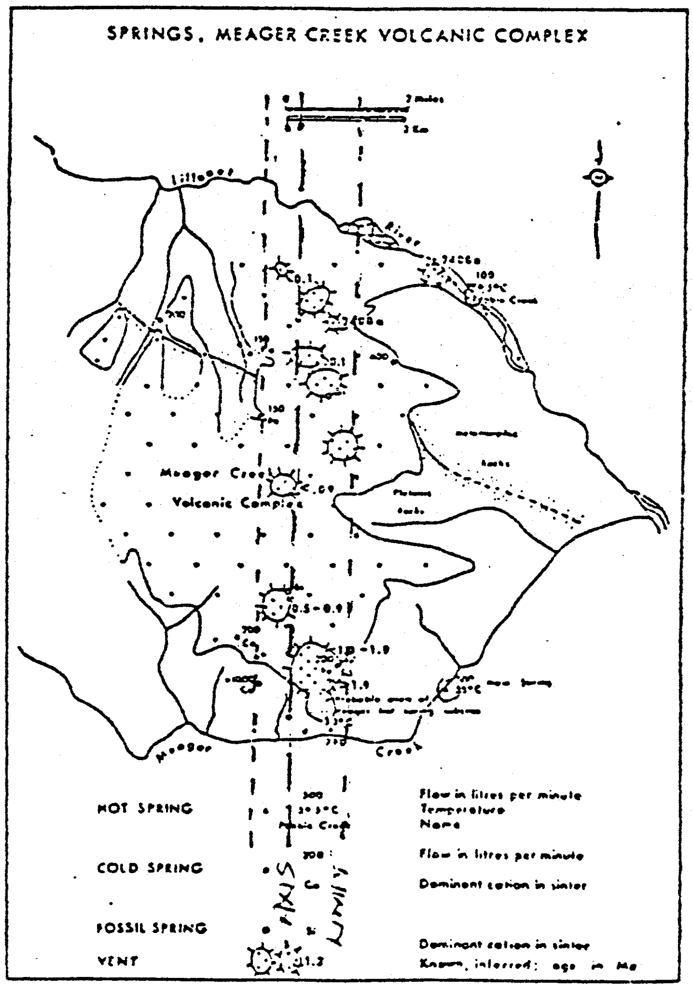

Fig. 3. Meager Creek volcanic vents
(after Read, 1978)

observes a dominant 130° fracture set dipping 60°SW and a secondary 20° fracture set dipping vertically. He observes some faults parallel to these trends. North-south fractures are strong and consistent. Fractures radial to the Meager Creek volcanic complex are not observed. Meager Creek appears to lie along an east-west fault dipping 45° to the north.

2.3 The Conceptual Model Implied by Local Volcanic and Structural Trends

The heat source would appear to be a linear NS trend of intrusives associated with the volcanic vents of Figure 3. Pulses of magma evidently introduced heat and fracturing along this NS trend. Where the topography has been deeply dissected, as at Meager Creek and the east-west segment of the Lillooet River to the north, access to high temperature regimes (~200°C) is afforded. The south fork of Meager Creek may afford the same deep access, although the potential source of heat south of Meager Creek is currently unknown. Barr Creek and Hot Spring Creek may also afford access to warm or hot fluids. Hot springs vent along fractures associated with the deeply dissecting valleys but the waters so vented are not intimately connected with the deep high temperature convective hydrothermal system (Hammerstrom and Brown, 1977). The drilling target would appear to be a fracture or preferably an intersection of fractures, of any orientation, at a depth sufficient to penetrate the deep high temperature part of this convective hydrothermal system. The system is conceptually bounded on the east and west by the dotted lines shown in Figure 3.

2.4 The Dipping Sheet Model (South Reservoir) of Nevin Sadlier-Brown Goodbrand Ltd.

Quoting Nevin et al (1978), "The south or Meager Creek Reservoir as it is presently known, is a tabular body which occupies about 5 sq. km and dips to the north under the volcanic edifice. The leading hypothesis is that it consists of a slow discharge-plume from a presumably permeable feeder pipe for the southernmost volcanics..."

