DATA ON GEOTHERMAL AREAS

CORDILLERAN YUKON, NORTHWEST TERRITORIES, AND ADJACENT BRITISH COLUMBIA

CANADA

J.T. Crandall and T.L. Sadlier-Brown

November 30, 1976

Prepared on behalf of

DEPARTMENT OF SUPPLY AND SERVICES

DEPARTMENT OF ENERGY, MINES AND RESOURCES

CANADA

Contract Number 1SQ5-0136

NEVIN | SADLIER-BROWN | GOODBRAND | LTD

DATA ON GEOTHERMAL AREAS
CORDILLERAN YUKON, NORTHWEST TERRITORIES, AND ADJACENT BRITISH COLUMBIA CANADA

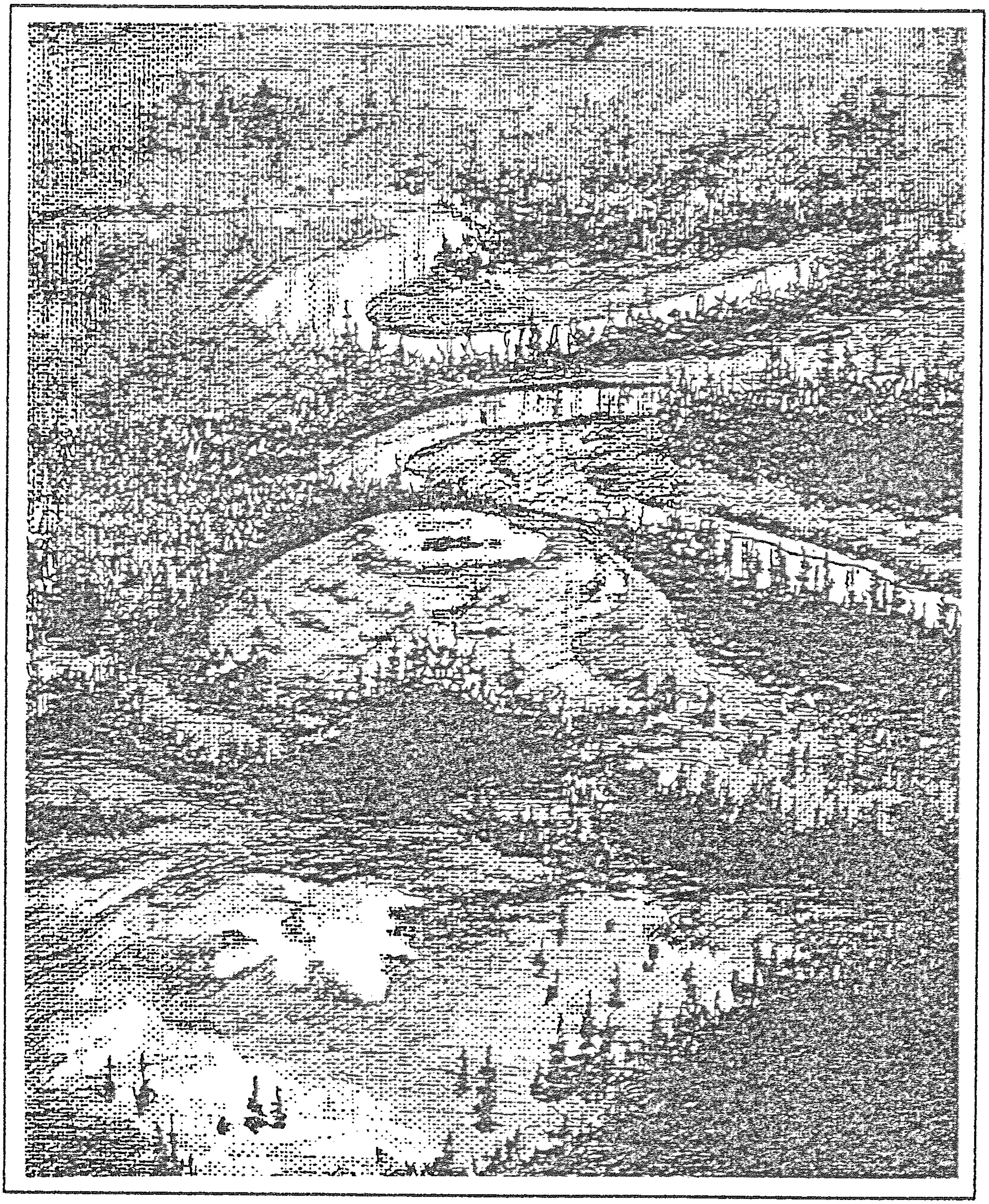
J.T. Crandall and T.L. Sadlier-Brown

November 30, 1976

Prepared on behalf of
DEPARTMENT OF SUPPLY AND SERVICES

DEPARTMENT OF ENERGY, MINES AND RESOURCES
CANADA

Contract Number 1SQ5-0136



Tufa Mound, Rabbitkettle Hotsprings, South Nahanni R. Area NWT

SUMMARY

Forty two thermal and mineral springs and two areas of Tertiary and Quaternary volcanism were examined in the Yukon Territory and Western District of Mackenzie during the 1976 field season. The work was carried out under the terms of Department of Supply & Services Contract No. 1SQ5-0136 by Nevin Sadlier-Brown Goodbrand Ltd., Consulting Geologists of Vancouver, B.C.

