Borehole Geophysical Logs and Physical Property Tables
for
Massive Sulphide Deposits in the Cordillera British Columbia:

Buttle Lake, Chu-Chua, Equity Silver, Goldstream, Highland Valley, Lara and Sullivan Deposits

P.G. Killeen, C.J. Mwenifumbo and B.E. Elliott
Borehole Geophysics Section
Mineral Resources Division
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario
K1A 0E8

OPEN FILE
DOSSIER PUBLIC
2610
Geological Survey of Canada
Commision Géologique Du Canada
OTTAWA

Natural Resources Canada
Ressources naturelles Canada

Canada

GSC OPEN FILE 2610

Borehole Geophysical Logs and Physical Property Tables for Massive Sulphide Deposits in the Cordillera British Columbia Including logs from the Buttle Lake, Chu chua, Equity Silver, Goldstream, Highland Valley, Lara and Sullivan Deposits.

P.G. Killeen, C.J. Mwenifumbo and B.E. Elliott

ABSTRACT 3

1. INTRODUCTION AND BACKGROUND 4

2. DEPOSIT DESCRIPTIONS 6
    2.1 The Buttle Lake Camp 8
    2.2 Chu Chua Deposit 9
    2.3 Equity Silver Mine 10
    2.4 Goldstream Deposit 11
    2.5 The Highland Valley J.A. Deposit 12
    2.6 Lara Deposit 13
    2.7 Sullivan Mine 14

3. LOGGING SYSTEM AND GEOPHYSICAL LOGS 15

4. DATA PROCESSING 16

5. RESULTS OF LOGGING 17

6. PHYSICAL PROPERTY TABLES 23

7. ACKNOWLEDGEMENTS 30

8. REFERENCES 30

APPENDIX 1 - The Logging System 32

APPENDIX 2 - Detailed Physical Property Data 43

APPENDIX 3 - Average Temperature Gradient Values 56

APPENDIX 4 - Coloured Plots of Geophysical and Lithological Logs 57

ABSTRACT

Borehole geophysical measurements have been conducted in several volcanogenic massive sulphide deposits and a porphyry copper deposit of the Cordillera using the R&D logging system of the Geological Survey of Canada in collaboration with several mining companies operating in British Columbia. The objective of the work was to improve the effectiveness of geophysical exploration for mineral deposits by obtaining better information on the physical characteristics of the deposits and their host rocks through borehole geophysics.

Measurements included IP, resistivity, self potential, magnetic susceptibility, conductivity, natural gamma, spectral gamma-gamma (density, heavy element indicator), temperature and temperature gradient.

In addition to determining in-situ physical properties for use in the interpretation of ground and airborne geophysical data, these borehole measurements have proven useful for delineating mineralized zones, mapping alteration zones associated with mineralization, hole-to-hole lithologic correlation, qualitative assaying of mineralization and detecting groundwater flow zones within the holes.

1. INTRODUCTION AND BACKGROUND

In early 1986, representatives of the Borehole Geophysics Section at the GSC met with the B.C. Minerals Logging Committee to discuss plans for a collaborative project on borehole logging in the Cordillera. The committee was composed of a group of geophysicists and geologists, representing mining companies active in British Columbia. They included Cominco Ltd., Corporation Falconbridge Copper, Esso Resources Canada Ltd., Noranda Exploration Co. Ltd., Placer Development Ltd., Utah Mines Ltd., and Westmin Resources Ltd. Based on the discussion, the philosophy of the group was outlined in the following statement:

> "We perceive that if the exploration effectiveness of geophysics is to improve, we need better information as to the physical characteristics of the targets we are looking for. While the technology of data acquisition has advanced tremendously in the last five years, our exploration models have varied little in the last 30 years. To bring the needed reality to our models, both to help interpret field data and generate forward solution models, we need accurate physical property measurements of ore deposits and their environments. These data are best obtained via in-situ borehole logging."

The remedy to this situation was to prepare a project to:

> "geophysically characterize a suite of 'typical' Western Cordilleran massive sulphide deposits. A primary goal of such a study is to help address the somewhat elusive question as to why the younger massive sulphide deposits show poor responses to 'conventional' Eastern Canadian geophysical techniques, especially EM".

The Committee felt there was a dearth of what could be called 'hard data' which compares geophysical results with geology. It was believed crucial to obtain some good, multiparameter borehole logs in and around the deposits under study. It was felt this type of measurement was the only reliable way of characterizing the geophysical response of the massive sulphides (and their host rocks).

The committee also stated:

> "The GSC's logging facility is really the only such system suited to minerals work in Canada. There are no academic centers of excellence in the field and the commercial slim-hole contractors are only set up for coal and uranium."

As a result of these discussions a cooperative study was initiated, and suitable deposits were selected for the program. The reasoning behind the committee's selection is quoted below:

> "The main targets selected for study are the volcanogenic massive sulphide deposits of the Cordillera. A number of these occurrences have been found and

> an economically significant number are being mined including Sullivan, Equity Silver and Westmin. One non-massive sulphide deposit, Valley Copper, was included. The group felt that this class of deposit was too important in B.C. not to gain some base geophysical data on. While geophysics, both airborne and ground, is being used intensively by many companies in their search for new deposits in the Cordillera, geophysics historically has not had the discovery success obtained in Eastern Canada.
>
> The proposed minerals logging program will provide useful information as to what some of these deposits look like in geophysical terms. With this information in hand, the minerals geophysicist will be able to do a better job at using geophysical techniques in the exploration for such deposits. This ability is particularly needed if geophysics is to assist non-geophysical prospecting techniques for those deposits buried at depths greater than 100-150 m. To date in the Cordillera, virtually all deposits found have been shallower than 100 m."

During the first field season (1986) the GSC logging system was used at Cominco's Sullivan Mine, Noranda's Goldstream deposit, Placer Development's Equity Silver deposit, and Falconbridge's Chu Chua deposit. In the summer of 1987 holes were logged at Highland Valley Copper's JA zone, Westmin's Buttle Lake Mine, Placer's Equity Silver, and Abermin's Lara deposit.

Throughout the project, annual meetings were held with the B.C. Minerals Logging Group to discuss the field logging results, to follow up on the information determined from the logs, and to answer questions generated by the logs.

In 1989, a report (Killeen et al.,1989), that included preliminary physical property tables was released to the mining companies involved in the study. A proprietary period followed, in which public release of the collaborative work was restricted. Numerous excerpts from the data have since been published as examples in oral presentations, poster papers and manuscripts on various aspects of the application of borehole geophysics to mineral exploration (Borehole Geophysics Section, 1991; Elliott, B.E., 1991; Elliott, B.E. et al., 1990; Killeen. P.G., 1988; 1990; 1991; Killeen, P.G. and Mwenifumbo, C.J., 1988A; 1988B; Killeen, P.G., et al., 1990A; 1990B; Killeen, P.G. et al., 1995; Kowalczyk, P., et al., 1990; Mwenifumbo, C.J. and Killeen, P.G., 1988; Mwenifumbo, C.J., et al., 1993). The original data were recorded on 9-track magnetic tape, processed on a main-frame computer and displayed as black and white plots generated on a Versatec electrostatic plotter. As a result of recent changes in computer and printer technology, the geophysical logging data have been reprocessed and displayed as colour plots for this Open File. It is hoped that this release of data from the collaborative project of the B.C. Minerals Logging Group will be of benefit to the mining exploration community at large.

2. DEPOSIT DESCRIPTIONS

Brief descriptions of the deposits which were logged in this (see map, Figure 1, for locations) project are presented in the following pages. A list of deposit names, hole numbers and the property owners/operators at the time of logging is given below.

Deposit Name	Hole No.	Owner/Operator
BUTTLE LAKE	PR061 W129	Westmin Resources Ltd.
CHU CHUA	CC055	Corporation Falconbridge Copper
EQUITY SILVER	86246 86250 86264	Placer Development Ltd.
GOLDSTREAM	NG049 NG050	Noranda Exploration Company Ltd.
HIGHLAND VALLEY (JA ZONE)	JA003 JA015 JA057	Highland Valley Copper
LARA	87204	Abermin
SULLIVAN	K6423	Cominco Exploration

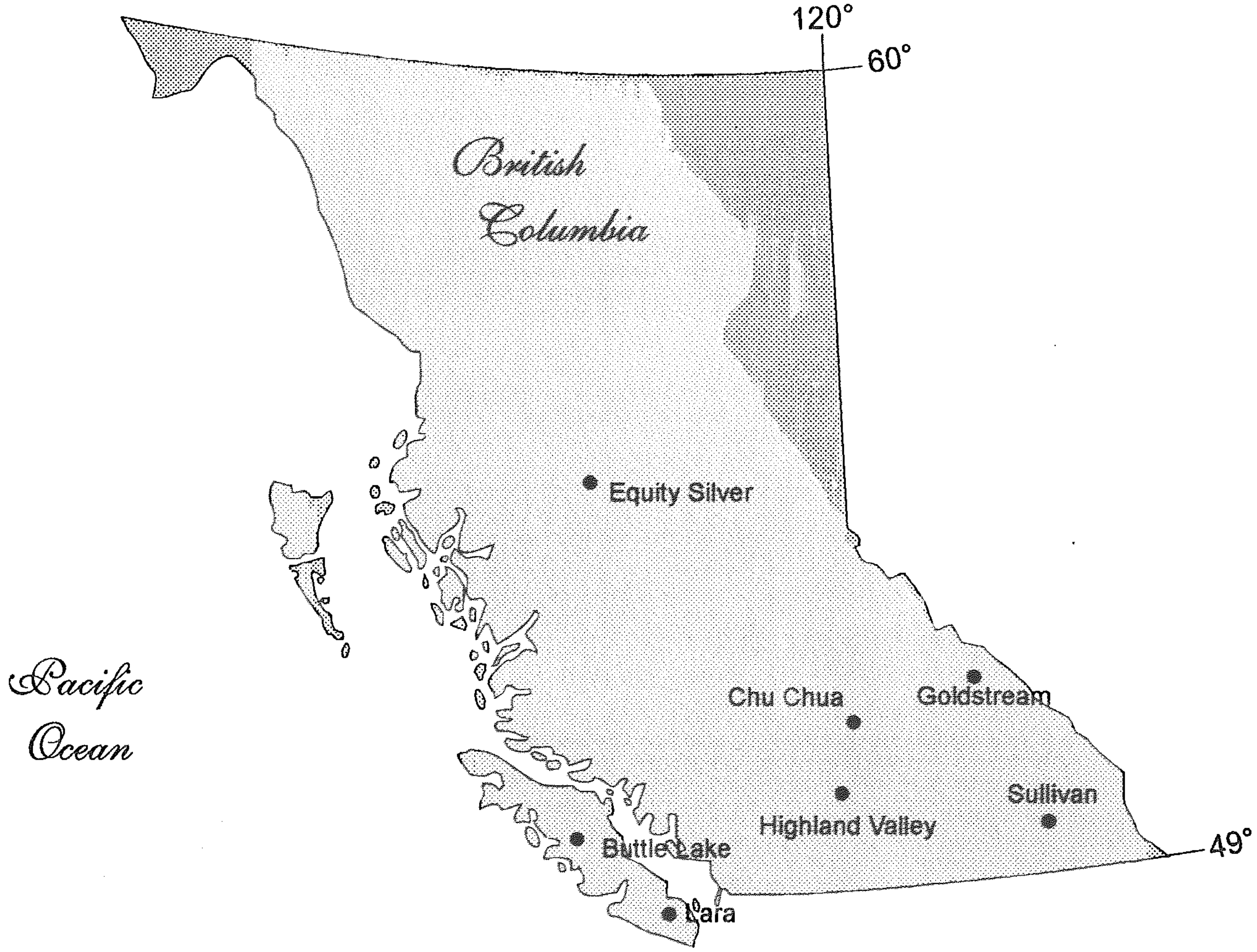


Figure 1

Location of massive sulphide and porphyry deposits in the Cordillera, British Columbia, where geophysical logs were collected with the GSC R & D logging system.

2.1 The Buttle Lake Camp (lat 49°34' long. 125°35')

The Buttle Lake camp includes the Price, Myra and Lynx mines and the H-W mine, referred to collectively as the Myra Falls operations of Westmin Resources Ltd. It is located on Vancouver Island, near Buttle Lake 90 km SW of Campbell River, British Columbia. Total reserves in the camp were estimated at 12.5 M tonnes averaging 2.0 g/t gold, 45.4 g/t silver, 1.9% copper, 0.5% lead and 6.7% zinc (Canadian Minesearch 1994-95).

The following brief description of the geology of the Buttle Lake Camp is extracted from Hoy, (1991). He states:
"The Buttle Lake deposits consist of a number of massive sulphide lenses within felsic volcanic rocks in the Late Paleozoic Sicker Group. The Sicker Group has been subdivided into four formations, the Late Devonian (or older) Price Formation, the Late Devonian Myra Formation, the Early Mississippian Thelwood Formation and the Pennsylvanian or Mississippian Flower Ridge Formation. The Price and Myra formations record cyclical volcanism, with early mafic to intermediate volcanism during constructive arc development, followed by rifting and associated hydrothermal alteration, sulphide mineralization and felsic arc volcanism, then mafic to ultramafic arc volcanism and finally volcanogenic sedimentation. The H.W. deposits are within felsic volcanic rocks of an early cycle, whereas the Lynx, Myra and Price deposits are in a later felsic succession".

Some details on ore and alteration were given by Walker (1985) as follows:
"Orebodies at Buttle Lake are primarily lensoidal beds of massive sulphide which have been variably folded and disrupted by faults. The principle minerals are pyrite, sphalerite, chalcopyrite, galena and barite. Minor minerals include tennantite, bornite and pyrrhotite. Composition of the massive sulphide varies widely both within lenses and among lenses. . . . . The H-W orebody exhibits strong lateral zoning from a massive pyrite central portion with high copper to zinc ratio to a sphalerite and barite rich marginal phase with low copper to zinc ratio and significant lead....

Ore-related alteration has been metamorphosed and is now manifested by broad zones of pyritic, sericitic schist. Within the more extensive sericitic schists, which contain a few percent disseminated pyrite, three separate zones of pyrite stringer mineralization have been recognized. The largest pyrite stringer zone underlies the H-W orebody. Here the pyrite content ranges from several to more than 30%.".

Reference:

Hoy, T.,
1991: Volcanogenic massive sulphide deposits in British Columbia, in, Ore Deposits, Tectonics and Metallogeny in the Canadian Cordillera, BC Energy Mines and Petroleum Resources, Paper 1991-4

Walker, R.R.
1985: Westmin Resources sulphide deposits, Vancouver Island; Geol. Soc. Am., Cord. Section Mtg., May 1985, Vancouver, B.C., Field Trip Guidebook, Trip 1, p.1-13.

2.2 Chu Chua Deposit (lat. 51°22'10" long. 120°03'30")

This deposit is a copper-zinc-gold-silver property, approximately 70 km N of Kamloops, B.C. Open pit reserves are estimated for the main Chu Chua deposit at 1,150,000 tons averaging 2.98% copper, 0.3% zinc, 0.3 oz/ton silver and 0.016 oz/ton gold (based on Canadian Minesearch 1994-95).

The following brief geological description is based on information in the GSC Mineral Deposits Data Bank, and on a paper by Aggarwal and Nesbitt (1984).

The Chu Chua deposit is a massive sulphide deposit occurring within the Fennell Formation comprising rocks that are mainly basaltic in composition. The basaltic rocks of the Fennell Formation dip steeply to the west and contain the massive sulphides which appear to be stratabound and also dip steeply west and trend north south. The deposit consists of two major lensoid massive sulphide bodies, the east and western sulphide bodies, comprising mainly pyrite and chalcopyrite underlain by chemically precipitated massive siliceous, and talc rocks. The sulphide bodies have sharp, upper contacts with the basalts. The eastern sulphide body, however, is enclosed within the siliceous unit. The contacts between the massive sulphides and the siliceous unit are marked by transition zones of disseminated sulphides.

The deposit has been delineated by extensive drilling, and the major sulphide bodies range from 100 to 200 m in length and 2 to 25 m in width, and have been proven to depths of 100 to 150 m (Aggarwal and Nesbitt, 1984). Massive talc-magnetite lenses occur partially enclosed within both the major sulphide bodies. In the western sulphide body, the talc-magnetite lenses overly the massive talc rocks.

Reference:

Canadian Minesearch (1994-1995),
1994: Southam Magazine and Information Group. Canadian Mines Handbook on Diskette.

GSC Mineral Deposit Data bank

P.K. Aggarwal and B.E. Nesbitt
1984: Geology and geochemistry of the Chu Chua massive sulphide deposit, British Columbia; Economic Geology, Vol. 79, p. 815-825.

<u>2.3 Equity Silver Mine</u> (lat. 54°11'20", long. 126°15'40")

This mine is a former silver-gold-copper producer, approximately 40 km SE of Houston, British Columbia.

Production began in October 1980 and through December 31, 1993, produced 66,708,580 troy oz silver, 511,296 troy oz gold and 178,223,000 lbs (81,010,000 kg) copper. The mine closed permanently on January 23, 1994, due to depletion of resources.

In 1980 the Northern Miner (03/07/80) reported the average grade was estimated to be 3.10 oz/ton silver, 0.028 oz/ton gold and 0.384% copper in two open pits. The Western Miner (July 1980) reported estimates for the Main zone of 98.4 g/tonne silver, 0.825 g/tonne gold, and 0.353% copper. Antimony and arsenic were also recovered.

The following brief geological description of the deposit is extracted from the GSC Mineral Deposits Data Bank.

The deposit is located in the Goosly Lake area and is underlain by Mesozoic and Tertiary volcanic rocks and a number of small intrusions. A typical east-west section of the area shows a thickness of about 800 m of steep, westerly dipping Mesozoic volcanic and sedimentary beds which are intruded by a swarm of nearly vertical Tertiary dykes with an apparent total thickness of about 150 m. The upper and most westerly Mesozoic beds are tuffs and lapilli tuffs with zones of chert pebble conglomerate and laminar bedded tuffaceous argillite. The center part of the section shows a progressive increase stratigraphically downward in the volume of tuff breccia and coarse volcanic debris. In the lower part of the succession, dacitic tuff breccia with some intercalated chert pebble conglomerate is found overlying a tongue-like body of shattered dacite. The base of the stratigraphic section is composed of nearly 100m of chert pebble conglomerate.

Pyrite occurs throughout the section in joint and cleavage fillings and less commonly as disseminations. The main mineralized zone, about 50 m thick, is composed of finely disseminated sulphides and coarse-grained sulphide replacement bodies located in the central part of the dacite. The disseminated sulphide phase forms the bulk of the mineralized zone. The coarse sulphide replacements are irregularly distributed in the zone of intense sulphide disseminations. These structures are lens-like bodies as much as 3 m thick.

2.4 Goldstream Deposit (lat. 51°38', long. 118°26')

The Goldstream deposit is a stratabound massive sulphide layer in Paleozoic metasedimentary rocks located in the Selkirk Mountains in southeastern British Columbia, approximately 100 km to the north of Revelstoke.

The mine first went into production in 1983, closed in 1984 and reopened in 1991. In 1982 reserves were reported as 4.3 M tons at 3.69% Cu, 2.67% Zn, and 0.56 oz/ton Ag (GSC Mineral Deposits Data bank).

The following brief geological description of the deposit is extracted from the GSC Data Bank and Hoy et al., (1984).

Host rocks include either basic metavolcanics or dark carbonaceous and calcareous phyllites, associated with thick accumulations of impure quartzite, greywacke, and calcareous rocks. Locally they are associated with ultrabasic rock.

The massive sulphide zone occurs within the host unit, a quartz-sericite-chlorite-biotite phyllite, as a continuous layer varying in thickness from 3 m to 6 m. It consists of a medium to coarse grained mixture of pyrrhotite, chalcopyrite, and sphalerite. The massive sulphide layer has a well defined lateral zonation. Inclusions of various types may comprise up to 30 per cent of the massive zone. Some of these are eyes of clear glassy quartz, generally less than 2 cm in diameter, eyes of white quartz up to 20 cm in diameter and containing irregular blebs of sulphides, biotite-chlorite-sulphide assemblage, and coarse grained sphalerite-rich sulphides. Pyrrhotite, chalcopyrite and sphalerite, where not massive, may comprise up to 25 per cent of the unit and occur as disseminated trains along foliations.

The contacts of the massive sulphide and the mineralized unit are very sharp and well defined. The deposit varies in thickness from 3 m to 6 m, in width from 150 m to 250 m, and it has been followed down-dip to 1,500 m.

Reference:

Hoy, T., Gibson, G. and Berg, N.W.
1984: Copper-zinc deposits associated with basic volcanism, Goldstream area, southeastern British Columbia; Economic Geology, Vol. 79, p. 789-814.

2.5 The Highland Valley J.A. Deposit (lat. 50°28'35" long. 120°58'30")

The J.A. deposit is located in the Highland Valley district, known for its large low-grade open pit porphyry copper-molybdenum mines. It is situated in south-central British Columbia about 350 kilometres northeast of Vancouver. In 1992, reserves based on drilling, were estimated at 286 M tons averaging 0.43% copper, and 0.017% molybdenum.

The following brief geological description is extracted from the GSC Mineral Deposits Data Bank, and McMillan (1985).

The J.A. deposit is elongated in a northwest direction with average dimensions of 1300 x 300 m. The deposit straddles the north-striking contact between granodiorites of the Guichon variety and the younger Bethlehem phase of the Upper Triassic Guichon Creek batholith. A small elliptical stock with a long axis subparallel to that of the ore lies along its southern contact.