2.5 Sources of Low Resistivity near a Convective Hydrothermal System

Brine saturated alluvium will exhibit resistivities in the 1 to 10 ohm metre range. Brines and associated clay alteration of feldspars will lower the resistivity in the close vicinity of a fracture in rock. The otherwise impermeable quartz diorite basement at Meager Creek will only possess low resistivities where highly fractured; the resistivities of such reservoir rocks ought to lie in the range 10 to 100 ohm metres.

3.0 Depth of Exploration and the "Lateral Range" of Dipole-Dipole Resistivity Surveys

The depth of exploration, d, of dipole-dipole resistivity surveys is conventionally given as

$$d=0.2(n+2)a$$

where n is the spacing (n-1,2,3,-6) and a is the dipole length. Thus for n=6 and a=1000 ft, the depth of exploration is 1600 ft. while for n=4 and a=1000 ft, it is 1200 ft. Recent work suggests that this formula is slightly pessimistic and that the simpler formula

$$d=2a \text{ to } 3a (\text{for } n=6)$$

is more appropriate. This would increase the depth of exploration for 1000 ft dipoles to 2000 ft to 3000 ft.

The lateral range of the method is the same, numerically, as the depth of exploration. Hence resistivity contrasts within about 2000 ft on either side of a 1000 ft dipole-dipole traverse line will affect the data and, unless great care is taken, may be interpreted to lie vertically below the traverse line.

4.0 Data Interpretation

4.1 Procedures

The pseudosections of apparent resistivity obtained with the dipole-dipole survey method were interpreted qualitatively with due regard for the factors entering the discussions of 2.5 and 3.0 above. Zones of low resistivity which are believed to be of significance to delineating the convective hydrothermal system have been marked on Figure 4, which is an overlay for Peter B. Read's 1:20,000 geologic map of Open File 603, Geological Survey of Canada. For Line K, a preliminary quantitative interpretation was available as noted earlier. The zones of anomalously low resistivity have been correlated with geology and topography for purposes of discussion.

4.2 South Reservoir

The resistivity low in the vicinity of the so-called South Reservoir is defined by resistivity data on lines D, K, and T, as follows:

4.2.1. Line D

There is an abrupt increase in resistivity west of 110W on Line D, approximately at the location of No Good Creek. East of 110W on this line, the resistivities are low to 10E, but from about 90W to 10E they are underlain by much higher resistivities. No quantitative interpretation of the data for this line has yet been made. The low resistivities at shallow depths from about 90W eastward may be attributed either to conductive glacial clay or to brine saturated valley fill. The latter explanation is preferred because of the abrupt increase in resistivity west of 110W, i.e. No Good Creek, and because warm and hot springs occur to the east but not to the west of No Good Creek. No attempt has been made to define the eastern boundary of the deep conductive zone, believed to exist between 110W and 90W, because no quantitative interpretation of this data has been made.

4.2.2. Line K

The resistivity pseudosection for Line K is similar to that for Line D, with the exception of a pronounced resistivity low associated with Meager Creek at 65E. While this latter feature may result from local hydrothermal convection, it more likely results from brine filled alluvium wherein the brine originated upstream, ie. near No Good Creek. More resistivity work is required to verify this preferred interpretation.

A preliminary quantitative interpretation of Line K has indicated a deep conductive zone, ie. well below valley fill, of 50 ohm metre material occurring between 40W and 60W. The western boundary of this zone coincides approximately with No Good Creek.

4.2.3. Line T

A very weak and surficial low resistivity anomaly occurs on Line T as an extension of the anomaly found on lines D and K. The significance of the anomaly is unknown.

4.2.4. Recommendations

1) The effects of overburden seem to be adequately accounted for in modeling the data from Line K, but there is a need to remodel the data using for control the following:

a) the latest geologic plan map,
b) the available geologic sections for AA', BB', CC', and DD',
c) the available seismic data depicting the bedrock profile beneath Meager Creek,
d) the inversely interpreted Schlumberger soundings when extended to AB/2 of 2 km,

c) sensitivity tests involving variation of width, depth extent, and resistivity of the 50 ohm metre block of low resistivity material in the bedrock.

2) Line D should be modelled with the same attention to detail recommended for Line K above.