Observations of the thermal springs included location, rate of discharge, temperature, nature of mineral precipitates, and local geological setting. Water samples were analyzed principally for SiO2, Na^+, K^+, Ca^{++}, Mg^{++}, $HCO3^-$, $SO4^{--}$, $CO3^-$, Cl^-. Semi quantitative spectrographic analyses were also carried out.

Electrical self potential traverses were run across thirteen selected spring areas and results indicate that the method can be useful as an exploration tool in the study area. Analytical results are plotted in tabular form and on a Piper Tri-linear diagram. Interpretation of the data produced a two-fold classification of the springs based upon chemical character of the waters and the nature of the geological terrane in which they occur. On this basis the majority of the springs were found to fall into 7 distinct groups. Subsurface temperature estimates were calculated from chemical data for eight springs.

No contemporaneous geothermal activity was observed during the examination of the two areas of Tertiary and Quaternary Volcanism.

Five general areas are presently felt to warrant further investigation as possible future sources of geothermal energy. They are the Nahanni North, Nahanni Headwater, Cantung and McArthur Springs and the Whitehorse-Takhini area.

Two communities, Whitehorse and Mayo, presently use very low grade geothermal energy in the form of warm groundwater which when added to municipal water systems, reduces the fossil fuel consumption required to prevent freezing in the winter.

Potential future uses of the resource in the Yukon and N.W.T. are expected to be primarily in the field of space and process heat but the possibility of electrical generation cannot be entirely ruled out.

TABLE OF CONTENTS

		Page No.
SUMMARY		
1.0	INTRODUCTION	
	1.1 Terms of Reference	1
	1.2 Scope of Study	1
	1.3 Previous Work	2
	1.4 Geographical Statement	3
	1.5 Personnel and Acknowledgements	3
2.0	PRINCIPLES AND PROCEDURES	
	2.1 General Statement	3
	2.2 Field Procedures	4
	2.3 Analytical Procedures	5
	2.4 Interpretation of Chemical Data	6
	2.5 Electrical Self-Potential Method	7
3.0	OBSERVATIONS	
	3.1 Chemistry of Spring Waters	8
	3.2 Sinter and Tufa Deposits	9
	3.3 Electrical Self-Potential	10
	3.4 Recent Volcanic Terranes	11
4.0	DISCUSSION	
	4.1 General Statement	12
	4.2 Broken Skull Group	13
	4.3 Nahanni Group	13
	4.4 Cantung Group	14
	4.5 Mountain-Ekwi Group	15
	4.6 Redstone Group	16
	4.7 Larsen Group	16
	4.8 Atlin Group	18

TABLE OF CONTENTS (Cont'd)

		Page No.
4.9	Liard	18
4.10	Portage Brule	18
4.11	Coal River	19
4.12	Takhini	19
4.13	Versluce	20
4.14	McArthur	20
4.15	Mayo Well	20
4.16	Jarvis Creek	21
5.0	CONCLUSION	
5.1	Feasibility of Future Use	21
5.2	Suggestions For Further Research	22

TABLES

APPENDICES

APPENDIX A Field Notes
APPENDIX B Formulae
APPENDIX C References (Regional)
APPENDIX D References (Geothermal, Geochemical & Geophysical)

DRAWINGS (in pocket)

LIST OF TABLES

1 Meteorological Data
2 Basic Data on Thermal Springs
3 Classification of Thermal Springs by Temperature
4 Apparent Classes of Thermal and Mineral Springs, Cordilleran Yukon, N.W.T., and Adjacent B.C.
5 Quantitative Chemical Data on Thermal Spring Waters
6 Compiled Analyses of Thermal Spring Waters after Brandon, and Gabrielse et al.
7 Semiquantitative Spectrographic Analyses of Thermal Spring Waters
8 Standardized Semiquantitative Analyses of Thermal Spring Waters
9 Summary of Self-Potential Responses

ILLUSTRATIONS

DRAWING NO.	DESCRIPTION
1	Location Map
2	Nahanni, Broken Skull and Cantung Spring Groups
3	Mountain-Ekwi Spring Group
4	Redstone Spring Group
5	Larsen Spring Group
6	Takhini, Versluce Springs
7	Mayo Well, McArthur Spring
8	Piper Tri-linear Plot - Generalized Fields
9	Self-Potential Profiles - Nahanni North, West Cantung, McArthur, Hole-in-the-Wall
10	Self-Potential Profiles - Coal R., Atlin, McPherson L., Rabbitkettle
11	Self-Potential Profiles - Larsen South, Pool Cr., Portage Brule, Ekwi, South Redstone