The outer chilled ring of the stock was fractured and flooded by potassic feldspar alteration. The stock cuts the Guichon/Bethlehem contact. It has a carapace of quartz-plagioclase aplite which grades inward to porphyritic biotite-quartz monzonite. This carapace is mineralized, and weakly disseminated sulphides occur throughout the stock.

Regional geology and bedrock geometry suggest that a series of steeply dipping northward- and northwestward-striking faults comprise the framework of the deposit.

Mineralization occurs primarily in fractures, veins and their alteration envelopes. The predominant economic mineral is chalcopyrite, with lesser bornite. Sulphide zoning is apparent as follows: a core zone in which bornite equals or exceeds chalcopyrite grades outward through a zone with chalcopyrite in excess of bornite to a zone with chalcopyrite in excess of pyrite and, finally, to a zone with pyrite in excess of chalcopyrite. Pyrite in the "halo" averages less than 2 per cent by volume. The orebody is predominantly within the chalcopyrite and chalcopyrite + pyrite zones; the pyrite and much of the bornite zone have subeconomic grades.

Molybdenite is common in small amounts throughout the bornite, chalcopyrite and chalcopyrite-pyrite zones. In general, the best molybdenum values appear to coincide with the best copper grades.

Reference:

McMillan, W.J.,
1985: The J.A. Deposit; in Geol. Assoc. Canada, Mineral Deposits Division, Field Guide and Reference Manual Series Number 1 "Geology and Ore Deposits of the Highland Valley Camp", p. 63-74.

2.6 Lara Deposit (lat. 48°52', long. 123°52')

The Lara deposit is a copper-zinc-gold property located on Vancouver Island near Duncan, B.C. Drilling indicated reserves at 583,000 tons averaging 1.01% copper, 1.22% lead, 5.87% zinc, 2.92 oz/ton silver (100.1 grams/tonne silver) and 0.138 oz/ton gold (4.73 grams/tonne gold). (Canadian Minesearch 1994-95).

Located at the Chemainus end of the Cowichan uplift of Sicker Group rocks, this polymetallic massive sulphide is in sheared felsic volcanics of the Paleozoic McLaughlin Ridge Formation. The property is underlain primarily by the paleozoic Sicker group which comprises well differentiated volcanic rocks with interbedded tuffaceous, carbonaceous and volcanoclastic sedimentary rocks. These rocks are strongly deformed (commonly schistose) and are regionally metamorphosed to lower and upper greenschist facies. Bands, laminae and stringers of sulphide minerals occur in a strongly silicified rhyolite host.

2.7 Sullivan Mine (lat. 56°05'11" long. 129°58'25")

The Sullivan lead-zinc deposit at Kimberly is located in the Purcell Anticlinorium in southeastern British Columbia. The Sullivan (Cominco Ltd.) has been in production almost continuously since 1909. Ore reserves in 1993 were estimated at 14.8 M tonnes averaging 4.7% lead, 8.0% zinc and 26 g/tonne silver. (Canadian Minesearch 1994-95).

The following brief geological description of the deposit is extracted from Ransom et al., (1985).

"The Sullivan sulphide orebody is hosted by the Middle Proterozoic Aldridge Formation. The Aldridge Formation in the Purcell Mountains is divided into Lower, Middle and Upper. The Lower Aldridge comprises at least 1500 m of rhythmically graded thin- to medium-bedded very fine grained wacke. The Middle Aldridge contains 2000 m of medium- to thick-bedded wacke and quartzitic wacke. Most of these rocks were deposited as turbidites. The Upper Aldridge consists of 300 m of thin-bedded to laminated argillite. The Aldridge Formation has been metamorphosed to lower and middle greenschist facies. It has been folded into generally broad, open north-plunging folds of the Purcell Anticlinorium. The Sullivan orebody lies conformably at the top of the Lower Aldridge on the east side of the Purcell Anticlinorium.

The Sullivan orebody is interpreted as a hydrothermal synsedimentary sulphide deposit which formed in a sub-basin on the Aldridge marine floor. It is located directly over cross-cutting bodies of fragmental rocks, products of pore overpressure release along lines of crustal weakness. Some chlorite alteration in the footwall and above the feeder took place during the early stages of sulphide mineralization. A post sulphide phase of hydrothermal activity produced albite-chlorite-pyrite alteration in the footwall, pyrite-chlorite-calcite alteration in the ore zone and albite-chlorite-pyrite alteration of the hanging wall.

The principal sulphide deposit is a stratiform upwardly convex lens and subordinate bands covering an area 1.6 x 2.0 km composed almost entirely of pyrrhotite, sphalerite, galena and lesser pyrite. Associated silver is economically important."

Reference:

Ransom, P.W., Delaney, G.D. and McMurdo, D.,
1985: The Sullivan Orebody; in Field Guides to Geology and Mineral Deposits in Southern Canadian Cordillera; Edited by D. Templeman-Kluit (proceedings of a GSA Cordilleran Section Meeting, Vancouver, B.C., May 1985).

3. LOGGING SYSTEM AND GEOPHYSICAL LOGS

A general description of the GSC logging tools and the geologic features to which they respond, is given in Appendix 1. However, some notes specific to the use of these logging tools in this project are given below.

Specifics of Logging Procedures and Tools as Used in This Project

Parameter	Logging Speeds
Spectral Gamma:	Equity Silver 86264 and Highland Valley JA003 and JA057 were logged at 1 m/minute, with a 3 second counting time. All other logging was at 3 m/minute with a 1 second counting time.
Spectral Gamma-gamma:	Equity Silver 86264 was logged at 3 m/minute. All other logging was at 6 m/minute. Sample intervals were all 1 second.
Induced Polarization:	The Single Point Resistance log for Sullivan was logged at 6 m/minute. All other logging was at 3 m/minute. Sample intervals were all 1 second.
Magnetic Susceptibility:	Chu chua was logged at 10 m/minute. All other logging was at 6 m/minute. Sample intervals were all 1 second.
Temperature:	Chu chua was logged at 10 m/minute. All other logging was at 6 m/minute. Sample intervals were all 1 second.

Parameter	Detectors
Spectral Gamma:	At Sullivan a 32mm x 127mm (1 1/4" x 5") Cesium Iodide detector was used. For all other logging a 25mm x 76mm (1" x 3") Cesium Iodide detector was used.
Spectral Gamma-gamma:	For all logging a 25mm x 76mm (1" x 3") Cesium Iodide detector was used.

Induced Polarization Arrays:

The lateral array was used at Buttle Lake and at Highland Valley JA003. The micronormal array was used at Chu chua and Goldstream. At Highland Valley JA057 both the lateral and micronormal arrays were used, and a run logged for self potential. At Sullivan the micronormal array was used and a run logged for Single Point Resistance.

4. DATA PROCESSING

A general description of data processing techniques is presented below. Details about extracting physical property information from the logs are given in the section on 'Physical property tables'.

General Correction and Compilation Techniques

The first step in data processing is to apply a depth shift related to the position of the sensing element in each of the five logging tools so that the location of "zero depth" is the same for all parameters measured. For example, in gamma ray logging the detector is actually located at 60 cm depth when the 'zero' is set on the well head pulley at the beginning of logging. Therefore, all depth values are in error by 60 cm until this correction is applied. At the same time a casing correction is applied to compensate for the length of casing protruding above ground level, and on which the well head pulley and depth counter are mounted. This brings the geophysical log zero depth into line with ground level for correlation with drill core geological logs.

The second step is to apply corrections to the data as required for each parameter. This may include dead time corrections for nuclear logs (gamma ray and gamma gamma density), hole size (diameter) corrections for magnetic susceptibility logs. Spectral stripping and conversion to concentrations (%K, ppm U, and ppm Th) may be done for gamma ray logs if counting statistics warrant, however only total count logs are presented in this report. The gamma gamma density log is a count rate which is inversely proportional to density. Thus raw logs labelled in cps (counts per second) show high values for low density zones, and where appropriate calibration factors were available, the density logs presented in this open file have been converted from cps to grams per cubic cm.

The third step is to compute any desired 'derived' logs such as the temperature gradient log.

The fourth step is to plot all of the digitally recorded logs on a single sheet of paper. Additional depth discrepancies become evident. Usually it can be seen from the logs that certain discontinuities associated with the geological contacts or dikes, etc. are not aligned properly from log to log. A cross-correlation program is used to shift all logs to a best fit match with each other. The geophysical logs are then correlated to the geology if the geological logs are available and if it appears necessary.

Sometimes in addition to a depth shift, a 'stretch' shift must be applied to the logs for proper depth alignment (logs from the same tool and same run (e.g. IP/R/SP) don't need shifting since they were recorded simultaneously.

It is also possible to correct the logs for 'drift' if required. The present equipment is so stable that this usually hasn't been found necessary. In certain cases some smoothing may be applied to the logs, in effect averaging over greater lengths of hole than the original detailed measurements taken every few centimeters. The logs are now ready for interpretation.

5. RESULTS OF LOGGING

The geophysical logging results are presented as a series of 19 coloured plots in Appendix 4. Table 1 summarizes the parameters presented in the coloured log plots. Some interpretive notes are also given in this section as an aid to understanding the significance of some of the logs. However, this should not be considered a detailed or comprehensive interpretation.

The following abbreviations are used in Table 1.

Abbreviation	Probe
GAM	Spectral Gamma
GAM-GAM	Density / Spectral Gamma-gamma Ratio
IP	Induced Polarization
MS(GEO)	Magnetic Susceptibility (Geoinstruments)
MS(ROM)	Magnetic Susceptibility (Romulus)
TMP	Temperature

Abbreviation	Parameter
TC	Total Count
DEN	Density
SGGR	Spectral Gamma-gamma Ratio
RES	Resistivity
IP	Induced Polarization
SPR	Single Point Resistance
SPG	Self Potential Gradient
MS	Magnetic Susceptibility
CON	Conductivity
TMP	Temperature
TMG	Temperature Gradient

Table 1: Areas, Boreholes, and Parameters Logged

	GAM	GAM-GAM	IP	MS (GEO)	MS (ROM)	TMP
Buttle Lake PR061	TC	DEN SGGR	RES IP	MS		TMP TMG
Buttle Lake W129	TC	DEN SGGR	RES IP	MS		TMP TMG
Chu chua CC055		DEN SGGR	RES IP	MS CON		TMP TMG
Equity Silver 86246		DEN SGGR	RES IP	MS CON		TMP TMG
Equity Silver 86250		DEN SGGR	RES IP	MS	MS CON	TMP TMG
Equity Silver 86264	TC	DEN SGGR	RES IP			
Goldstream NG049	TC	DEN SGGR	RES IP	MS		TMP TMG
Goldstream NG050	TC	DEN SGGR	RES IP		MS	TMP TMG
Highland Valley JA003	TC	DEN SGGR	RES IP SPG			TMP TMG
Highland Valley JA015						TMP TMG
Highland Valley JA057	TC	DEN SGGR	RES IP SPG SP	MS		TMP TMG
Lara 87204						TMP TMG
Sullivan K6423	TC	DEN SGGR	RES IP SPR	MS	MS CON	TMP TMG

Notes on coloured log displays in Appendix 4

1) All depth scales are 20 metres downhole per centimetre on paper.

2) All gamma ray logs are total count logs (energy range, 0.1 - 3 MeV).

3) Buttle Lake, PR061: water level occurs at approximately 15 m.

4) Buttle Lake, W129: top 44 m is overburden with steel casing to 50 m, so there are no logs in first 50 m.

5) Equity Silver, 86246: density in top 30 m is in air, and therefore not valid.

6) Equity Silver, 86250: density in top 10 m is in air, and therefore not valid.

7) Goldstream, NG049: note that there was probably more massive sulphide at 290 m, than indicated by the pink colour (see thickness of SGG log anomaly) and it was probably badly fractured or jointed with much water flow at joints around this depth.

8) Goldstream, NG050: Temperature logs above 60 m are not shown.

9) Highland Valley, JA003: there was casing in the top 100 m of overburden not shown. A geological log was not available for this hole.

10) Highland Valley, JA015: Only temperature logs were collected because of poor hole condition. A geological log was not available for hole.

11) Highland Valley, JA057: there is casing in the top 150 m of overburden not shown. A geological log was not available for this hole.

12) Lara, 87204: hole was unstable. Only temperature data were collected and further logging was abandoned. A geological log was not available for the hole.

13) Sullivan, K6423: MS for GEO and ROM probes do not correlate well mainly because of the differences in measurement geometries of the two probes. There is overburden and steel casing in the top 60 m of the hole and hence no logging data.

Some detailed comments on the logging data from the Chu Chua deposit

Introduction

One hole was logged at the Chu Chua massive sulphide deposit during the B.C. minerals logging program in September, 1986. This was the last of the four deposits visited and because of time constraints only a few of the parameters scheduled to be logged were carried out. The parameters that were logged included: IP, resistivity, self potential gradient, magnetic susceptibility and conductivity with the Geoinstrument probe, spectral gamma gamma, temperature and temperature gradient.

Hole CC55 is a BQ size hole, drilled through light grey green, fine grained pillowed and massive basalts. The top 15 m of the basalts are highly fractured. Tuffite is intersected from 374 to 397.7 m. The bottom part of the hole from 397.7 to 447 intersects massive basalts which are strongly carbonatized and chloritized. The sulphide mineralization along this hole consists of pyrite and chalcopyrite and occurs within siliceous tuffs. Two sulphide zones are intersected. The major zone occurs at the base of the tuffite. A very narrow, low grade sulphide zone occurs at the top of the tuffite. The following table shows the pyrite-chalcopyrite intersections along the hole:

Depth Range	% Pyrite /Chalcopyrite	
374.0 - 375.2	2 - 5%	banded pyrite
388.0 - 393.8	10 - 15%	pyrite/chalcopyrite
393.8 - 394.6	60%	pyrite/chalcopyrite
394.6 - 395.9	30%	pyrite/chalcopyrite
395.9 - 397.7	25%	pyrite/chalcopyrite
397.7 - 400.0	10 - 15%	pyrite disseminated in breccia sections
432.0 - 465.0	10 - 15%	pyrite in fractured sections

Geophysical Measurements

The resistivity logging was carried out with the micronormal array. The resistivities of the basalts are very high and are beyond the sensitivity range of this array. Most of the resistivity log is therefore saturating. The altered basalts have lower resistivities ranging from 1000 - 2000 ohm-m. The tuffite has apparent resistivities around 900 ohm-m which are lower than most of the unaltered basalt. The sulphide mineralization above and below the tuffite is clearly indicated on both the resistivity and IP logs. The upper sulphide zone has resistivities around 600 ohm-m and the lower zone has resistivities ranging from 70 to 600 ohm-m depending on the percentage of the sulphide mineralization. The sulphides between 432 and 467 give a slightly lowered resistivity response but a very distinct high IP response. It should be noted that these resistivities are apparent resistivities and are given only to provide approximate relative variations in resistivities.

The spectral gamma gamma logs provide information on the rock density and heavy mineral content (pyrite, chalcopyrite) along the drill hole. The density is uncalibrated and is therefore indicated as high or low density. The density of the basalt is fairly uniform but shows lowered densities within altered zones that correlate fairly well with the low resistivity zones. These responses are mainly due to porosity changes. The upper section of the tuffite unit has lower density than the basalt. This is the unmineralized part of the unit (between 375.2 to 388 m). The spectral gamma gamma ratio (SGGR), a ratio of a high energy window of the back-scattered gamma rays to a low energy window, is used to determine and locate mineralized zones with heavy elements. The sulphide zones above the tuffite and that below are clearly indicated on the ratio log. The ratio log also indicates a lower ratio in the tuffite than in the basalts. This suggests that the two media have different effective atomic numbers, Zeq. Basalts have a high Zeq because of the high percentage of magnesium and iron oxides whereas tuffites that consist principally of quartz (about 83 percent SiO_2) have low Zeq because they contain elements with low atomic numbers, Z.

The conductivity log from the Geoinstrument probe shows variations in conductivity which correlate with the lower resistivity zones of the altered basalts on the resistivity log. The tuffite and the sulphide zones show higher conductivities; the highest conductivities being indicated within the sulphide mineralizations. The variations in the susceptibility log do not reflect changes in alteration of the basalt or changes in lithology (e.g. basalt to tuffite). The susceptibility data is suspect.

The temperature logs show fairly uniform increases in temperature (or constant temperature gradients) within the top 387 m of the basalts. The tuffite shows slightly higher temperature gradients than upper basaltic layers. Below 395 the temperature gradients are lower than those of the upper basalts.

Some comments on the logging data collected at the Goldstream deposit

Two holes were geophysically logged at the Goldstream deposit. The holes intersect limestone, phyllite, dark banded phyllite, graphitic phyllite and semi-massive sulphides. The geophysical logs show very interesting features with regard to lithology and mineralization and some of these features are summed up below by L. Bradish, Noranda Exploration.

> "**Magnetic Susceptibility** proved to be most interesting in that it identified substantial magnetic packages within the dark banded phyllite. The routine geological logging did not identify any changes within the DBP and unfortunately the core is no longer available for detail logging.
>
> **Temperature:** The temperature gradient log was very interesting in mapping sharp changes in temperature. Again a re-examination of the drill core would be very informative.
>
> **Conductivity and Density:** This pair of parameters has shown some ability to differentiate between the graphitic and sulphide sources. Individually these parameters show significant variations, however, correlation with the drill core is not possible.
>
> Overall, despite the logistical problems, the data collected was very enlightening and well worth the effort. Unfortunately the drill core from the two Goldstream holes is no longer available for close scrutiny. An ideal system would provide the geologist with the logs following the completion of the drill hole. This I feel would be worth the additional investment of time and money."

6. PHYSICAL PROPERTY TABLES

After the data processing procedures described earlier were completed, the physical properties for each rock unit could be derived from the logs. The compilation of physical properties is affected by the rock 'unit' assignments recorded in the geological logs, as well as the selection of data points in the geophysical logs.

Compilation of Physical Properties from Borehole Geophysical Logs

To derive representative values for the physical properties of each rock unit encountered, the following procedure was adopted. For each hole logged, the geological logs were used to select relatively homogeneous sections of the hole over which the borehole geophysical measurements could be averaged. As much as possible narrow zones were avoided due to the possibility of errors in location of the boundaries of the zone in the geological log due to lost core or other reasons. Also averages over wide zones did not include data points near the boundaries for the same reason. The logs were averaged to a depth interval of 0.5 m, and the statistical package SYSTAT used to generate averages over each rock type.

For each borehole the rock units chosen are based on the definitions/descriptions found in the geological logs supplied by the company which drilled the hole. (Highland Valley and Lara geological logs were unavailable.) In some cases thick geological units which were considered to be homogeneous in the core log, showed obvious changes in the geophysical logs. Sometimes descriptive terms are somewhat subjective and distillation /revision /combination of the rock units may be possible with further study of the geophysical logs.

The results of this compilation are summarized and presented in Table 1. to Table 5. below. In these summary tables, only the means and standard deviations are given.

Appendix 2 contains additional details about the physical property data tables.
Tables in the Appendix include rock unit, and for each parameter the minimum, maximum and mean value and standard deviation. The number of data points averaged is also given so that the standard error of the mean could be computed.

Temperature gradient data have been compiled separately in Appendix 3 which lists the average values and depth ranges for temperature gradients for all areas, except Equity Silver, borehole 86264, where temperature was not recorded.

PHYSICAL PROPERTY DATA SUMMARY TABLES

Summary Table of Means and Standard Deviations

Table	Area, Hole Number
1A.	Buttle Lake, Borehole PR061
1B.	Buttle Lake, Borehole W129
2.	Chu Chua, Borehole CC055
3A.	Equity Silver, Borehole 86246
3B.	Equity Silver, Borehole 86250
3C.	Equity Silver, Borehole 86264
4A.	Goldstream, Borehole NG049
4B.	Goldstream, Borehole NG050
5.	Sullivan, Borehole K6423

The following abbreviations are used in the tables:

TC	Gamma Ray-Total Count (cps)
DEN	Density (g/cm^3)
SPR	Single Point Resistance (Ohms)
IP	Induced Polarization (mV/V)
RES	Resistivity (Ohm-m)
CN(G)	Conductivity-Geoinstruments (S/m)
CN(R)	Conductivity-Romulus (S/m)
MS(G)	Magnetic Susceptibility-Geoinstruments (micro SI)
MS(R)	Magnetic Susceptibility-Romulus (micro SI)

Bad data values have been deleted from the tables.