3) If a deep production test well is to be drilled at an early date, then its most logical location would be within 200m east to west of gradient hole M7, with the western part of this zone preferred. However, the resistivity interpretation noted above should be completed and two shallow (600m) gradient holes should be drilled, 200m on either side of gradient hole M7, prior to spudding the production test well. Local vertical and lateral temperature gradients are expected to be markedly influenced by convecting fractures so that much attention is required to optimize the location of the deep production test well.

4.3 M12 Area

4.3.1. Lines T and S

A resistivity low exists between 10E and 13E on Line T. This may be due to hydrothermal alteration but seems more likely to be due to brine saturated valley sediments since gradient hole M12 intersected a warm brine. Note, however, the resistivity low east of M12 on Line S. There is some question about the validity of some of the data on Line T, due to the loss of shallow resistivity measurements between 9E and 18E.

4.3.2 Recommendations

Much more resistivity data is required in order to ascertain the significance of the M12 Area and its relationship to the South Reservoir and the North Anomaly. Accordingly, the following are recommended:

1) Conduct a dipole-dipole traverse up the South Fork of Meager Creek in order to determine where the assumed brine saturation of the alluvium ceases. The southernmost upwelling of brine may be located by this technique.

2) Conduct a dipole-dipole traverse SSW through M12 between Line S and the South Fork of Meager Creek. A possible east-west resistivity low through M12 may be delineated by the data for this traverse and for Line S.

3) Repeat Line T from 3E to Barr Creek in order to fill in the missing data points.

4) Map the area south from M12 in search for a volcanic vent which may be a source of heat.

4.4 The Hot Springs Creek Area

4.4.1. Observations

Some unusual resistivity readings occurred beneath 112S on Line S and a resistivity low occurred beneath 125S on Line S. Both could be attributed to some form of current channeling along orthogonally connected (fracture-controlled?) streambeds.

4.4.2. Recommendations

It is recommended that Line S be repeated with 100m dipoles from 114W to 133W so as to restrict the survey to one streambed.

4.5 South Area, General

4.5.1. Observations

There is considerable uncertainty about the resistivity response of stream beds downstream from Meager Creek Hot Spring. Hence a need arises to conduct Schlumberger soundings at selected locations along Meager Creek.

4.5.2. Recommendations

Conduct five or six carefully selected Schlumberger soundings along Meager Creek (using AB/2 of 2km if possible) in order to assess the importance of variation of brine saturation of valley sediments to the interpretation of dipole-dipole data in the vicinity of Meager Creek. Some dipole-dipole data has gone uninterpreted because of our uncertainty over how to proceed (ie. we are lacking data vital to interpretation).

4.6 North Anomaly

4.6.1. Observations

A continuous zone of low resistivity (of order 150 to 200 ohm metres) has been indicated on Lines L, N. O, Q, and V. This zone is permitted by the data on Line P but the latter line is insufficiently long to provide definitive data. While not of as low resistivity as the South Reservoir anomaly, it still is worthy of attention.

4.6.2. Recommendations

1) Line P should be completed with dipole-dipole resistivity data from its current eastern end to about 83W on Line Q.

2) The west halves of Lines L and Q should be modelled quantitatively.

5.0 Resistivity and the Conceptual Models

1) The resistivity data at the South Reservoir and at the North Anomaly both support the conceptual model presented in 2.3 above.

2) The resistivity data neither confirm nor deny the dipping sheet conceptual model presented in 2.4 above.

3) The resistivity data at the M12 Area and the Hot Spring Creek Area are not easily related to either conceptual model because of a lack of data.

4) Were it appropriate to do so, given all of the constraints of the exploration program at Meager Creek, both the recommended resistivity surveys and interpretation and the trace element geochemistry study proposed elsewhere should be completed prior to spudding the first deep production test well. This recommendation is based on the observation that any conceptual model so far presented to the writer, including those described herein, are tenuous at best.

5) The dipole-dipole resistivity method certainly seems capable of contributing to development of a reasonably firm conceptual model of the Meager Mountain convective hydrothermal system.

Respectfully submitted,

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(Original signed)

Vancouver, B.C.
May 9, 1981

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