Summary Tables of Means and Standard Deviations:

NOTATION: Mean/Standard Deviation

TABLE 1A: BUTTLE LAKE, BOREHOLE PR061:

	TC	RES	IP	MS(G)
MAFIC CHERTY	25/15	21673/19182	7.0/3.3	47637/34605
FELDSPAR DYKE	49/14	43207/23948	7.1/2.6	31279/10728
ALTERED DIABASE	12/ 5	19431/13842	7.7/2.1	47761/21883
ARGILLITE	29/16	3434/4208	--	36353/4577
MAFIC DACITE	41/14	36870/17156	8.8/2.0	27585/3729
MAFIC PORPHYRY ANDESITE	36/18	54408/9327	8.3/0.7	23884/1249
RHYOLITE	49/11	40785/18885	6.8/1.2	26212/23662
MASSIVE DACITE	63/8	23079/5537	6.9/0.9	106113/68860

TABLE 1B: BUTTLE LAKE, BOREHOLE W129:

	TC	RES	IP	MS(G)
MAFIC DACITE	25/9	16948/5479	4.1/0.8	57190/5047
MAFIC MASSIVE	10/3	18905/4930	4.1/0.6	82770/54396
MAFIC PORPHYRY	17/5	17809/3165	4.5/0.5	51288/508
JASPER WITH SULPHIDE	14/8	13577/6430	13.3/12.1	142131/112659
MAFIC MASSIVE DYKE	19/5	8958/4004	5.7/1.1	52018/1416

TABLE 2: CHU CHUA, BOREHOLE CC055:

	RES	IP	CN(G)	MS(G)
BASALT	5538/1817	9.4/12.2	2.8/0.9	4971/720
TUFFITE	788/477	16.6/27.2	5.7/0.5	5285/446

TABLE 3A: EQUITY SILVER, BOREHOLE 86246:

	DEN	RES	IP	CN(G)	MS(G)
CHERTY CONGLOMERATE	2.82/0.02	1146/179	10.9/1.9	8.7/0.2	598/120
ANDESITE DYKE	2.86/0.03	548/58	19.4/1.7	8.6/0.0	3345/3021
ASH LAPILLI TUFF	3.09/0.13	377/200	36.5/16.8	9.7/1.4	10573/32285
PLAG PORPHYRY	2.93/0.05	283/99	13.6/1.2	10.0/0.2	36790/18244

TABLE 3B: EQUITY SILVER, BOREHOLE 86250:

	DEN	RES	IP	CN(R)	MS(G)	MS(R)
PORPHYRY DYKE	2.87/0.04	439/64	9.8/8.3	0.6/0.0	14190/9024	18951/5667
GABBRO	2.88/0.08	452/260	11.3/3.6	0.6/0.0	21758/18654	21861/11777
ANDESITE DYKE	2.82/0.11	450/365	12.2/6.3	0.6/0.0	15001/19634	18771/15832
QUARTZ DYKE	2.58/0.17	144/16	5.8/1.5	0.6/0.0	848/181	7372/148
ASH LAPILLI TUFF	3.00/0.14	248/100	31.0/16.4	0.6/0.0	4818/6249	10784/3654

TABLE 3C: EQUITY SILVER, BOREHOLE 86264:

	TC	DEN	RES	IP
SEDIMENTARY VOLCANIC DUST TUFF	60/ 5	2.89/0.08	842/ 401	33.4/20.3
SEDIMENTARY VOLCANIC CHERT PEBBLE CONGLOMERATE	22/ 2	2.78/0.07	2542/1705	38.5/24.4
QUARTZ LATITE DYKE	100/ 8	2.48/0.09	148/ 37	14.9/12.1
PYROCLASTIC DUST TUFF	84/12	2.97/0.04	428/ 206	28.2/17.8
SEDIMENTARY VOLCANIC QUARTZ SANDSTONE	34/ 8	2.87/0.06	2095/1001	42.4/20.8

TABLE 4A: GOLDSTREAM, BOREHOLE NG049:

	TC	RES	IP	MS(G)
PHYLLITE	87/14	1307/617	30.0/16.9	24806/18357
PHYLLITE WITH GARNET	111/12	1577/133	14.2/2.3	18540/4811
DARK BANDED PHYLLITE	86/10	961/629	42.1/20.4	9753/13251
DARK BANDED PHYLLITE WITH QUARTZ	80/8	576/627	50.9/19.4	14204/16552
LIMESTONE	54/12	1255/357	39.1/9.6	3205/5591
QUARTZ SERICITE SCHIST	63/15	530/612	26.8/69.9	137802/297479

TABLE 4B: GOLDSTREAM, BOREHOLE NG050:

	TC	RES	IP	MS(R)
IMPURE LIMESTONE	45/14	2334/202	12.3/4.4	433/89
LIMESTONE	15/9	4378/917	10.9/2.6	159/87
PHYLLITE	110/15	1291/431	21.6/8.5	714/265
DARK BANDED PHYLLITE	88/11	1068/767	37.6/17.5	815/641
DARK BANDED PHYLLITE WITH QUARTZ	91/10	822/607	48.1/19.1	974/816
CALCAREOUS DARK BANDED PHYLLITE	91/3	1017/167	43.7/2.8	287/07
GRAPHITIC DARK BANDED PHYLLITE WITH QUARTZ	74/23	21/41	150.2/75.4	8183/1420

TABLE 5. SULLIVAN, BOREHOLE K6423:

	TC	SPR	RES	IP	MS(G)
ARGILLITE/ SILTY ARGILLITE/ ARGILLACEOUS SILTSTONE	167/19	2311/230	433/259	24.4/5.5	15323/2256
QUARTZITE	160/41	2353/255	598/336	24.8/9.2	14586/3302
SILTY ARGILLITE	178/25	2227/187	264/193	17.5/4.5	18416/2676
SULPHIDE	178/14	2051/145	103/136	21.0/11.2	25036/3049
SILTSTONE/ SILTY ARGILLITE/ ARGILLACEOUS SILTSTONE	177/8	2419/106	539/168	23.3/ 3.3	14470/844
ARGILLITE/ SILTY ARGILLITE/ QUARTZITE	131/30	2589/106	576/74	20.8/3.5	13445/374
ARGILLITE/ SILTY ARGILLITE	203/19	2074/ 54	310/ 99	25.0/3.3	14112/1131

7. ACKNOWLEDGEMENTS

The authors would like to thank the mining companies in the B.C Minerals Logging Group, who collaborated in this project, in particular Cliff Pearson of Westmin, Lyndon Bradish and Roger Pemberton of Noranda, Jan Klein of Cominco, Peter Kowalczyk of Placer, Zig Doborzynski of Esso, Dave Watkins of Falconbridge and especially Ken Witherly of Utah Mines, who was a primary stimulus to the formation of the B.C. Minerals Logging Group and whose skills at communication kept the project on track over several years. We also thank the numerous individuals who provided logistical support and assistance during the field operations. Special thanks are accorded to Bill Hyatt who took the GSC R&D Logging System to locations better suited to mountain goats, and returned with high quality data. We also acknowledge K.A. Richardson and K.A. Pflug for their critical reviews and constructive suggestions.

8. REFERENCES

Borehole Geophysics Section

1991: New developments and applications of borehole geophysics to mineral exploration; GSC Forum (Jan. '91), Program with Abstracts, p. 18.

Elliott, B.E.

1991: An Overview of Processing, Display and Enhancement Methods used on Borehole Geophysical Logging Data at the Geological Survey of Canada. Poster and in Proceedings of the 4th International Symposium on Borehole Geophysics for Minerals, Geotechnical and Groundwater Applications, Toronto, August 18-22, 1991, p. 227-235.

Elliott, B.E., Mwenifumbo, C.J. and Killeen, P.G.

1990: Lithological correlation and determination of physical rock properties with borehole geophysics; Prospectors & Developers Poster session.

Killeen. P.G.

1988: The role of borehole geophysics in mineral exploration; in: 'Recent Developments in Geophysics Applied to Mineral Exploration'; the 17th Adams Club Symposium, Montreal, Quebec, March 11, 1988 (Abstract).

1990: Geophysics in the third dimension: An overview of downhole research and development at the GSC; GSC Minerals Colloquium, Ottawa, Program with Abstracts, p. 7.

1991: Borehole geophysics: Taking geophysics into the third dimension; in GEOS, Vol. 20, No. 2, 1991, p. 1-10.

Killeen, P.G. and Mwenifumbo, C.J.

1988A: Applications of borehole geophysics to massive sulphide deposits in the cordillera;

in: B.C. Roundup, Vancouver, Feb. 2, 1988 (abstract).

1988B: Interpretation of new generation geophysical logs in Canadian mineral exploration; in: 2nd International Symposium on Borehole Geophysics for Minerals, Geotechnical and Groundwater Applications, Oct. 6-8, 1987, Golden, Colorado, p. 167-178.

Killeen, P.G., Elliott, B.E. and Mwenifumbo, C.J.

1989: Borehole geophysics applied to massive sulphide deposits in the Cordillera: A report on the 'B.C. Mineral Logging Group' Study, Preliminary Report, May, 2, 1989, submitted to the B.C. Mineral logging Group, 44 pages.

1990A: Lithological correlation and determination of physical rock properties with borehole geophysics; GSC Minerals Colloquium, Ottawa, Program with Abstracts, p. 18.

1990B: Borehole geophysics applied to massive sulphide deposits in the Cordillera: A report on the 'B.C. Mineral Logging Group' Study; (Preliminary report).

Killeen, P.G., Mwenifumbo, C.J. and Elliott, B.E.

1995: The pseudo-geological log: using geophysical logs as an aid to geological logging in volcanogenic massive sulphides; in Current Research 1995-E; Geological Survey of Canada, p. 1-10.

Kowalczyk, P., Killeen, P.G. and Mwenifumbo, C.J.

1990: Borehole geophysics in the British Columbia mineral logging project; the Equity Silver Deposit; GSC Minerals Colloquium, Ottawa, Program with Abstracts, p. 7.

Mwenifumbo, C.J. and Killeen, P.G.

1988: Borehole geophysical responses of massive sulphide deposits in the cordillera; in: Geol. Surv. Can., Current Activities Forum, Jan. 19-20, 1988 (abstract).

Mwenifumbo, C.J., Killeen, P.G. and Elliott, B.E.

1993: Classic examples from the Geological Survey of Canada data files illustrating the utility of borehole geophysics; in Proceedings of the 5th International Symposium of the Minerals & Geotechnical Logging Society, Tulsa, October 24-28, 1993, paper K, p. 1-15.

APPENDIX 1 - The Logging System

The GSC Borehole Geophysical Logging System

Applications of geophysical logging encompass both mining exploration and geotechnical problems. These include: delineating ore zones, identifying and mapping alteration associated with ore, mapping lithology and hole-to-hole stratigraphic correlation. Also possible is in situ assaying of ore, and in situ determination of physical rock properties for calculating geotechnical (rock strength) parameters. Groundwater flow patterns in joints and fractures intersected by the holes can be detected as well.

The primary components of the GSC R&D digital logging system are:

1. the borehole probe containing the geophysical sensor;
2. the logging cable and winch for sending the signal to the surface instruments, and for sending power down to the probe;
3. a depth counter attached to a wellhead pulley for keeping track of the location of the probe in the hole;
4. an analog-to-digital converter (ADC) to convert the signal to digital form for recording;
5. a computer, keyboard and CRT monitor to acquire data and display information;
6. a 9-track magnetic tape recorder;
7. a multi-pen chart recorder to provide a hard copy in the field.

Most modern 'slim-hole' tools are 38 to 50 in mm diameter, designed to run in BQ holes or larger. The logging speed is usually about 6 m/minute and can be run in air- and/or water-filled holes depending on the sensor. Data sampling rate ranges from 1 to 5 samples per second, providing a measurement every 2 to 10 cm along the hole.

The GSC truck-mounted system has five logging tools (probes) with different sensors that in total can measure up to twelve parameters. The characteristics of the logging tools and their measuring principles are briefly described below.

General Description of GSC Logging Tools and Geologic Responses

1. GAMMA-RAY SPECTRAL LOGGING

1.1 Geologic Interpretation of Gamma-Ray Spectral Logs

Gamma-ray measurements detect variations in the natural radioactivity originating from changes in concentrations of the trace elements uranium (U) and thorium (Th) as well as changes in concentration of the major rock forming element potassium (K). Since the concentrations of these naturally occurring radioelements vary between different rock types, natural gamma-ray logging provides an important tool for lithologic mapping and stratigraphic correlation. Gamma-ray logs are important for detecting alteration zones, and for providing information on rock types. For example, in sedimentary rocks, sandstones can be easily distinguished from shales due to the low potassium content of the sandstones compared to the shales.

In sedimentary rocks, potassium is in general the principal source of natural gamma radiation, primarily originating from clay minerals such as illite and montmorillonite. In igneous and metamorphic geologic environments, the three sources of natural radiation may contribute equally to the total number of gamma rays detected by the gamma probe. Often in base metal and gold exploration areas, the principal source of the natural gamma radiation is potassium because alteration, characterized by the development of sericite (sericitization), is prevalent in some of the lithologic units and results in an increase in the element potassium in these units. This renders sericitized zones excellent targets for gamma-ray logging. The presence of feldspar porphyry sills, which contain increased concentrations of K-feldspar minerals, would also show higher than normal radioactivity on the gamma-ray logs. During metamorphism and hydrothermal alteration processes, uranium and thorium may be preferentially concentrated in certain lithologic units.

1.2 Principle of Gamma-Ray Spectral Logging

A gamma-ray probe's sensor is usually a sodium iodide or cesium iodide scintillation detector. Unlike an ordinary gamma-ray tool which only counts the total gamma rays, the spectral gamma-ray tool also measures the energy of each gamma ray detected. K, U and Th produce gamma rays with characteristic energies so geophysicists can estimate the individual concentrations of the three radioelements.

Potassium decays into two stable isotopes (argon and calcium) which are no longer radioactive, and emits gamma rays with energies of 1.46 MeV. Uranium and thorium, however, decay into daughter-product isotopes which are unstable (i.e. radioactive). The decay of uranium forms a series of about a dozen radioactive elements in nature which finally decay to a stable form of lead. The decay of thorium forms a similar series of radioelements. As each radioelement in the disintegration series decays, it is accompanied by emissions of alpha or beta particles or gamma rays. These gamma rays have specific energies associated with the decaying radioelement. The most prominent of the gamma rays in the uranium series originates from decay of ^{214}Bi (bismuth), and in the thorium series originates from decay of ^{208}Tl (thallium).

Because there should be an equilibrium relationship between the daughter product and parent, it is possible to compute the quantity (concentration) of parent uranium (^{238}U) and thorium (^{232}Th) in the decay series by counting gamma rays from ^{214}Bi and ^{208}Tl respectively, if the probe has been properly calibrated (Killeen, 1982).

During each second while the probe is moving along the hole, the gamma rays are sorted by energy into an energy spectrum. The number of gamma rays in three pre-selected energy windows centred over ^{40}K, ^{214}Bi and ^{208}Tl peaks in the spectrum is computed, as is the total gamma-ray count. These four numbers represent gamma rays originating from potassium, uranium, thorium and Total Count (TC) detected during that one second of counting time.

These data are recorded along with the depth and are displayed on the chart recorder to produce gamma-ray spectral logs. The raw gamma-ray spectral logs (Total Count log, K log, U log and Th log) provide more information than a non-spectral (gross count) log, and it is possible to convert them to quantitative logs of percent K, ppm U and ppm Th. This requires that the probe be calibrated in model boreholes with known concentrations of K, U and Th such as the models constructed by the GSC at Bells Corners near Ottawa (Killeen, 1986).

Because gamma rays can be detected through steel, logging can be done inside drill rod or casing with a slight decrease in sensitivity.

1.3 The GSC Gamma-Ray Spectral Logging Equipment

The GSC R&D logging system utilizes gamma-ray spectral data acquisition equipment similar to that found in modern airborne gamma-ray spectrometers. Full 256 channel gamma-ray spectra over an energy range of approximately 0.07 to 3.0 MeV are recorded from a scintillation detector in the probe. The storage media is a 9-track magnetic tape. Scintillation detectors of different materials, and of different sizes are used by the GSC. These include:

Name	Composition	Density (g/cm^3)
Cesium Iodide	CsI (Na)	4
Sodium Iodide	NaI (Tl)	3.67
Bismuth Germanate (BGO)	$Bi_4 Ge_3 O_{12}$	7.0

Probe housings of outside diameter 1.25" (32 mm), 1.5" (38 mm) or 2" (50 mm), contain detectors of sizes ¾" x 3", 1" x 3", and 1.25" x 5", respectively, for use in AQ, BQ, and NQ holes, respectively. The selection of probe (and detector) for logging is determined by the hole diameter. The largest diameter probe that will safely fit in the borehole is selected to maximize the count rate and provide good counting statistics. For smaller probes, the higher density (higher efficiency) materials are chosen. (These are also higher cost). If the count rate is too low due to the extremely low concentrations of K, U and Th, such as is often the case in limestones for example, it may not be possible to produce a K log, U log and Th log. In that case only the Total Count log is produced which is the count rate of all gamma rays above a preselected threshold energy (usually 100 KeV or 400 KeV). A number of factors determine the logging speeds and sample times during the acquisition of gamma-ray data. The critical factors are the anticipated levels of radioactivity and the size of detector in the probe. Gamma-ray spectral logging is usually done at 3 m/minute but can be done as fast as 6 m/minute or as slow as 0.5 m/minute for more detailed information. The volume sampled is about 0.5 cubic metres of rock surrounding the detector, at each measurement (i.e. 10 to 30 cm radius depending on the rock density).

2. DENSITY/SPECTRAL GAMMA-GAMMA (SGG) LOGGING

2.1 Geologic Interpretation of Density and SGG Logs

The density/SGG logging tool measures rock density and SGG ratio. The SGG ratio (defined below) is related to the effective atomic number of the rock, which depends on the chemical composition of the rock. The SGG ratio log is particularly useful for detecting base metals since these elements have high atomic numbers compared to most rock forming minerals, and they can occur in high enough concentrations to significantly increase the effective atomic number of the rock. The SGG ratio log may also be useful for lithologic mapping in areas where the iron content differs significantly between different rock types.

The density of rock is affected by porosity, water content and chemical composition. Most of the density variations within igneous and metamorphic rocks are due to variations in mineralogical composition. Rocks with higher percentages of mafic minerals (Fe, Mg silicates) have higher densities than those with higher percentages of felsic minerals (Ca, Na, K, Al silicates). The presence of minerals containing heavy elements such as base metals tend to increase the overall density of the host rock. In sedimentary rocks, density variations may be a result of differing degrees of compaction (induration) rather than changes in elemental composition.

In ore tonnage and reserve computations, one of the parameters used is the specific gravity and hence a knowledge of in-situ densities of the rocks may provide valuable information for ore reserve estimations. The density log is also useful for locating fractures since open fractures intersected by the borehole often appear as low density zones on the density log (Wilson et al, 1989).

2.2 The GSC Density/SGG Logging Equipment

The density and SGG ratio (or heavy element indicator) logs are derived from the spectral gamma-gamma probe (Killeen and Mwenifumbo, 1988). The density/SGG tool is essentially a spectral gamma-ray logging tool with the addition of a weak (10 millicurie = 370 MBq) gamma-ray source (e.g. ^{60}Co) on the nose of the probe. The tool has a 23 mm by 76 mm (0.9" x 3") cesium iodide detector which measures gamma rays from the source that are backscattered by the rock around the borehole.

Complete backscattered gamma-ray spectra are recorded in 1024 channels over an energy range of approximately 0.03 to 1.0 MeV. Density information is determined from the count rate in an energy window above 200 keV while information about the elemental composition or heavy element content is derived from the ratio of the count rates in two energy windows (spectral gamma-gamma ratio, SGG): one at high energy (above 200 keV) and one at low energy (below 200 keV). When there is a change in the density of the rock being measured, the count rates recorded in both windows will increase or decrease due to the associated change in compton-scattered gamma rays reaching the detector. However, if there is an increase in the content of high Z (atomic number) elements in the rock, the associated increase in photoelectric absorption (which is roughly proportional to Z^5) will cause a significant decrease in count rate in the low energy window with relatively little change in the high energy window. Since the low energy window is affected by both density and Z while the high energy window is mainly affected by density, the ratio of counts in the high energy window to the counts in the low energy window can be used to obtain information on changes in Z. This ratio increases when the probe passes through zones containing high Z materials. Thus the log can be considered as a heavy element indicator, and can be calibrated to produce an assay tool for quantitative determination of the heavy element concentration in situ along the borehole, without resorting to chemical assaying of the core (Killeen and Mwenifumbo, 1988).

The sample volume is smaller than for natural gamma ray logging since the gamma rays must travel out from the probe, into the rock and back to the detector. A 10 to 15 cm radius around the probe is "seen". Data are acquired at a logging speed of 6.0 m/minute with a sample time of 1 second, giving a measurement every 10 cm.

3. IP/R/SP LOGGING

The Induced Polarization (IP) tool consists of an assembly of electrodes which are placed in the borehole, usually including a current electrode and two potential (measurement) electrodes. A square wave current with an 'off' time between positive and negative parts of the waveform is transmitted (waveforms may be from 1 second to 8 seconds duration). Potential measurements made at selected times in the waveform can be related to the IP effect (chargeability of the rocks), the resistivity (R) of the rocks, and to self-potentials (SP) generated in the rocks. The transmitter is a constant current source located at the surface. A detailed explanation of the IP probe will be given below.

3.1 Geological interpretation of IP/R/SP Logs

3.1.1 Induced Polarization (IP)

In time domain IP measurements, the ratio of the secondary voltage measured during the current off-time to the primary voltage measured during the current on-time is related to the electrical polarizability of the rock and is called chargeability. A high chargeability response is an indication of the presence of metallic sulphides and oxides or cation-rich clays such as illite and montmorillonite (Mwenifumbo, 1989). One of the major alteration processes within a number of base metal and gold mining camps is pyritization and this is a target for most IP logging.

3.1.2 Resistivity

The electrical resistivity of rocks depends on several factors including the presence of conductive minerals such as base metal sulphides or oxides and graphite in the rock. Most rocks without these minerals are usually poor conductors and their resistivities are governed primarily by their porosity, degree of fracturing, salinity of the pore water, the degree of saturation of the pore spaces, and to a lesser extent by the intrinsic minerals that constitute the rock. Some alteration processes such as silicification and carbonatization tend to reduce the porosity and hence increase the resistivity of the rock. In igneous and metamorphic rocks, the resistivity log is useful mainly in mapping conductive minerals and fracture zones. In sedimentary rocks, the resistivity log is frequently used in lithologic mapping because changes in lithology are often associated with changes in porosity.

3.1.3 Self Potential or Spontaneous Polarization (SP)

SP anomalies are mainly an indication of the presence of graphite and/or high concentrations of base metal sulphides including pyrite. Large self potentials observed within and around sulphide and graphite bodies are mainly caused by electrochemical processes (Sato and Mooney, 1960, Hovdan and Bolviken, 1984). Low resistivity anomalies correlating with SP and IP anomalies are, therefore, good indications of the presence of conductive minerals. Also SP anomalies can be generated by fluid flow in porous media (electrokinetic or streaming potentials - Bogoslovsky and Ogil'vy, 1970, 1972) and heat flow (thermal electric coupling - Corwin and Hoover, 1979).

3.2 The IP Logging Tool Description

The transmitter on surface is a constant current source capable of supplying up to 250 mA. There are 4 selectable pulse times for the current waveforms: 0.25s, 0.5s, 1s and 2s (i.e. full waveforms of 1 second to 8 seconds duration). The long pulse times would mean logging at very low speeds in order to avoid errors that may be introduced in smearing measurements over large depth intervals. The volume of rock sampled is roughly related to the electrode spacings. The full waveform is recorded (digitized at 4ms intervals) on 9-track magnetic tape. Logging speed varies in the range 1 to 6 m/minute according to the chosen pulse length (waveform duration). The sample interval is dependant on the chosen logging speed and chosen waveform period. Typically, a 1 second period with a logging speed of 6 m/minute results in sampling every 10 cm along the borehole. This tool must be run in uncased, water-filled holes.

3.2.1 Induced Polarization

The standard IP parameter is the chargeability determined during the early middle or center of the 'off' time of the decaying waveform. The apparent chargeabilities can be measured with 3 types of electrode arrays: 40-cm normal array, lateral array (pole-dipole array) and the 10-cm Dakhnov micronormal array. The downhole current and potential electrodes are gold-plated brass cylinders, 40 mm in diameter.

3.2.2 Self Potential or Spontaneous Polarization (SP)

The self potential is determined during the late 'off' time of the IP decay waveform. SP measurements are carried out either in the gradient mode with the same arrays as are used in the IP measurements, or in the Potential mode with a single Pb or $Cu/CuSo_4$ electrode downhole and a reference electrode on the surface. SP can be measured simultaneously with the IP/Resistivity measurements or in a separate logging run with current off. The latter is the preferred approach.

3.2.3 Resistivity (R)

The resistivity measurements are derived from the waveforms received during the constant current 'on' time of the square waveform, after the initial IP charging effects are over. Resistivity measurements are made with the same arrays as are used in the IP measurements. Single point resistance measurements can also be made using a single downhole current/potential electrode (Pb) and a return/reference electrode on the surface.

4. MAGNETIC SUSCEPTIBILITY LOGGING

4.1 Geologic Interpretation of Magnetic Susceptibility Logs

The magnetic susceptibility (MS) of a volume of rock is a function of the amount of magnetic minerals, mainly magnetite, and pyrrhotite, contained within the rock. MS measurements can provide a rapid estimate of the ferromagnetism of the rock. These measurements can be interpreted to reflect lithological changes, degree of homogeneity and the presence of alteration zones in the rock mass. During the process of hydrothermal alteration, primary magnetic minerals (e.g. magnetite) may be altered (or oxidized) to weakly- or non-magnetic minerals (e.g. hematite). Anomalously low susceptibilities within an otherwise homogeneous high susceptibility (ferromagnetic) rock unit may be an indication of altered zones.

Basic flows and diabase dikes containing higher concentrations of magnetic minerals can be easily outlined from magnetic susceptibility measurements when they occur within a sedimentary sequence which normally contain little or no magnetic minerals.

4.2 The Magnetic Susceptibility Logging Tool Description

4.2.1 MS Measurement with the Geoinstrument TH-3C Probe

The magnetic susceptibility tool consists of a Geoinstruments model TH-3C probe and uses a signal processing unit developed at the GSC (Bristow and Bernius, 1984; Bristow, 1985). The probe contains a coil, 42 mm in diameter by 0.5 m in length, in an electrical bridge circuit energized at a frequency of 1400 Hz. When the probe passes through magnetically susceptible material, the coil inductance changes causing the bridge to become unbalanced. The bridge is balanced automatically by changing the energizing frequency. This change in frequency is converted to magnetic susceptibility. Since the measurements are made inductively (i.e., with EM coils not contact electrodes), the tool can be used inside plastic casing and in dry holes. Susceptibilities within the range from 0 to 2.0 SI can be measured with this tool. The volume of investigation or 'sample volume' is roughly a sphere of 30 cm radius, surrounding the sensing coil in the probe. Logging is normally carried out at 6 m/minute and a measurement is taken every second or each 10 cm along the hole.

4.2.2 MS measurement with the BRGM 'ROMULUS' probe

The Romulus probe is a low-frequency (4 KHz), two-coil electromagnetic induction probe. It consists of coaxial transmitting and receiving coils spaced 85 cm apart. It compensates for the primary field and measures in-phase and quadrature components of the secondary field. These two quantities are approximately proportional to magnetic susceptibility and electrical conductivity of the rock around the borehole.

For the magnetic susceptibility (in-phase) measurement, the sensitivity is 3.14×10^{-3} μSI/volt and the measuring range is 10^{-5} to 3.5×10^{-2} μSI.

4.3 The Conductivity Logging Tool Description

4.3.1 Conductivity Measurement with the Geoinstruments TH-3C probe

The Maxwell-bridge circuit which is used in the TH-3 probe also allows conductivity of material close to the coil to be measured simultaneously with susceptibility. This is possible by resolving the change in complex impedance seen by the bridge into its inductive and resistive vector components. (Resistive material around the coil causes the coil to behave as a transformer with the resistive material acting as a combined and distributed "secondary winding" and "load"). Resistivity measurements using this technique are limited however to a range of 10^{-1} ohm-m to 10^{3} ohm-m. In practice only a few sedimentary formations would normally have resistivities low enough to fall within this range, while in igneous rocks only graphitic conductors or mineralized zones such as massive sulphides would be included (Bristow and Bernius, 1984).

4.3.3. Conductivity measurement with the BRGM 'ROMULUS' probe

As mentioned above in the section on magnetic susceptibility, the secondary field at the receiver coil is measured and the out of phase component is proportional to electrical conductivity (quadrature). The sensitivity is 0.46 mho/m/volt and the measuring range is 10^{-3} to 5.5 mho/m.

5. TEMPERATURE/T-GRADIENT LOGGING

5.1 Geologic Interpretation of Temperature Logs

Temperature measurements are used to detect changes in thermal conductivity of the rocks along the borehole or to detect water flow through cracks or fractures. Fractures or shear zones may provide pathways for groundwater to flow if hydrologic gradients exist within the rock mass. Groundwater movements produce characteristic anomalies and their detection may provide information on the location of the fractured rock mass and hence aid in the structural interpretation of the area. The temperature gradient log amplifies small changes in the temperature log, making them easier to detect.

Large concentrations of metallic sulphides and oxides may perturb the isothermal regime locally since metallic minerals have very high thermal conductivities. This perturbation may be delineated with the high sensitivity temperature logging system. This, however, would be observed only in a thermally 'quiet' environment. In areas where there are numerous fracture zones with ground water movements, thermal anomalies due to ground water movements are much larger than those that would be observed due to perturbation caused by the presence of metallic minerals.

5.2 The Temperature Logging Tool Description

The ultra-high sensitivity temperature probe designed at the GSC has a 10 cm long tip of thermistor beads with sensitivity of 0.0001 degrees Celsius. Changes in temperature of the fluid in the borehole are measured and sent as a digital signal to the surface. The signal is then converted into true temperature after correcting for the effect of the thermistor time constants; the temperature gradients are computed from the temperature data. All temperature logging is carried out during a downhole run so the sensor is measuring the temperature of the undisturbed fluid. The usual logging speed is 6 m/minute with data sampled every 1/5 of a second (approximately every 2 cm). This high spatial resolution of data is necessary if accurate temperature gradients are to be determined from the temperature data.

Selected Bibliography on Borehole Geophysical Logging

Bogoslovsky, V.A. and Ogil'vy, A.A.
1970: Natural potential anomalies as a quantitative index of the rate of seepage from water reservoirs. Geophysical Prospecting, 18:261-268.

Bogoslovsky, V.A. and Ogil'vy, A.A.
1972: The study of streaming potentials on fissured media models (faults). Geophysical Prospecting, 20:109-117.

Bristow, Q. and Bernius, G.
1984: Field evaluation of a magnetic susceptibility logging tool; in Current Research, Part A, Geological Survey of Canada, Paper 84-1A, pp. 453-462.

Bristow, Q. and Conaway, J.G.
1984: Temperature gradient measurements in boreholes using low noise high resolution digital techniques; in Current Research, Part B, Geological Survey of Canada, Paper 84-1B, pp. 101-108.

Bristow, Q.
1985: A digital processing unit for the GeoInstruments magnetic susceptibility sensors, with analogue and RS-232C outputs; in Current Research, Part B, Geological Survey of Canada, Paper 85-1B, pp. 463-466.

Corwin, R.F. and Hoover, D.B.,
1979: The self-potential method in geothermal exploration. Geophysics, 44:226-245.

Hovdan, H. and Bolviken, B.,
1984: Sulphide self potentials in relation to oxygen content in drill-hole water. Geoexploration, 23:387-394.

Killeen, P.G.
1982: Borehole logging for uranium by measurement of natural gamma radiation - a review; International Journal of Applied Radiation and Isotopes, Vol. 34, No. 1, pp. 231-260.

Killeen, P.G.
1986: A system of deep test holes and calibration facilities for developing and testing new borehole geophysical techniques; in Borehole Geophysics for Mining and Geotechnical Applications, ed. P.G. Killeen, Geological Survey of Canada, Paper-85-27, 1986, pp. 29-46.

Killeen, P.G. and Mwenifumbo, C.J.
1988: Downhole assaying in Canadian mineral deposits with the spectral gamma-gamma method; in Current trends in nuclear borehole logging techniques for elemental analysis, IAEA-ECDOC-464, pp. 23-29

Mwenifumbo, C.J.
1989: Optimization of logging parameters in continuous, time-domain induced polarization measurements. in Proceeding of the Third International Symposium on Borehole Geophysics for Mineral, Geotechnical, and Groundwater Applications, Oct. 2-5, Las Vegas, Nevada, vol. 1, 201-232.

Mwenifumbo, C.J.
1993: Temperature logging in mineral exploration. Journal of Applied Geophysics, 30:297-313.

Mwenifumbo, C.J. and Killeen, P.G.
1987: Natural gamma ray logging in volcanic rocks: the Mudhole and Clementine base metal prospects; in Buchans Geology, Newfoundland, ed. R.V. Kirkham; Geological Survey of Canada, Paper 86-24, pp. 263-272, Report 16, 1987.

Pflug, K.A., Killeen, P.G. and Mwenifumbo, C.J.
1994: Acoustic velocity logging at the McConnell nickel deposit, Sudbury area, Ontario:preliminary in situ measurements; in Current Research 1994-C, Geological Survey of Canada, pp. 279-286.

Sato, M. and Mooney, H.M.
1960: The electrochemical mechanism of sulphide self potentials. Geophysics, 25:226-249.

Wilson, H.C., Michel, F.A., Mwenifumbo, C.J. and Killeen, P.G.
1989: Application of borehole geophysics to groundwater energy resources; in Proceedings of the 3rd International Symposium on Borehole Geophysics for Minerals and Geotechnical Logging, 2-5 Oct., 1989, Las Vegas, Nevada, pp. 317-336.

APPENDIX 2 - Detailed Physical Property Data

Tables of Maximums, Minimums, Means and Standard Deviations

Table	**Area, Hole Number**
A2-1A.	Buttle Lake, Borehole PR061
A2-1B.	Buttle Lake, Borehole W129
A2-2.	Chu Chua, Borehole CC055
A2-3A.	Equity Silver, Borehole 86246
A2-3B.	Equity Silver, Borehole 86250
A2-3C.	Equity Silver, Borehole 86264
A2-4A.	Goldstream, Borehole NG049
A2-4B.	Goldstream, Borehole NG050
A2-5.	Sullivan, Borehole K6423

The following abbreviations are used in the tables:

TC	Gamma Ray-Total Count (cps)
DEN	Density (g/cm^3)
SPR	Single Point Resistance (Ohms)
IP	Induced Polarization (mV/V)
RES	Resistivity (Ohm-m)
CN(G)	Conductivity-Geoinstruments (S/m)
CN(R)	Conductivity-Romulus (S/m)
MS(G)	Magnetic Susceptibility-Geoinstruments (micro SI)
MS(R)	Magnetic Susceptibility-Romulus (micro SI)

Minimums, Maximums, Means and Standard Deviation Tables by Borehole:

TABLE A-1A. BUTTLE LAKE, BOREHOLE PR061:

MAFIC CHERTY:
NUMBER OF DATA POINTS: 678

	TC	RES	IP	MS(G)
MINIMUM	4	823	0.1	21847
MAXIMUM	76	102372	46.9	305397
MEAN	25	21673	7.0	47637
STANDARD DEV	15	19182	3.3	34605

FELDSPAR DYKE:
NUMBER OF DATA POINTS: 44

	TC	RES	IP	MS(G)
MINIMUM	21	3165	0.0	24906
MAXIMUM	73	92369	10.1	69607
MEAN	49	43207	7.1	31279
STANDARD DEV	14	23948	2.6	10728

ALTERED DIABASE:
NUMBER OF DATA POINTS: 28

	TC	RES	IP	MS(G)
MINIMUM	6	6051	4.0	33928
MAXIMUM	27	44112	11.4	123628
MEAN	12	19431	7.7	47761
STANDARD DEV	5	13842	2.1	21883

ARGILLITE:
NUMBER OF DATA POINTS: 6

	TC	RES	IP	MS(G)
MINIMUM	15	75	--	31192
MAXIMUM	52	10033	--	43946
MEAN	29	3434	--	36353
STANDARD DEV	16	4208	--	4577

MAFIC DACITE:
NUMBER OF DATA POINTS: 312

	TC	RES	IP	MS(G)
MINIMUM	5	8141	4.5	23600
MAXIMUM	78	91922	16.3	76229
MEAN	41	36870	8.8	27585
STANDARD DEV	14	17156	2.0	3729

MAFIC PORPHYRY ANDESITE:
NUMBER OF DATA POINTS: 26

	TC	RES	IP	MS(G)
MINIMUM	18	38230	7.1	21578
MAXIMUM	74	71246	9.6	26263
MEAN	36	54408	8.3	23884
STANDARD DEV	18	9327	0.7	1249

RHYOLITE:
NUMBER OF DATA POINTS: 108

	TC	RES	IP	MS(G)
MINIMUM	25	9922	1.0	19887
MAXIMUM	85	93340	9.3	225207
MEAN	49	40785	6.8	26212
STANDARD DEV	11	18885	1.2	23662

MASSIVE DACITE:
NUMBER OF DATA POINTS: 94

	TC	RES	IP	MS(G)
MINIMUM	42	4860	3.6	28293
MAXIMUM	78	42054	9.1	277565
MEAN	63	23079	6.9	106113
STANDARD DEV	8	5537	0.9	68860

TABLE A-1B. BUTTLE LAKE, BOREHOLE W129:

MAFIC DACITE:

NUMBER OF DATA POINTS: 208

	TC	RES	IP	MS(G)
MINIMUM	8	2495	2.6	50292
MAXIMUM	51	31081	7.4	71257
MEAN	25	16948	4.1	57190
STANDARD DEV	9	5479	0.8	5047

MAFIC MASSIVE:

NUMBER OF DATA POINTS: 244

	TC	RES	IP	MS(G)
MINIMUM	4	5172	2.6	54457
MAXIMUM	24	33642	5.8	420063
MEAN	10	18905	4.1	82770
STANDARD DEV	3	4930	0.6	54396

MAFIC PORPHYRY:

NUMBER OF DATA POINTS: 12

	TC	RES	IP	MS(G)
MINIMUM	8	11722	3.7	50762
MAXIMUM	28	21849	5.2	52479
MEAN	17	17809	4.5	51288
STANDARD DEV	5	3165	0.5	508

JASPER WITH SULPHIDE:

NUMBER OF DATA POINTS: 4

	TC	RES	IP	MS(G)
MINIMUM	6	6807	0.7	61950
MAXIMUM	21	20407	25.5	309036
MEAN	14	13577	13.3	142131
STANDARD DEV	8	6430	12.1	112659

MAFIC MASSIVE DYKE:

NUMBER OF DATA POINTS: 118

	TC	RES	IP	MS(G)
MINIMUM	4	2950	4.1	49114
MAXIMUM	40	16470	13.9	58291
MEAN	19	8958	5.7	52018
STANDARD DEV	5	4004	1.1	1416

TABLE A-2. CHU CHUA, BOREHOLE CC055:

BASALT:

NUMBER OF DATA POINTS: 828

	RES	IP	CN(G)	MS(G)
MINIMUM	257	<0.0	1.2	1381
MAXIMUM	6962	59.0	6.0	6610
MEAN	5538	9.4	2.8	4971
STANDARD DEV	1817	12.2	0.9	720

TUFFITE:

NUMBER OF DATA POINTS: 30

	RES	IP	CN(G)	MS(G)
MINIMUM	0	<0.0	5.0	4427
MAXIMUM	1553	88.7	6.9	5800
MEAN	788	16.6	5.7	5285
STANDARD DEV	477	27.2	0.5	446

TABLE A-3A. EQUITY SILVER, BOREHOLE 86246:

CHERTY CONGLOMERATE:

NUMBER OF DATA POINTS: 20

	DEN	RES	IP	CN(G)	MS(G)
MINIMUM	2.78	863	8.0	8.2	447
MAXIMUM	2.86	1442	15.2	9.0	997
MEAN	2.82	1146	10.9	8.7	598
STANDARD DEV	0.02	179	1.9	0.2	120

ANDESITE DYKE:

NUMBER OF DATA POINTS: 4

	DEN	RES	IP	CN(G)	MS(G)
MINIMUM	2.83	483	17.0	8.6	993
MAXIMUM	2.89	622	20.9	8.7	7533
MEAN	2.86	548	19.4	8.6	3345
STANDARD DEV	0.03	58	1.7	0.0	3021

ASH LAPILLI TUFF:

NUMBER OF DATA POINTS: 166

	DEN	RES	IP	CN(G)	MS(G)
MINIMUM	2.66	5	15.3	7.8	328
MAXIMUM	3.46	973	98.8	4.8	212478
MEAN	3.09	377	36.5	9.7	10573
STANDARD DEV	0.13	200	16.8	1.4	32285

PLAG PORPHYRY:

NUMBER OF DATA POINTS: 5

	DEN	RES	IP	CN(G)	MS(G)
MINIMUM	2.85	167	12.2	9.8	15963
MAXIMUM	2.97	405	15.3	10.3	56893
MEAN	2.93	283	13.6	10.0	36790
STANDARD DEV	0.05	99	1.2	0.2	18244

TABLE A-3B. EQUITY SILVER, BOREHOLE 86250:

PORPHYRY DYKE:

NUMBER OF DATA POINTS: 14

	DEN	RES	IP	CN(R)	MS(G)	MS(R)
MINIMUM	2.77	323	4.7	0.6	1925	11585
MAXIMUM	2.97	577	37.0	0.6	31257	27101
MEAN	2.87	439	9.8	0.6	14190	18951
STANDARD DEV	0.04	64	8.3	0.0	9024	5667

GABBRO:

NUMBER OF DATA POINTS: 36

	DEN	RES	IP	CN(R)	MS(G)	MS(R)
MINIMUM	2.67	134	5.0	0.6	1097	7783
MAXIMUM	3.04	971	20.8	0.6	59128	46408
MEAN	2.88	452	11.3	0.6	21758	21861
STANDARD DEV	0.08	260	3.6	0.0	18654	11777

ANDESITE DYKE:

NUMBER OF DATA POINTS: 18

	DEN	RES	IP	CN(R)	MS(G)	MS(R)
MINIMUM	2.60	70	4.1	0.6	844	7511
MAXIMUM	2.98	1072	26.3	0.6	46246	46573
MEAN	2.82	450	12.2	0.6	15001	18771
STANDARD DEV	0.11	365	6.3	0.0	19634	15832

QUARTZ DYKE:

NUMBER OF DATA POINTS: 6

	DEN	RES	IP	CN(R)	MS(G)	MS(R)
MINIMUM	2.46	129	4.2	0.6	721	7096
MAXIMUM	2.90	172	8.4	0.6	1209	7498
MEAN	2.58	144	5.8	0.6	848	7372
STANDARD DEV	0.17	16	1.5	0.0	181	148

ASH LAPILLI TUFF:

NUMBER OF DATA POINTS: 145

	DEN	RES	IP	CN(R)	MS(G)	MS(R)
MINIMUM	2.27	41	8.8	0.6	708	1076
MAXIMUM	3.65	494	95.4	0.6	32254	25496
MEAN	3.00	248	31.0	0.6	4818	10784
STANDARD DEV	0.14	100	16.4	0.0	6249	3654

TABLE A-3C. EQUITY SILVER, BOREHOLE 86264:

SEDIMENTARY VOLCANIC DUST TUFF:

NUMBER OF DATA POINTS: 41

	TC	DEN	RES	IP
MINIMUM	51	2.78	266	13.1
MAXIMUM	71	3.01	1944	100.4
MEAN	60	2.89	842	33.4
STANDARD DEV	5	0.08	401	20.3

SEDIMENTARY VOLCANIC CHERT PEBBLE CONGLOMERATE:

NUMBER OF DATA POINTS: 60

	TC	DEN	RES	IP
MINIMUM	17	2.68	19	9.7
MAXIMUM	28	3.10	5509	98.2
MEAN	22	2.78	2542	38.5
STANDARD DEV	2	0.07	1705	24.4

QUARTZ LATITE DYKE:

NUMBER OF DATA POINTS: 5

	TC	DEN	RES	IP
MINIMUM	86	2.39	111	4.5
MAXIMUM	106	2.62	202	30.5
MEAN	100	2.48	148	14.9
STANDARD DEV	8	0.09	37	12.1

PYROCLASTIC DUST TUFF:

NUMBER OF DATA POINTS: 80

	TC	DEN	RES	IP
MINIMUM	54	2.88	20	7.5
MAXIMUM	109	3.08	950	91.1
MEAN	84	2.97	428	28.2
STANDARD DEV	12	0.04	206	17.8

SEDIMENTARY VOLCANIC QUARTZ SANDSTONE:

NUMBER OF DATA POINTS: 8

	TC	DEN	RES	IP
MINIMUM	22	2.82	761	17.1
MAXIMUM	50	3.01	3635	80.0
MEAN	34	2.87	2095	42.4
STANDARD DEV	8	0.06	1001	20.8

TABLE A-4A. GOLDSTREAM, BOREHOLE NG049:

PHYLLITE:

NUMBER OF DATA POINTS: 170

	TC	RES	IP	MS(G)
MINIMUM	45	2	10.4	5691
MAXIMUM	122	2358	112.8	135849
MEAN	87	1307	30.0	24806
STANDARD DEV	14	617	16.9	18357

PHYLLITE WITH GARNET:

NUMBER OF DATA POINTS: 12

	TC	RES	IP	MS(G)
MINIMUM	93	1368	11.2	10702
MAXIMUM	136	1799	18.0	26629
MEAN	111	1577	14.2	18540
STANDARD DEV	12	133	2.3	4811

DARK BANDED PHYLLITE:

NUMBER OF DATA POINTS: 192

	TC	RES	IP	MS(G)
MINIMUM	39	5	15.4	-4426
MAXIMUM	114	2242	116.6	54985
MEAN	86	961	42.1	9753
STANDARD DEV	10	629	20.4	13251

DARK BANDED PHYLLITE WITH QUARTZ:

NUMBER OF DATA POINTS: 98

	TC	RES	IP	MS(G)
MINIMUM	62	8	15.6	-4448
MAXIMUM	109	2145	128.8	53245
MEAN	80	576	50.9	14204
STANDARD DEV	8	627	19.4	16552

LIMESTONE:

NUMBER OF DATA POINTS: 6

	TC	RES	IP	MS(G)
MINIMUM	37	591	28.6	-4159
MAXIMUM	68	1561	52.5	10864
MEAN	54	1255	39.1	3205
STANDARD DEV	12	357	9.6	5591

QUARTZ SERICITE SCHIST:

NUMBER OF DATA POINTS: 8

	TC	RES	IP	MS(G)
MINIMUM	32	<0.01	0.0	890
MAXIMUM	79	1477	101.9	871932
MEAN	63	530	26.8	137802
STANDARD DEV	15	612	69.9	297479

TABLE A-4B. GOLDSTREAM, BOREHOLE NG050:

IMPURE LIMESTONE:
NUMBER OF DATA POINTS: 8

	TC	RES	IP	MS(R)
MINIMUM	26	2126	8.2	295
MAXIMUM	62	2619	19.2	564
MEAN	45	2334	12.3	433
STANDARD DEV	14	202	4.4	89

LIMESTONE:
NUMBER OF DATA POINTS: 56

	TC	RES	IP	MS(R)
MINIMUM	6	2157	7.0	-1
MAXIMUM	53	6167	18.1	386
MEAN	15	4378	10.9	159
STANDARD DEV	9	917	2.6	87

PHYLLITE:
NUMBER OF DATA POINTS: 86

	TC	RES	IP	MS(R)
MINIMUM	60	1	1.0	359
MAXIMUM	164	2149	59.4	1533
MEAN	110	1291	21.6	714
STANDARD DEV	15	431	8.5	265

DARK BANDED PHYLLITE:
NUMBER OF DATA POINTS: 111

	TC	RES	IP	MS(R)
MINIMUM	59	1	0.0	-6
MAXIMUM	109	2446	81.9	4170
MEAN	88	1068	37.6	815
STANDARD DEV	11	767	17.5	641

DARK BANDED PHYLLITE WITH QUARTZ:
NUMBER OF DATA POINTS: 208

	TC	RES	IP	MS(R)
MINIMUM	60	19	18.9	98
MAXIMUM	121	2290	100.3	3662
MEAN	91	822	48.1	974
STANDARD DEV	10	607	19.1	816

CALCAREOUS DARK BANDED PHYLLITE:

NUMBER OF DATA POINTS: 6

	TC	RES	IP	MS(R)
MINIMUM	85	729	39.8	182
MAXIMUM	95	1176	48.2	492
MEAN	91	1017	43.7	287
STANDARD DEV	3	167	2.8	107

GRAPHITIC DARK BANDED PHYLLITE WITH QUARTZ:

NUMBER OF DATA POINTS: 22

	TC	RES	IP	MS(R)
MINIMUM	33	1	30.4	5266
MAXIMUM	121	139	250.0	9108
MEAN	74	21	150.2	8183
STANDARD DEV	23	41	75.4	1420

TABLE A-5. SULLIVAN, BOREHOLE K6423:

ARGILLITE/SILTY ARGILLITE/ARGILLACEOUS SILTSTONE:

NUMBER OF DATA POINTS: 276

	TC	SPR	RES	IP	MS(G)
MINIMUM	107	1882	55	10.2	12367
MAXIMUM	238	3207	1423	42.1	25039
MEAN	167	2311	433	24.4	15323
STANDARD DEV	19	230	259	5.5	2256

QUARTZITE:

NUMBER OF DATA POINTS: 32

	TC	SPR	RES	IP	MS(G)
MINIMUM	111	1938	47	13.4	11253
MAXIMUM	286	2819	1152	55.3	24291
MEAN	160	2353	598	24.8	14586
STANDARD DEV	41	255	336	9.2	3302

SILTY ARGILLITE:

NUMBER OF DATA POINTS: 36

	TC	SPR	RES	IP	MS(G)
MINIMUM	119	1981	50	8.2	14738
MAXIMUM	234	2869	978	27.8	26639
MEAN	178	2227	264	17.5	18416
STANDARD DEV	25	187	193	4.5	2676

SULPHIDE:

NUMBER OF DATA POINTS: 10

	TC	SPR	RES	IP	MS(G)
MINIMUM	158	1915	4	6.7	21247
MAXIMUM	201	2302	447	42.5	29536
MEAN	178	2051	103	21.0	25036
STANDARD DEV	14	145	136	11.2	3049

SILTSTONE/SILTY ARGILLITE/ARGILLACEOUS SILTSTONE:

NUMBER OF DATA POINTS: 6

	TC	SPR	RES	IP	MS(G)
MINIMUM	166	2302	387	18.5	13140
MAXIMUM	186	2553	809	27.0	15319
MEAN	177	2419	539	23.3	14470
STANDARD DEV	8	106	168	3.3	844

ARGILLITE/SILTY ARGILLITE/QUARTZITE:
NUMBER OF DATA POINTS: 6

	TC	SPR	RES	IP	MS(G)
MINIMUM	84	2438	522	16.0	12853
MAXIMUM	169	2680	721	26.1	14029
MEAN	131	2589	576	20.8	13445
STANDARD DEV	30	106	74	3.5	374

ARGILLITE/SILTY ARGILLITE:
NUMBER OF DATA POINTS: 4

	TC	SPR	RES	IP	MS(G)
MINIMUM	175	2012	213	21.3	13047
MAXIMUM	216	2139	435	29.2	15634
MEAN	203	2074	310	25.0	14112
STANDARD DEV	19	54	99	3.3	1131

APPENDIX 3 - Average Temperature Gradient Values

Area Borehole	Start Depth (m)	End Depth (m)	Number of Data Values	Average Temperature Gradient (mK/m)
Buttle Lake PR061	20.0	686.9	13341	12.1
Buttle Lake W129	50.0	394.9	6901	17.1
Chu Chua CC055	25.1	476.1	9024	18.9
Equity Silver 86246	28.2	143.9	2313	17.8
Equity Silver 86250	30.1	207.5	3548	16.1
Goldstream NG049	26.9	297.5	9022	49.6
Goldstream NG050	61.0	288.4	7584	49.6
Highland Valley JA003	100.0	310.3	4208	29.3
Highland Valley JA015	46.3	215.9	3393	28.1
Highland Valley JA057	150.0	289.0	2800	32.4
Lara 87204	6.8	421.9	8304	5.2
Sullivan K6423	24.0	299.0	5521	21.6

APPENDIX 4 - Coloured Plots of Geophysical and Lithological Logs

The following 19 plots are included in this appendix, in the form of 11" x 17" coloured logs. The depths are hole lenghs and not true vertical depths of the hole.

Buttle Lake
  Borehole PR061
    PLOT 1 - Multiparameter logs, depths 0 to 300 m
    PLOT 2 - Multiparameter logs, depths 300 to 600 m
    PLOT 3 - Multiparameter logs, depths 600 to 692 m

  Borehole W129
    PLOT 1 - Multiparameter logs, depths 0 to 300 m
    PLOT 2 - Multiparameter logs, depths 300 to 400 m

Chu Chua
  Borehole CC055
    PLOT 1 - Multiparameter logs, depths 0 to 300 m
    PLOT 2 - Multiparameter logs, depths 300 to 479 m

Equity Silver
  Borehole 86246
    PLOT 1 - Multiparameter logs, depths 0 to 148 m

  Borehole 86250
    PLOT 1 - Multiparameter logs, depths 0 to 212 m

  Borehole 86264
    PLOT 1 - Multiparameter logs, depths 0 to 145 m

Goldstream
  Borehole NG049
    PLOT 1 - Multiparameter logs, 0 to 301 m

  Borehole NG050
    PLOT 1 - Multiparameter logs, 0 to 302 m

Highland Valley
  Borehole JA003
    PLOT 1 - Multiparameter logs, depths 110 to 313 m

  Borehole JA015
    PLOT 1 - Temperature Probe logs, depths 45 to 218 m
  Borehole JA057
    PLOT 1 - Multiparameter logs, depths 150 to 294 m
    PLOT 2 - IP logs, depths 150 to 294 m

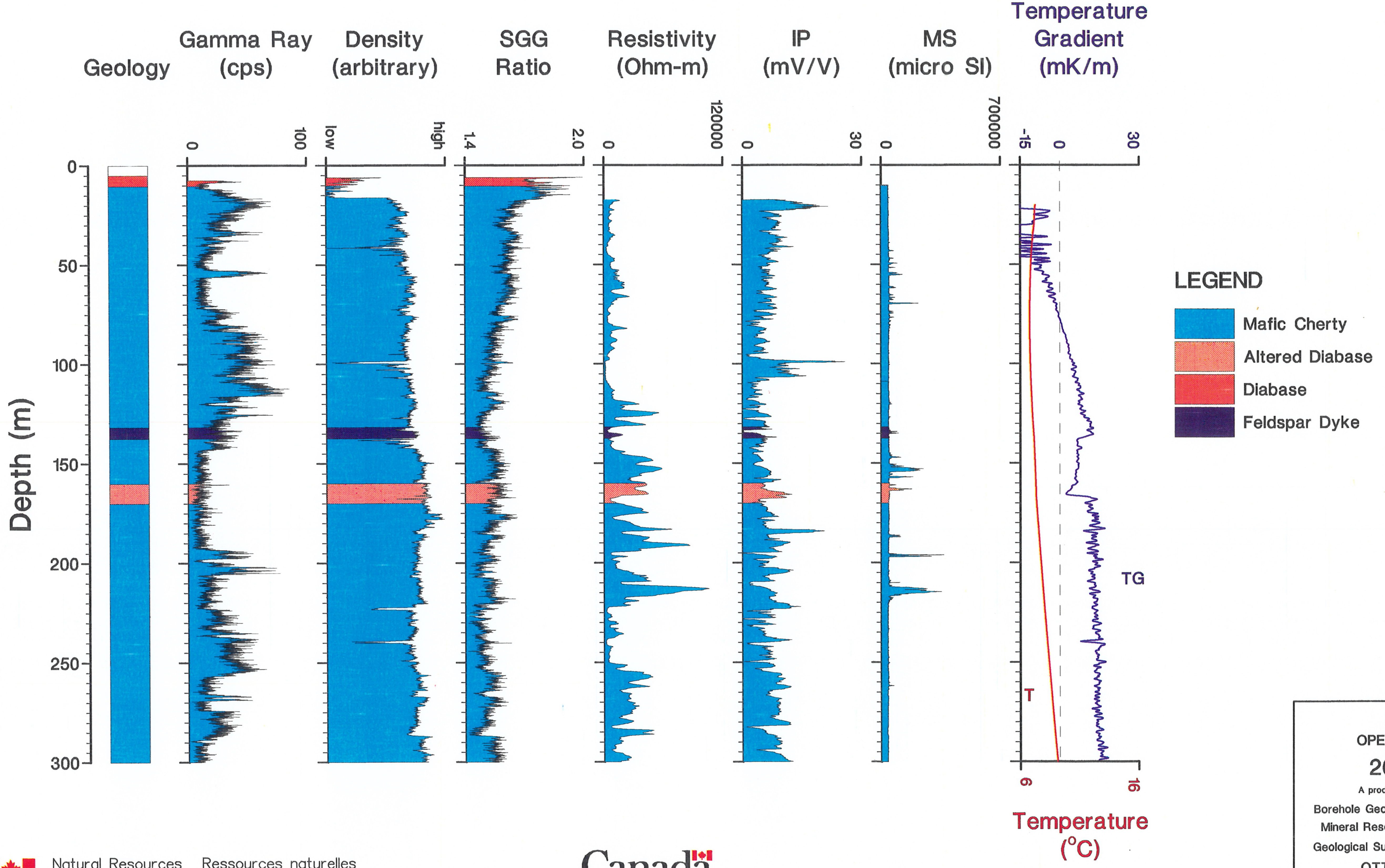
Lara
  Borehole 87204
    PLOT 1 - Temperature Probe logs, depths 0 to 300 m and 300 to 422 m.

Sullivan
  Borehole K6423
    PLOT 1 - Multiparameter logs, depths 0 to 300 m
    PLOT 2 - IP logs, depths 0 to 300 m

BUTTLE LAKE, BRITISH COLUMBIA

Latitude (49°,41',0"), Longitude (125°,33',0")

Borehole PR061, Plot 1 of 3



OPEN FILE

2610

A product of the

Borehole Geophysics Section

Mineral Resources Division

Geological Survey of Canada

OTTAWA

Natural Resources Canada

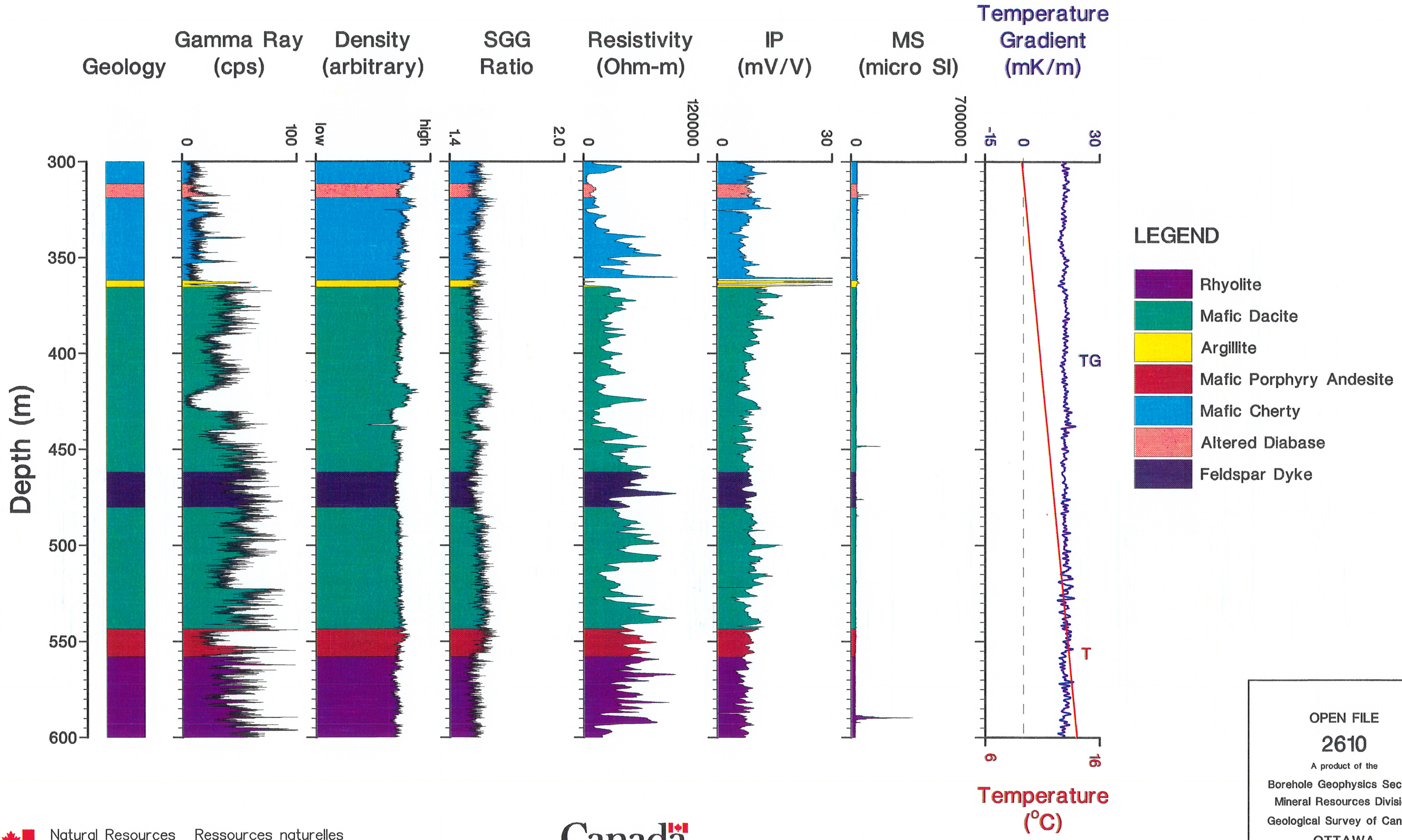
Ressources naturelles Canada

Canada

BUTTLE LAKE, BRITISH COLUMBIA

Latitude (49°,41',0"), Longitude (125°,33',0")

Borehole PR061, Plot 2 of 3



OPEN FILE
2610
A product of the
Borehole Geophysics Section
Mineral Resources Division
Geological Survey of Canada
OTTAWA

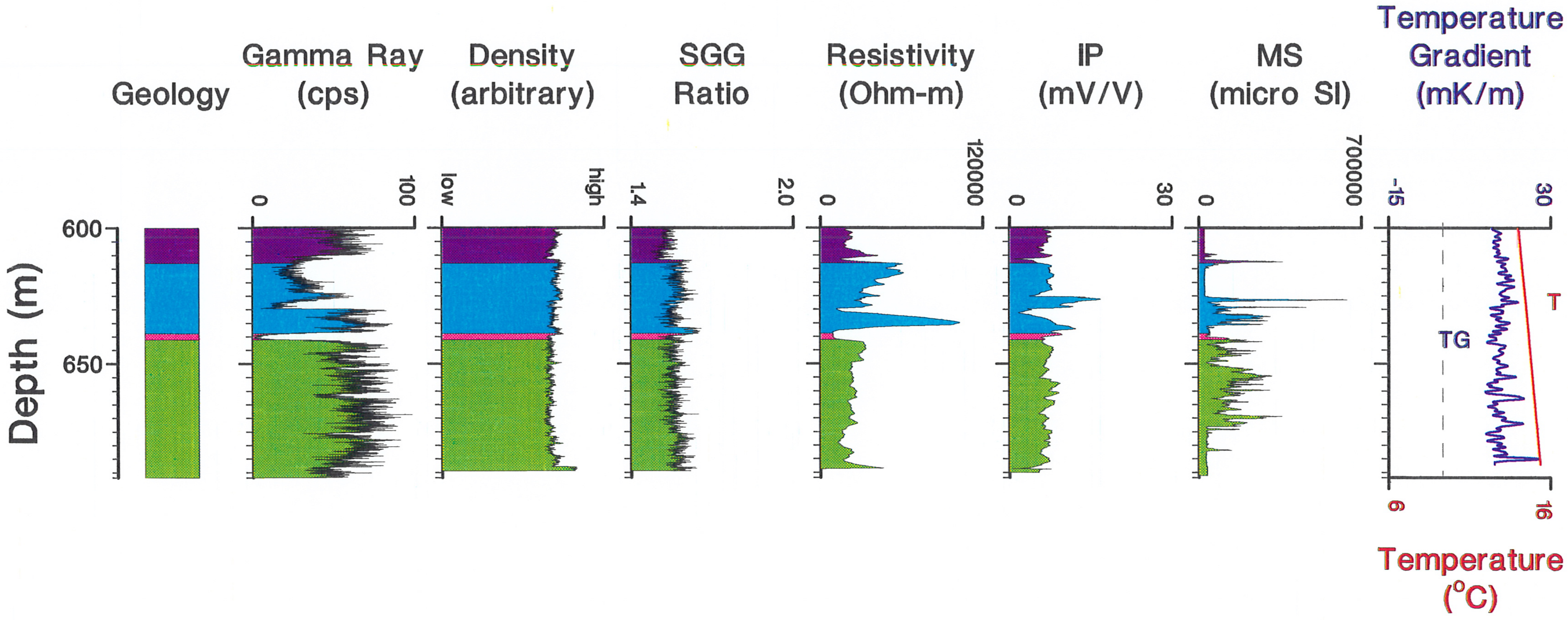
Natural Resources Canada Ressources naturelles Canada

Canada

BUTTLE LAKE, BRITISH COLUMBIA

Latitude (49°,41',0"), Longitude (125°,33',0")

Borehole PR061, Plot 3 of 3



LEGEND

- 🟦 Mafic Cherty
- 🟪 Rhyolite
- 🟥 Mafic Dyke
- 🟩 Massive Dacite
- 🟥 Mafic Porphyry Andesite

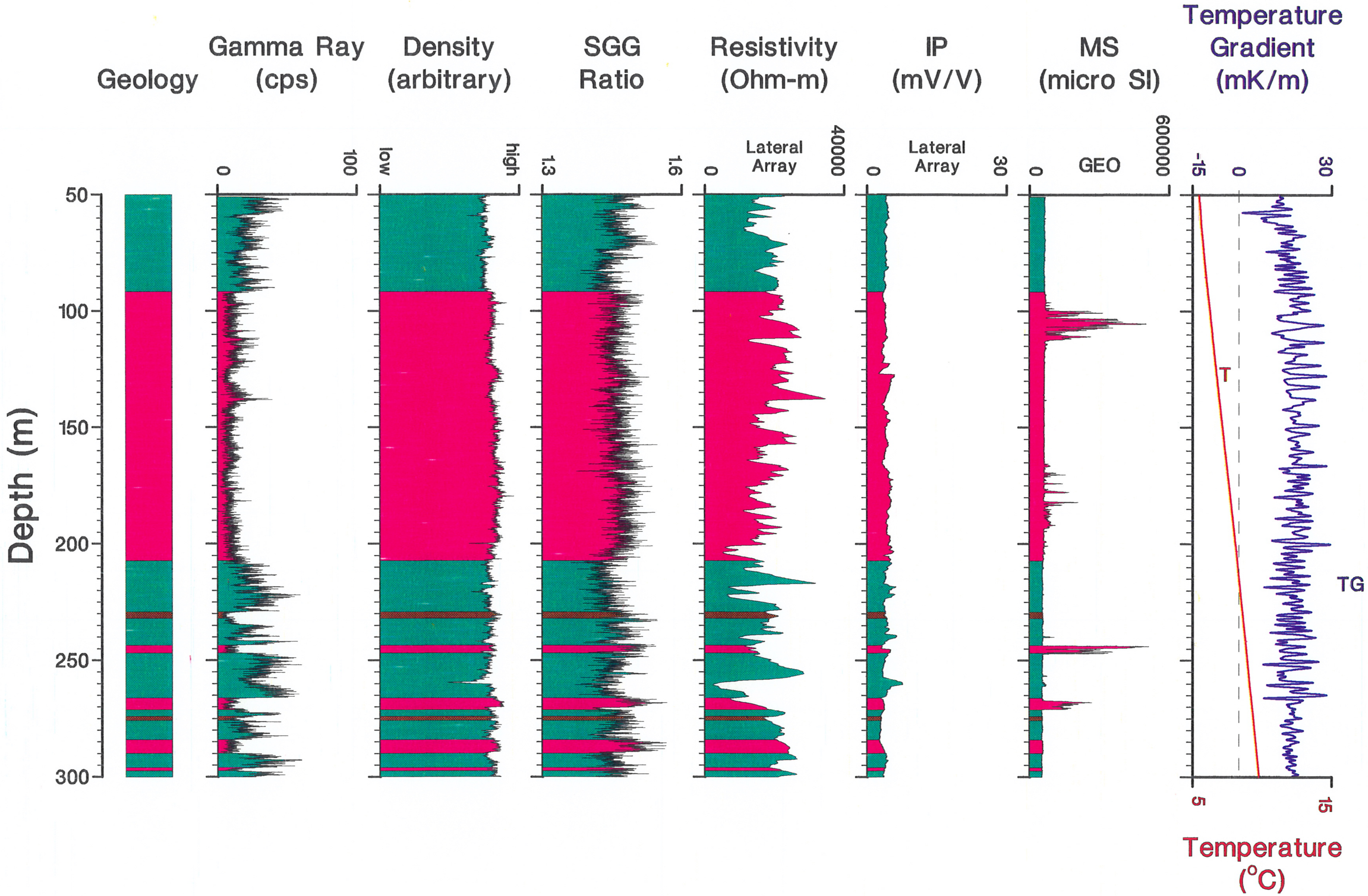
OPEN FILE
2610
A product of the
Borehole Geophysics Section
Mineral Resources Division
Geological Survey of Canada
OTTAWA

Natural Resources Canada
Ressources naturelles Canada
Canada

BUTTLE LAKE, BRITISH COLUMBIA

Latitude (49°,41',0"), Longitude (125°,33',0")

Borehole W129, Plot 1 of 2



LEGEND

🟩 Mafic Dacite

🟥 Mafic Massive

🟫 Mafic Porphyritic

OPEN FILE

2610

A product of the

Borehole Geophysics Section

Mineral Resources Division

Geological Survey of Canada

OTTAWA

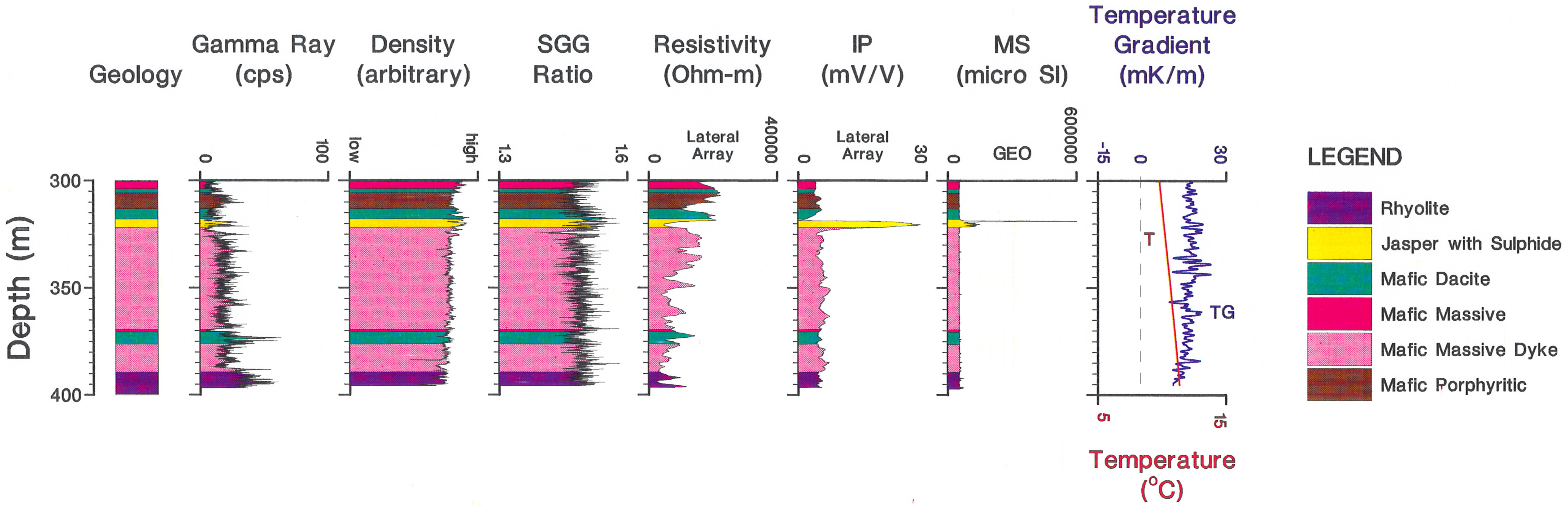
Natural Resources Canada   Ressources naturelles Canada

Canada

BUTTLE LAKE, BRITISH COLUMBIA

Latitude (49°,41',0"), Longitude (125°,33',0")

Borehole W129, Plot 2 of 2



OPEN FILE

2610

A product of the
Borehole Geophysics Section
Mineral Resources Division
Geological Survey of Canada
OTTAWA

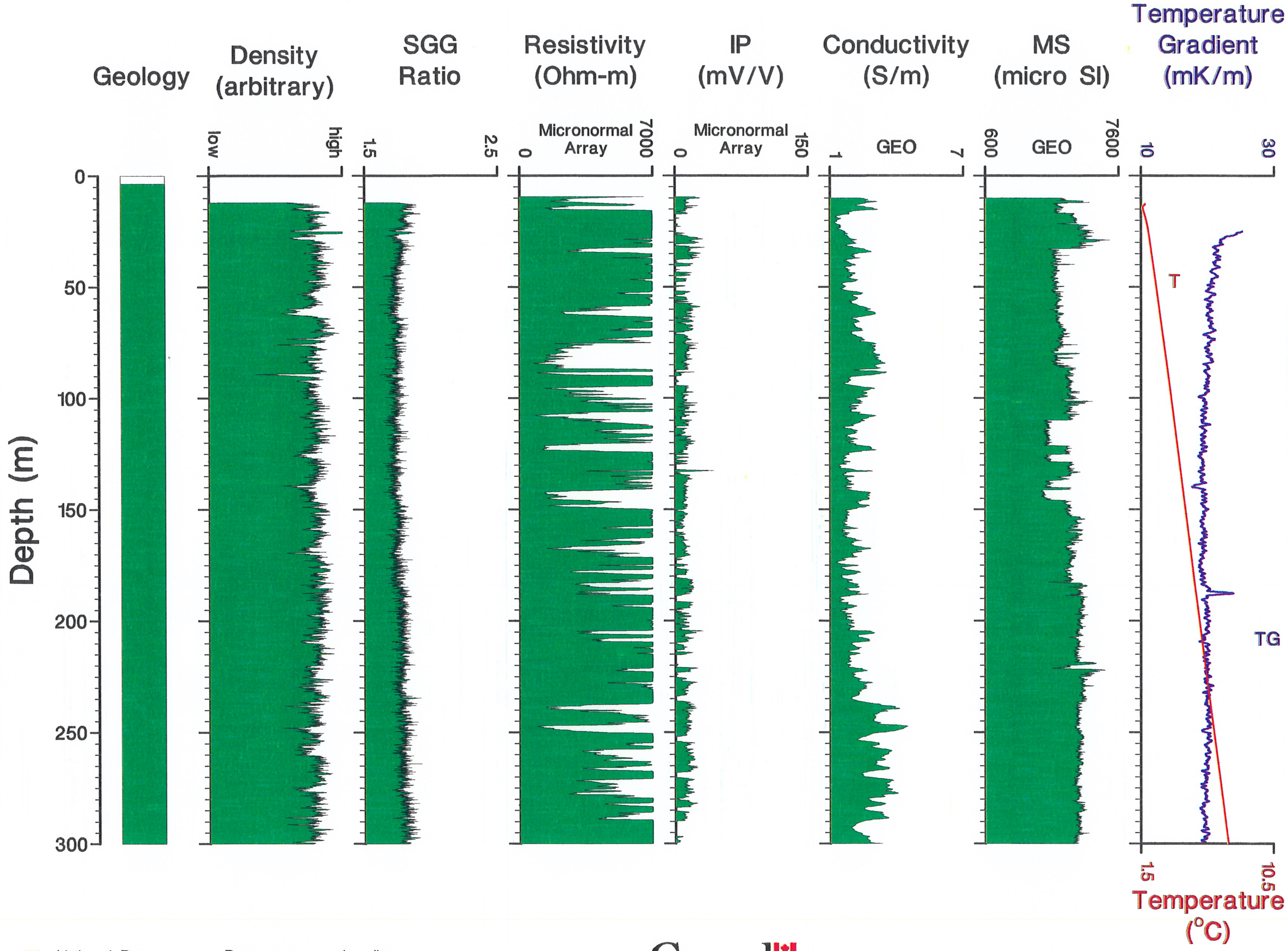
Natural Resources Canada Ressources naturelles Canada

Canada

CHU-CHUA, BRITISH COLUMBIA

Latitude (51°,21',0"), Longitude (120°,10',0")

Borehole CC055, Plot 1 of 2



LEGEND

🟩 Basalt

OPEN FILE

2610

A product of the

Borehole Geophysics Section

Mineral Resources Division

Geological Survey of Canada

OTTAWA

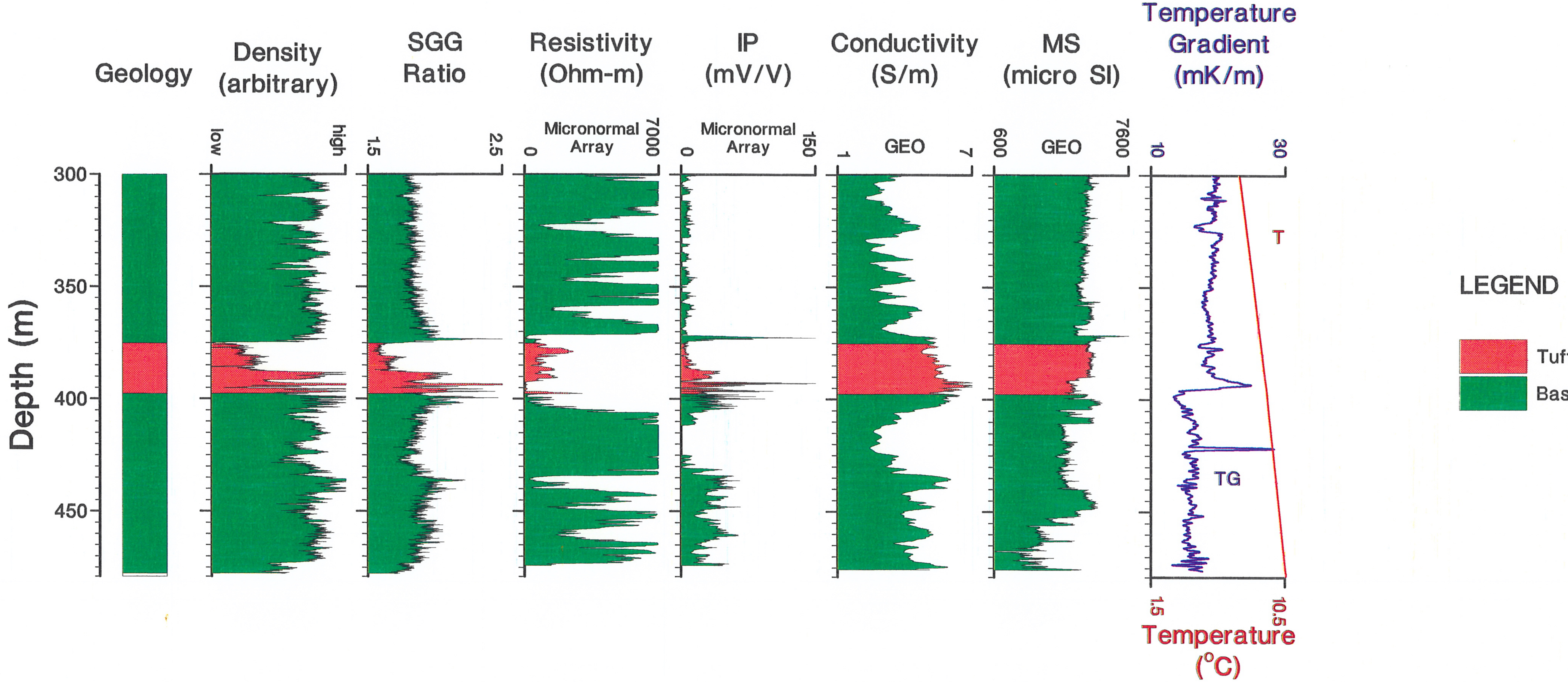
Natural Resources Canada Ressources naturelles Canada

Canada

CHU-CHUA, BRITISH COLUMBIA

Latitude (51°,21',0"), Longitude (120°,10',0")

Borehole CC055, Plot 2 of 2



OPEN FILE

2610

A product of the

Borehole Geophysics Section

Mineral Resources Division

Geological Survey of Canada

OTTAWA

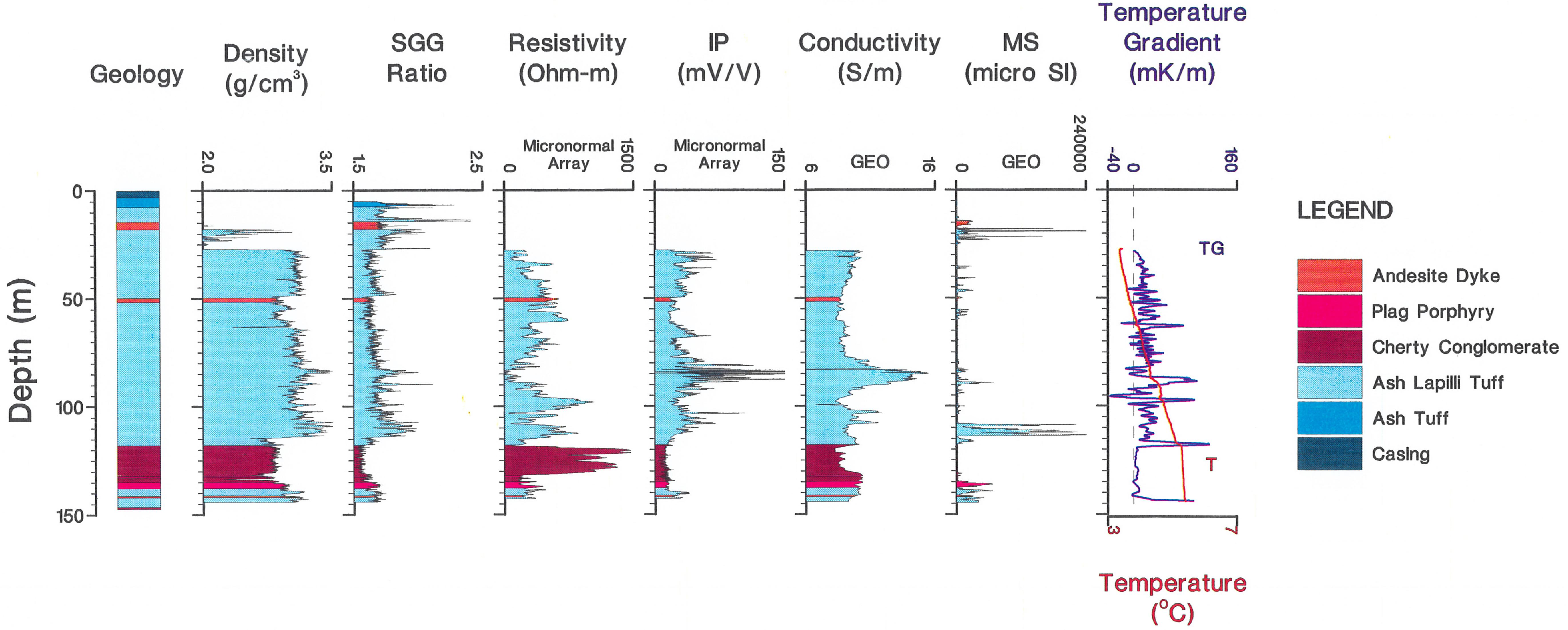
Natural Resources Canada　Ressources naturelles Canada

Canada

EQUITY SILVER, BRITISH COLUMBIA

Latitude (54°,12',0"), Longitude (124°,30',0")

Borehole 86246



Natural Resources Canada
Ressources naturelles Canada

Canada

OPEN FILE

2610

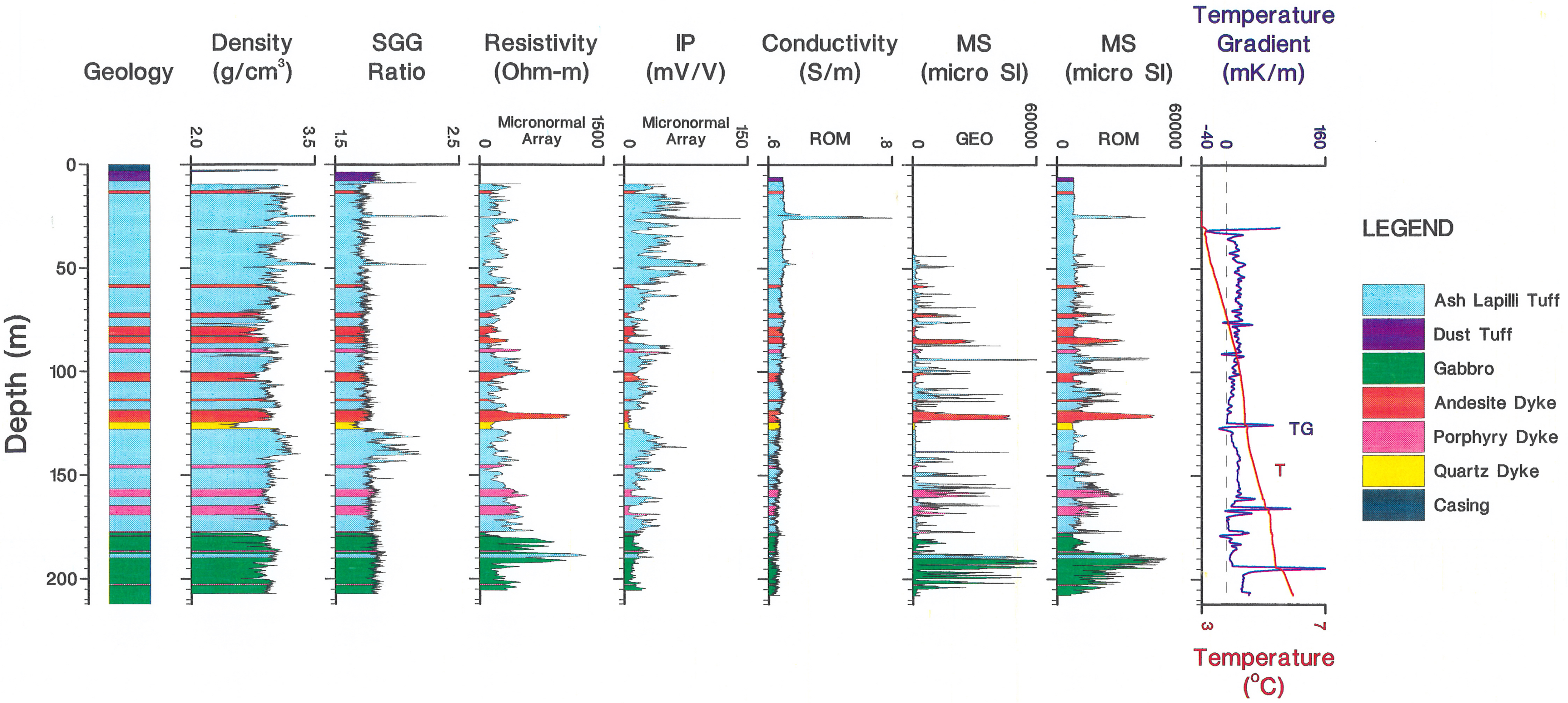
A product of the

Borehole Geophysics Section
Mineral Resources Division
Geological Survey of Canada
OTTAWA

EQUITY SILVER, BRITISH COLUMBIA

Latitude (54°,12',0"), Longitude (124°,30',0")

Borehole 86250



Natural Resources Canada   Ressources naturelles Canada

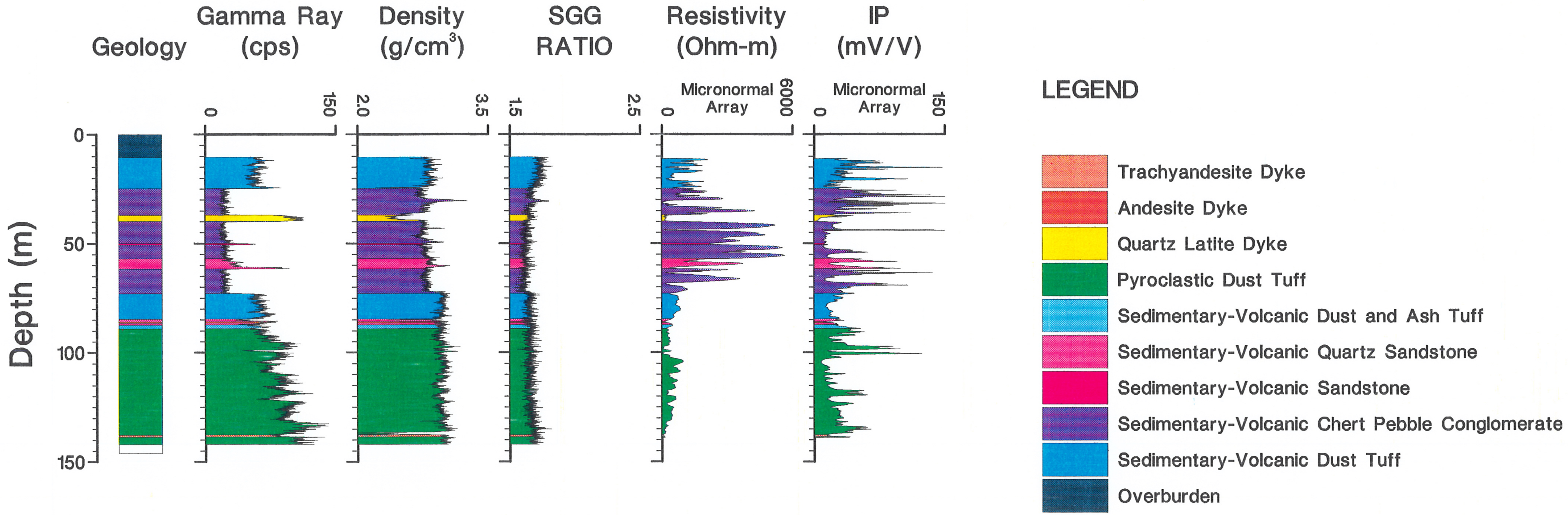
Canada

OPEN FILE
2610
A product of the
Borehole Geophysics Section
Mineral Resources Division
Geological Survey of Canada
OTTAWA

EQUITY SILVER, BRITISH COLUMBIA

Latitude (54°,12',0"), Longitude (124°,30',0")

Borehole 86264



OPEN FILE

2610

A product of the
Borehole Geophysics Section
Mineral Resources Division
Geological Survey of Canada
OTTAWA

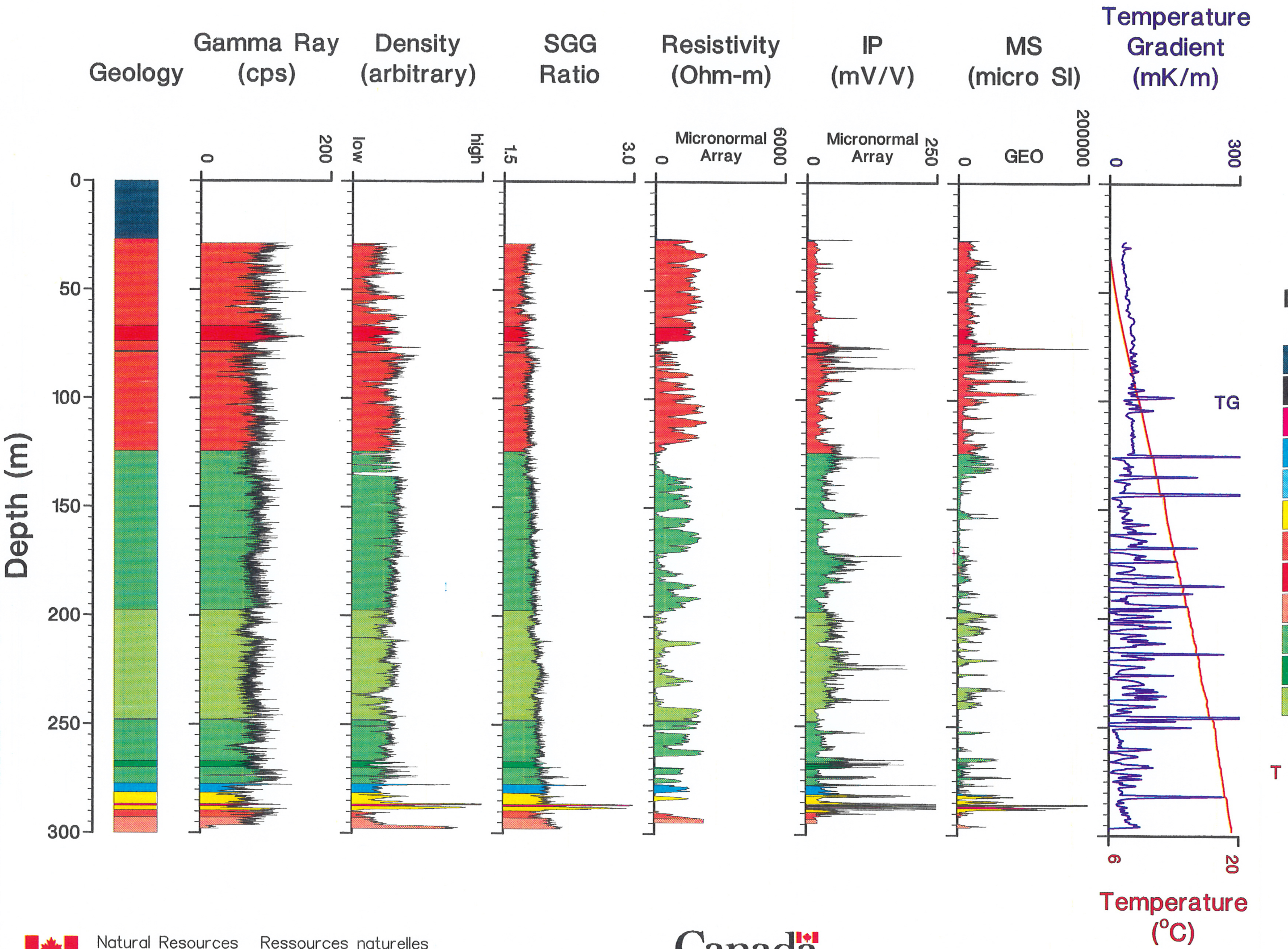
Natural Resources Canada   Ressources naturelles Canada

Canada

GOLDSTREAM, BRITISH COLUMBIA

Latitude (52°,0',0"), Longitude (118°,30',0")

Borehole NG049



LEGEND

- 🟦 Overburden
- ⬛ Graphite
- 🟪 Semi-massive Sulphides
- 🟦 Limestone
- 🟦 Impure Limestone
- 🟨 Quartz Sericite Schist
- 🟥 Phyllite
- 🟥 Phyllite with Garnet
- 🟧 Calcareous Phyllite
- 🟩 Dark Banded Phyllite
- 🟩 Dark Banded Phyllite with Garnet
- 🟩 Dark Banded Phyllite with Quartz

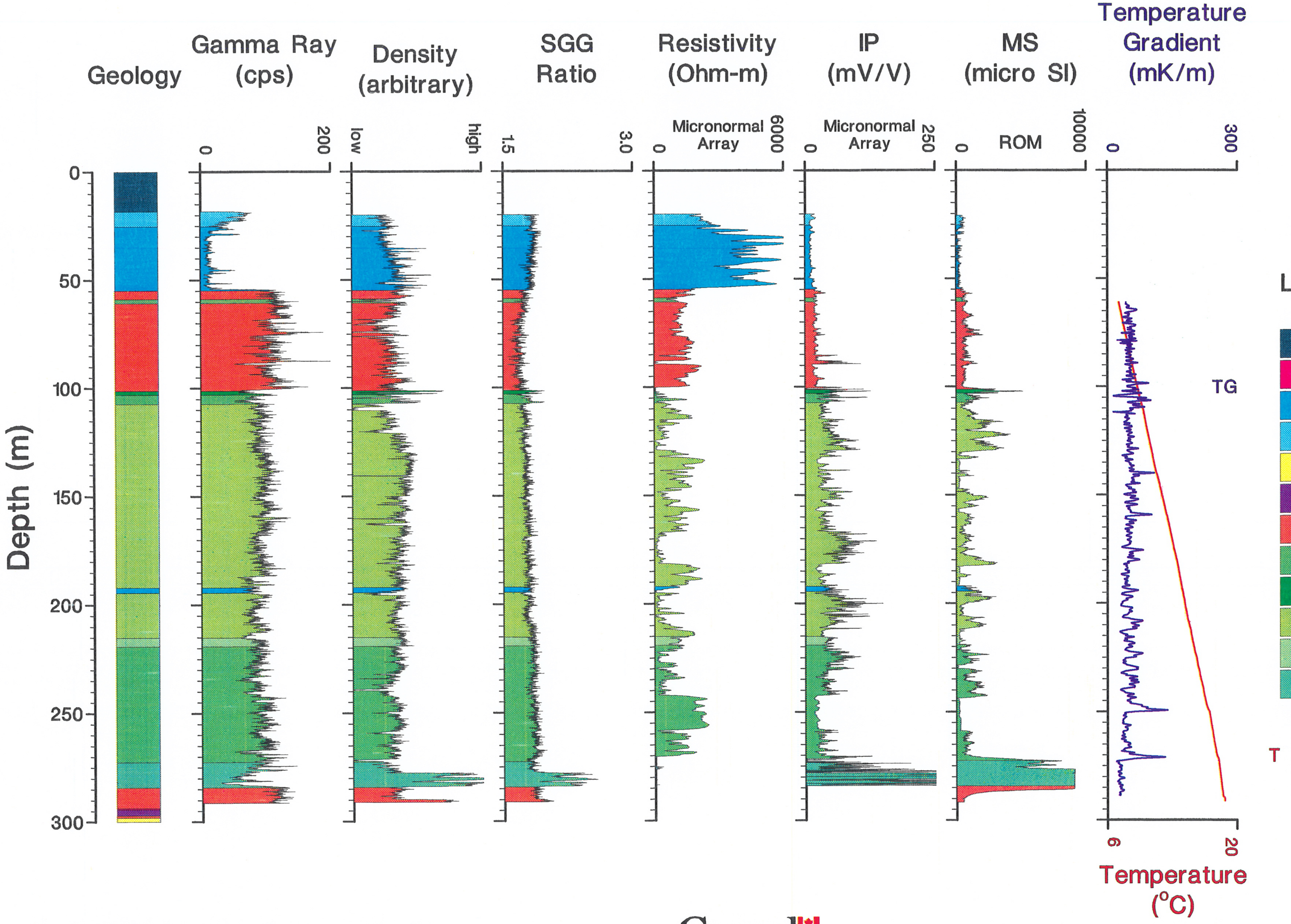
OPEN FILE
2610
A product of the
Borehole Geophysics Section
Mineral Resources Division
Geological Survey of Canada
OTTAWA

Natural Resources Canada
Ressources naturelles Canada
Canada

GOLDSTREAM, BRITISH COLUMBIA

Latitude (52°,0',0"), Longitude (118°,30',0")

Borehole NG050



LEGEND

- 🟦 Overburden
- 🟥 Semi-massive Sulphides
- 🟦 Limestone
- 🟦 Impure Limestone
- 🟨 Quartz mottled with Carbonate
- 🟪 Banded Chert-Pyrite
- 🟥 Phyllite
- 🟩 Dark Banded Phyllite
- 🟩 Dark Banded Phyllite with Garnet
- 🟩 Dark Banded Phyllite with Quartz
- 🟩 Calcareous Dark Banded Phyllite
- 🟩 Graphitic Dark Banded Phyllite with Quartz

OPEN FILE

2610

A product of the
Borehole Geophysics Section
Mineral Resources Division
Geological Survey of Canada
OTTAWA

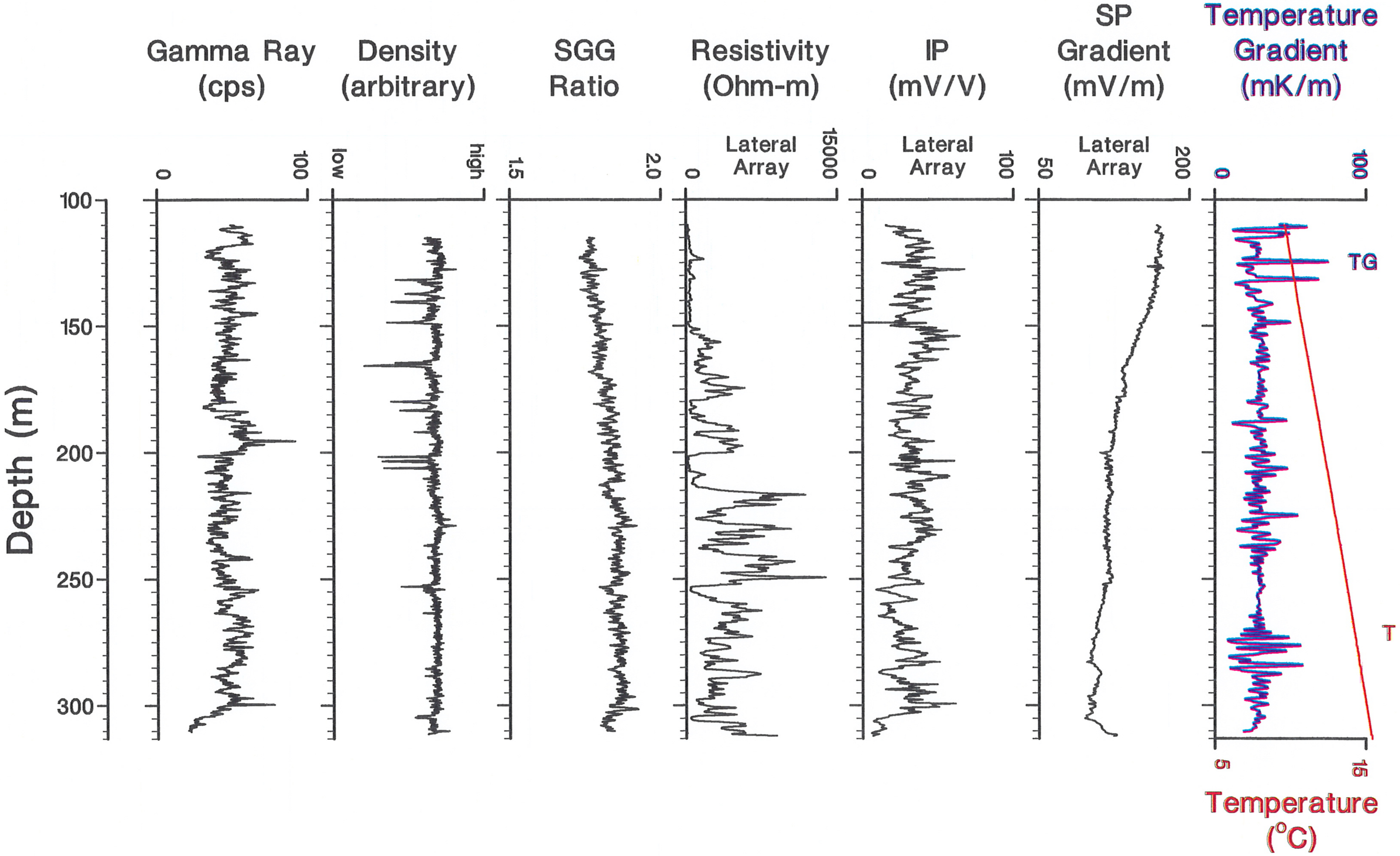
Natural Resources Canada Ressources naturelles Canada

Canada

HIGHLAND VALLEY, BRITISH COLUMBIA

Latitude (50°,29',0"), Longitude (121°,0',0")

Borehole JA003

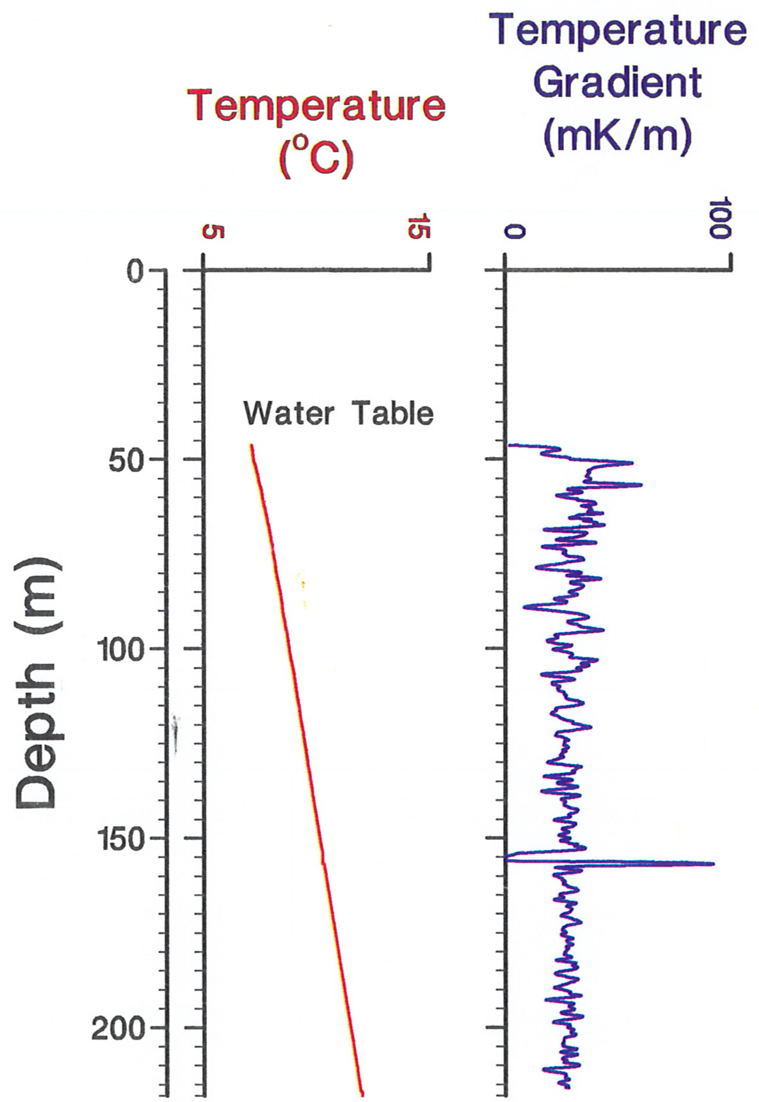


OPEN FILE
2610
A product of the
Borehole Geophysics Section
Mineral Resources Division
Geological Survey of Canada
OTTAWA

HIGHLAND VALLEY, BRITISH COLUMBIA

Latitude (50°,29',0"), Longitude (121°,0',0")

Borehole JA015



OPEN FILE

2610

A product of the

Borehole Geophysics Section

Mineral Resources Division

Geological Survey of Canada

OTTAWA

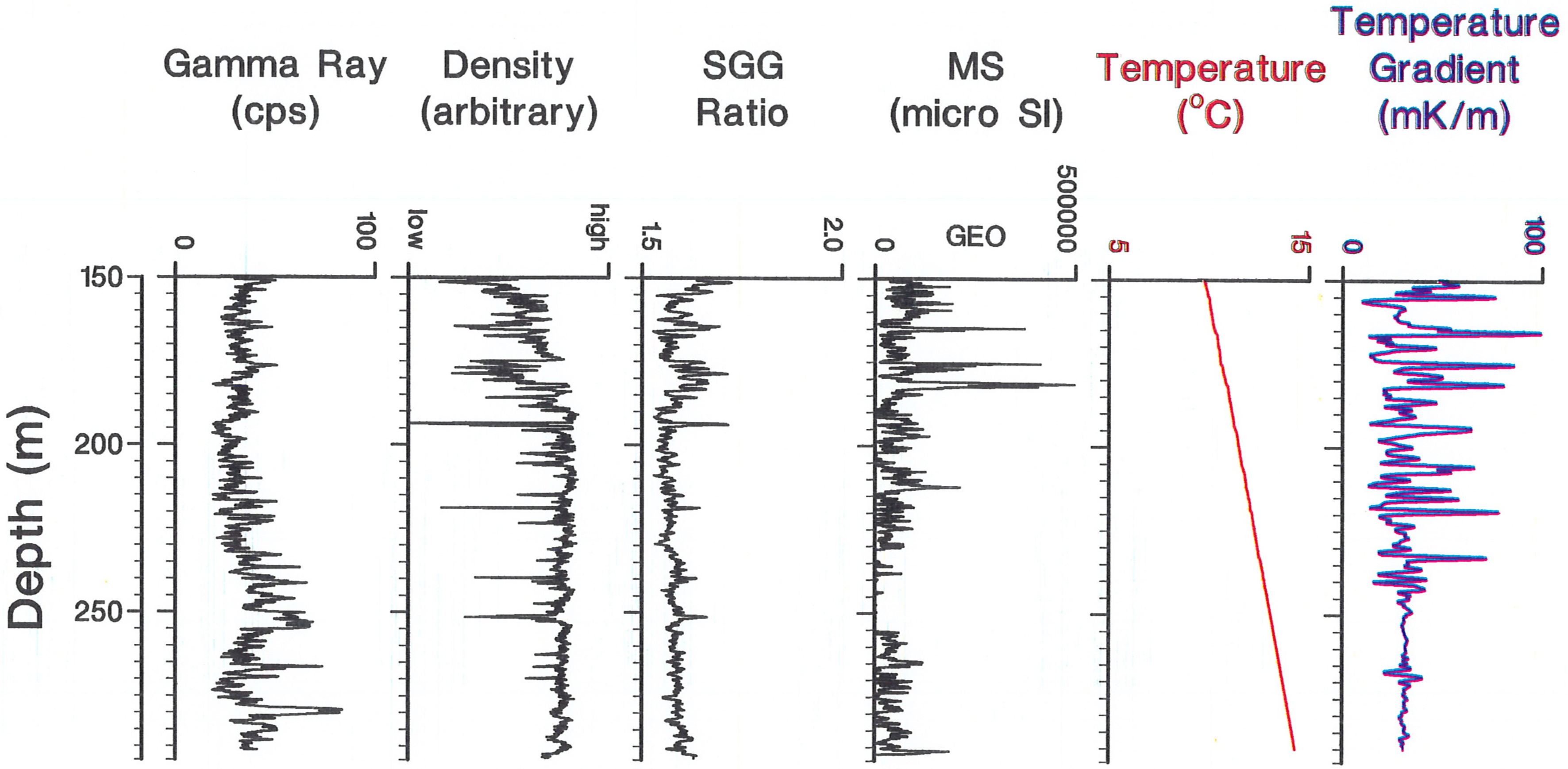
Natural Resources Canada Ressources naturelles Canada

Canada

HIGHLAND VALLEY, BRITISH COLUMBIA

Latitude (49^{o},41',0"), Longitude (125^{o},33',0")

Borehole JA057, Plot 1 of 2



Natural Resources Canada   Ressources naturelles Canada

Canada

OPEN FILE

2610

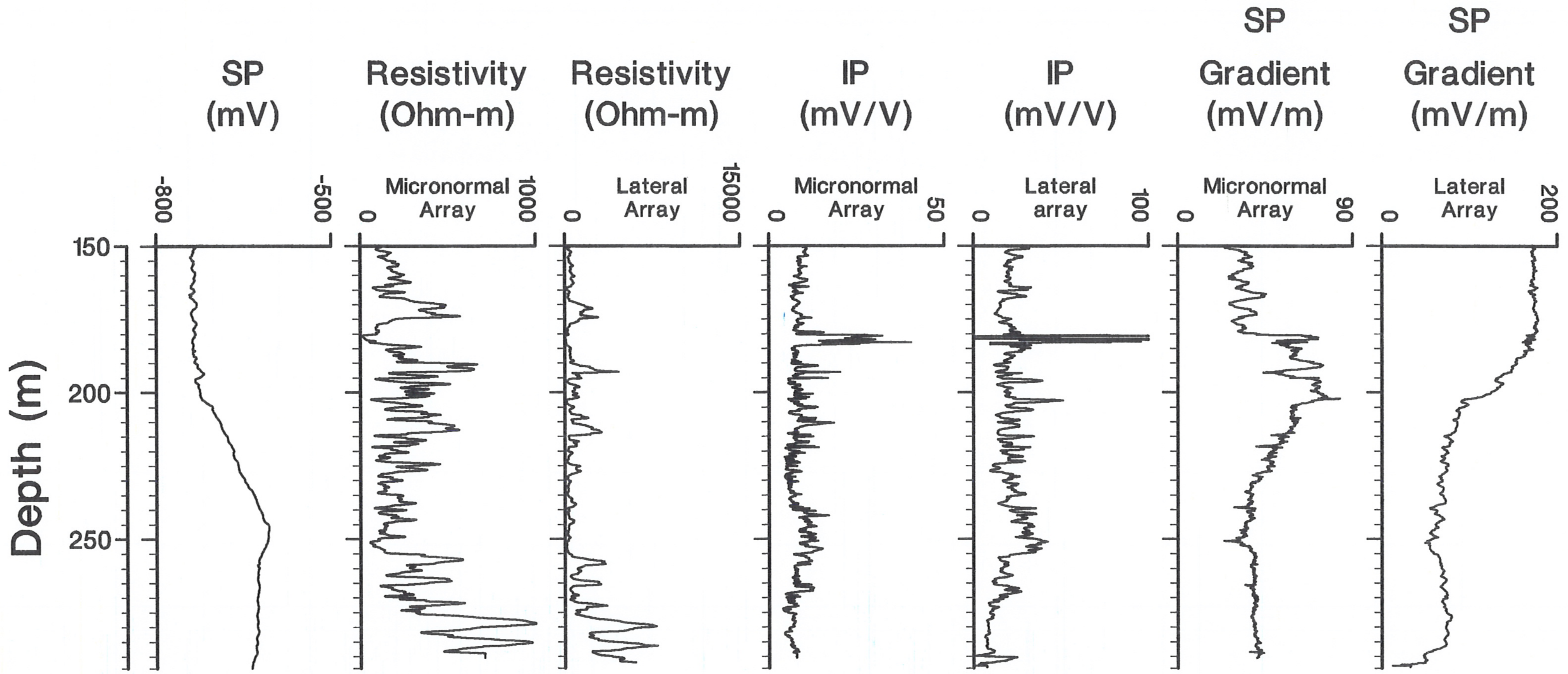
A product of the

Borehole Geophysics Section
Mineral Resources Division
Geological Survey of Canada
OTTAWA

HIGHLAND VALLEY, BRITISH COLUMBIA

Latitude (49°,41,'0"), Longitude (125°,33',0")

Borehole JA057, Plot 2 of 2



OPEN FILE

2610

A product of the

Borehole Geophysics Section

Mineral Resources Division

Geological Survey of Canada

OTTAWA

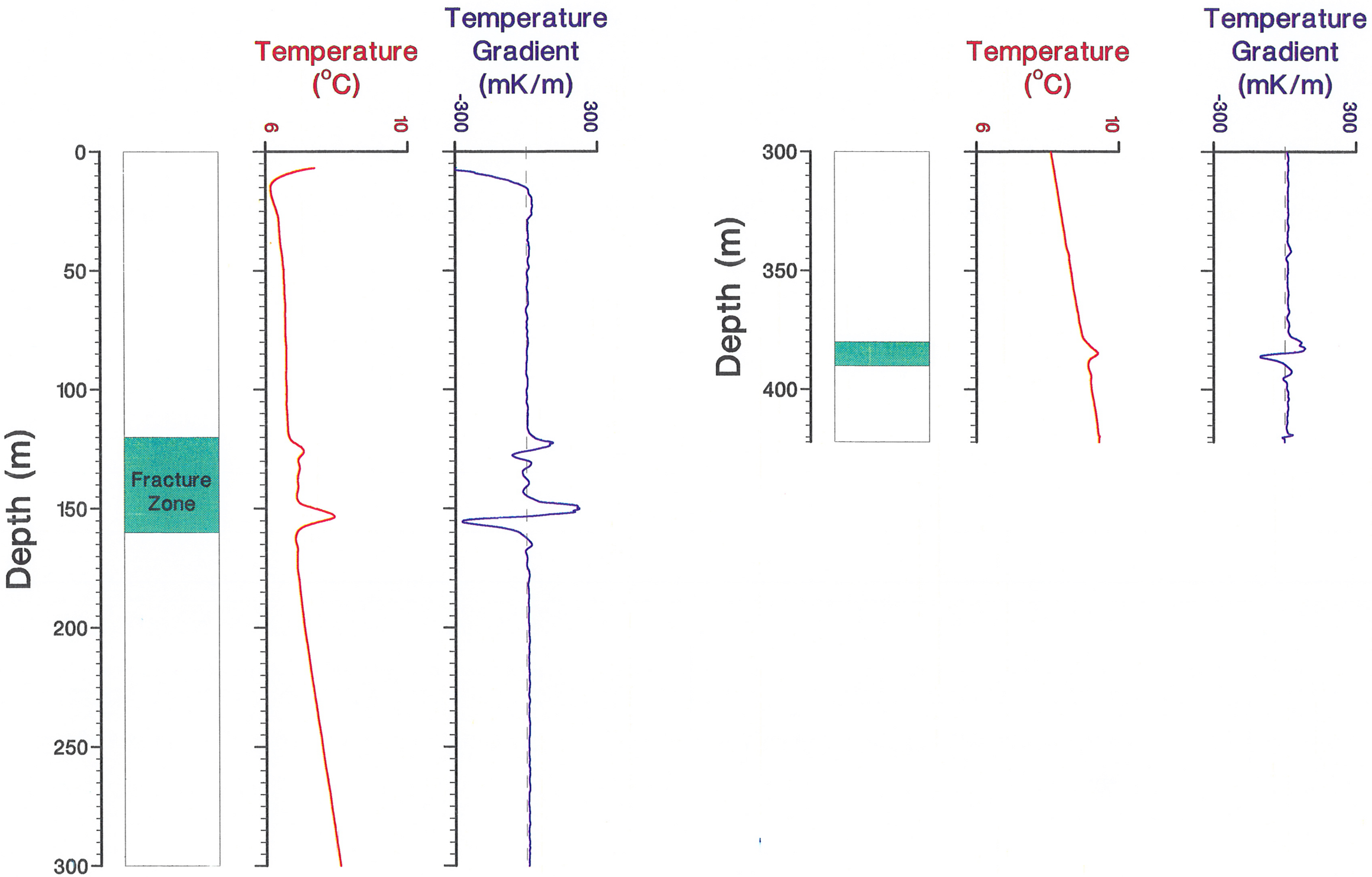
Natural Resources Canada   Ressources naturelles Canada

Canada

LARA, BRITISH COLUMBIA

Latitude (49°,9',0"),Longitude (123°,24',0")

Borehole 87204



Natural Resources Canada
Ressources naturelles Canada

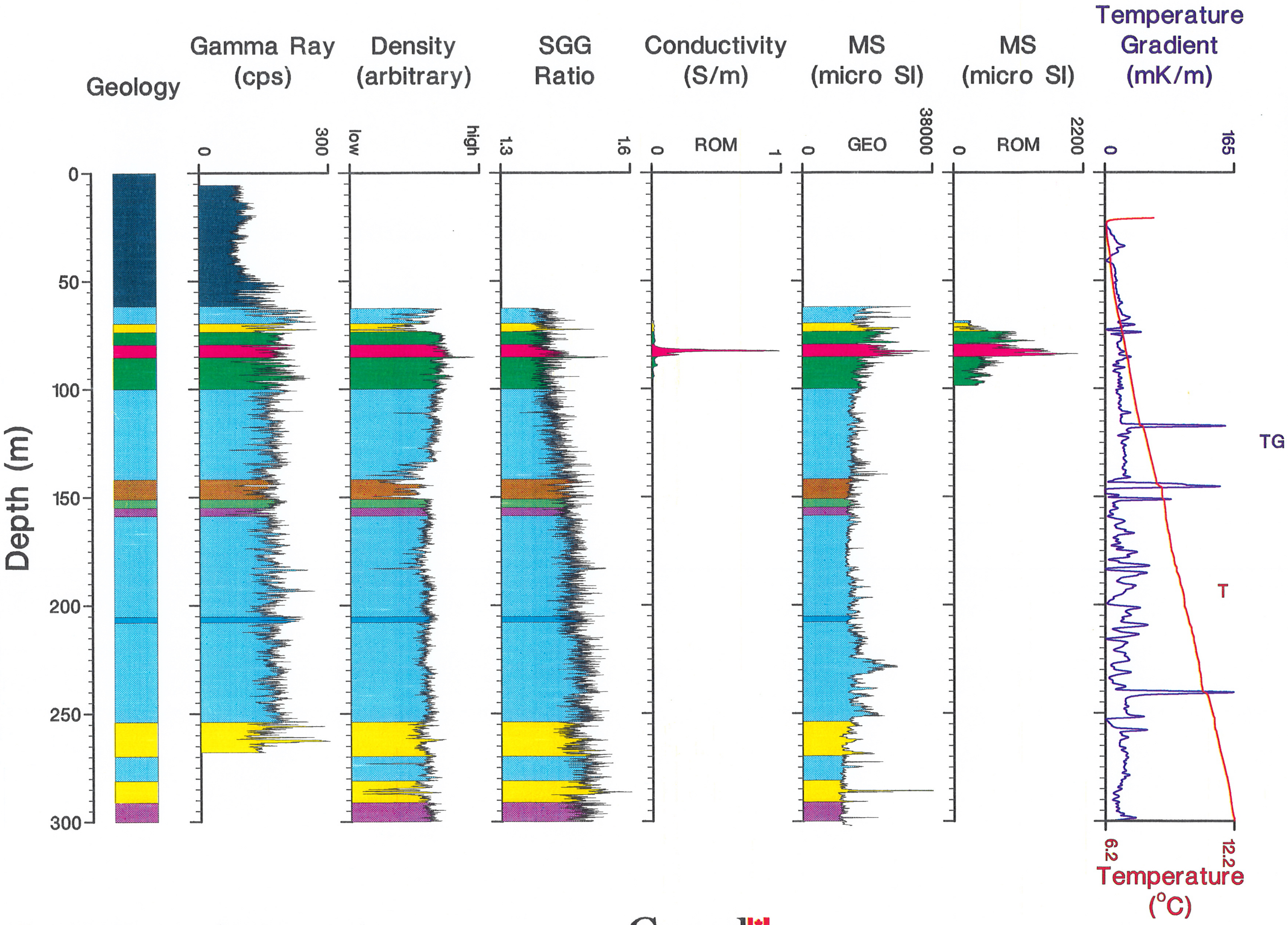
Canada

OPEN FILE
2610
A product of the
Borehole Geophysics Section
Mineral Resources Division
Geological Survey of Canada
OTTAWA

SULLIVAN, BRITISH COLUMBIA

Latitude (49°,41',0"), Longitude (115°,59',0")

Borehole K6423, Plot 1 of 2



LEGEND

- 🟩 Siltstone/Silty Argillite/ Argillaceous Siltstone
- 🟩 Silty Argillite
- 🟪 Argillite/Silty Argillite/ Quartzite
- 🟦 Argillite/Silty Argillite/ Argillaceous Siltstone
- 🟦 Argillite/Silty Argillite
- 🟥 Sulphide
- 🟨 Quartzite
- 🟫 Fracture Zone
- 🟦 Overburden

OPEN FILE
2610
A product of the
Borehole Geophysics Section
Mineral Resources Division
Geological Survey of Canada
OTTAWA

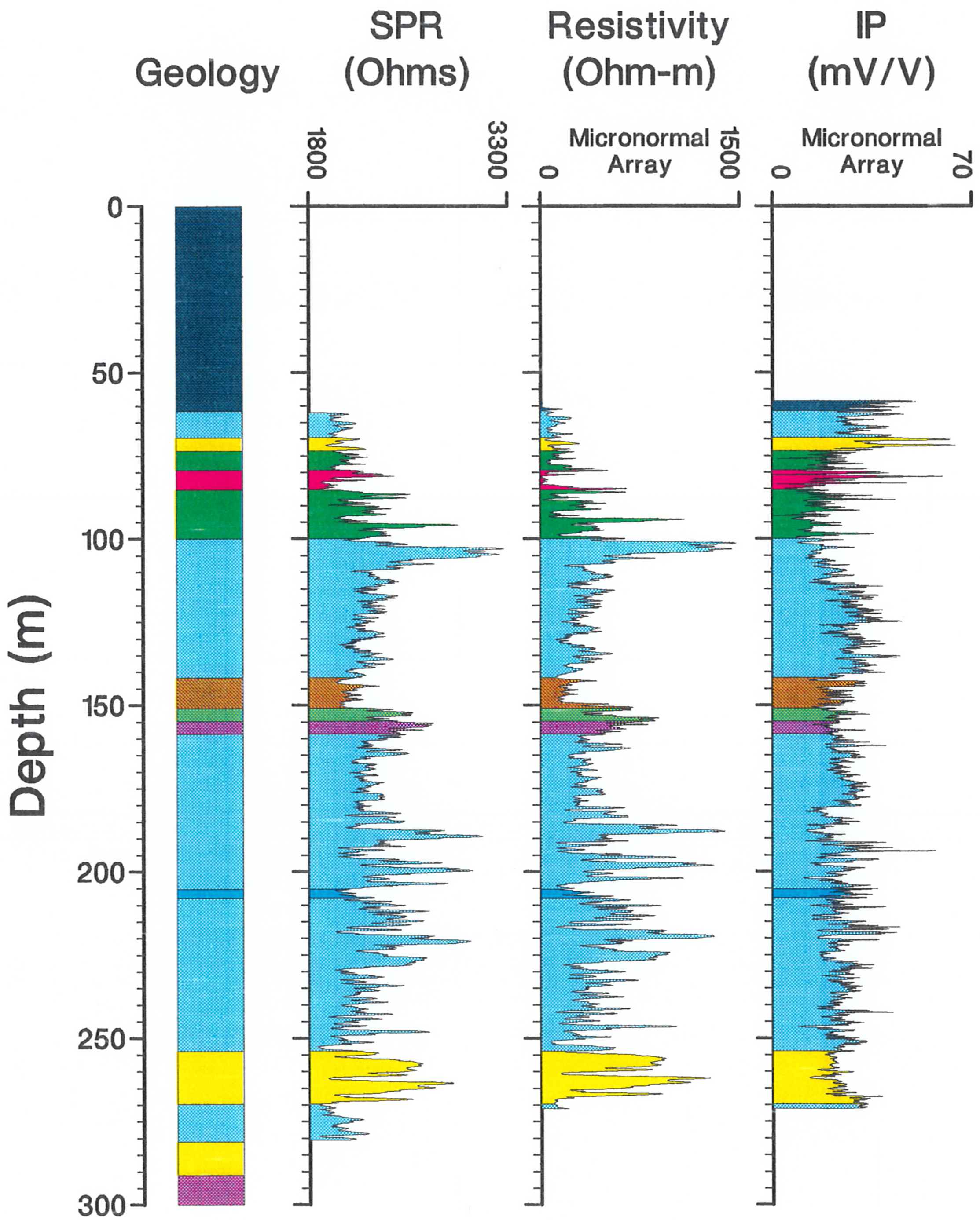
Natural Resources Canada Ressources naturelles Canada

Canada

SULLIVAN, BRITISH COLUMBIA

Latitude (49°,41',0"), Longitude (115°,59',0")

Borehole K6423, Plot 2 of 2



LEGEND

🟩 Siltstone/Silty Argillite/ Argillaceous Siltstone
🟩 Silty Argillite
🟪 Argillite/Silty Argillite/ Quartzite
🟦 Argillite/Silty Argillite/ Argillaceous Siltstone
🟦 Argillite/Silty Argillite
🟥 Sulphide
🟨 Quartzite
🟫 Fracture Zone
⬛ Overburden

Natural Resources Canada
Ressources naturelles Canada

Canada

OPEN FILE
2610
A product of the
Borehole Geophysics Section
Mineral Resources Division
Geological Survey of Canada
OTTAWA