1.0 INTRODUCTION

1.1 Terms of Reference

This study originated from an unsolicited proposal entitled "Proposal for Assessment of Geothermal Resources, Cordilleran Yukon and Northwest Territories, Canada", dated October 28, 1975, submitted to the Department of Supply and Services by Nevin Sadlier-Brown Goodbrand Ltd. Contract number 1SQ5-0136 was awarded March 26, 1976. It called for field examination of thermal springs in the southern Yukon Territory and western Northwest Territories and preliminary measurements and interpretation of their important physical, geological, chemical, and geophysical properties. At the suggestion of the Scientific Authority, Dr. J.G. Souther, of the Geological Survey of Canada, some thermal springs in northern British Columbia were added to the list.

1.2 Scope of Study

The study is based on field work done during the months of July, August and September, 1976. Its theme is the accumulation of basic scientific information on the thermal springs of the region. This is information which to date has been either unknown, unavailable in an orderly form, or collected prior to interest in geothermal resources and subsequent development of current sampling methods for thermal springs.

We collected such fundamental data as location, estimated rate of discharge, and temperature, of 42 thermal springs. Water samples were taken and analyzed quantitatively for principal cations and anions, and semiquantitatively for several metallic constituents. Geological settings were established where possible and examinations were made of two areas of geothermal interest where no springs were known to occur. In addition we ran electrical self-potential surveys over 13 selected thermal springs.

At this early stage we have limited the interpretation of these data to classification of groups of springs based on chemical similarities among waters, geological settings, and geographical proximity. We are offering preliminary comments on some aspects of development and utilization of geothermal resources in some areas. These comments, however, are subjective, as the economic potential of the resource cannot yet be fully appreciated or evaluated in this largely remote region. We should point out, also, that while thermal springs are often the first clues to the existence of underlying geothermal resources, not all economically significant geothermal reservoirs discharge to the surface.

Logistical constraints prevented the examination of every known, reported, or rumoured thermal spring. We have indicated however (Dwg. 1) those springs we did not examine, as well as numerous reported possible areas of thermal or mineral springs or anomalous snow free phenomena.

Methods of geochemical study on thermal springs are well established and the study simply followed current practice. This is not true, however, for the self-potential technique, which we tested during the course of the project as a rapid, inexpensive geophysical method for determining the boundaries of shallow components of geothermal reservoirs in subarctic climates.

1.3 Previous Work

Thermal springs in the Yukon and District of Mackenzie have not received concerted attention prior to this report. Those in the vicinity of settlements have long been known and have been discussed briefly in various publications. Analysis of the Atlin spring was performed early in this century. Bostock described the Volcano Mountain area in 1936 and the McArthur spring in 1947. Brandon (1965) discusses several thermal springs from the Mackenzie R. to the central Yukon. Most recently Gabrielse et al. (1973) have reported on some of the springs on the Flat and South Nahanni Rivers in the District of Mackenzie. Analyses published by Brandon and Gabrielse et al. have been reproduced in Table 6. The majority of the springs included in our study, however, were previously untested and were located in recent years principally by mineral exploration workers.

Two Yukon municipalities, Whitehorse and Mayo, presently make use of naturally warm groundwater as a supplement to their domestic water supplies. Recently, Hydrogeological Consultants Ltd. of Edmonton carried out a study for the City of Whitehorse as part of a project intended to expand the supply of this resource (Clissold, 1976).

1.4 Geographical Statement

The investigation was carried out in the Yukon Territory, The District of Mackenzie, Northwest Territories, and adjacent parts of British Columbia between 59° 21' and 64° 40' N. Latitude and 125° 30' and 138° 00' W. Longitude (Dwg. 1). The area may be divided into four broad physiographic units; the Mackenzie-Selwyn Mountains, the Liard - Hyland Plateau, the Liard Plain, and the Yukon Plateau. For the most part the area supports a boreal coniferous forest. The climate is rigorous with bitter cold winter temperatures and warm, sometimes hot summer temperatures. Mean temperature and rainfall data for principal communities is given in Table 1.

The main communities in the region studied (Dwg. 1) are Whitehorse, Watson Lake, Carmacks, Mayo and Haines Junction, Yukon Territory; Tungsten, NWT; and Atlin, B.C. Examples of population as of the 1976 census are: Whitehorse - 13,045; Watson Lake - 795; and Mayo - 433.

1.5 Personnel and Acknowledgments

T.L. Sadlier-Brown, J.T. Crandall and one locally-hired assistant conducted the field work. The principal technical sub-contractor was Chemex Labs Ltd., of North Vancouver, B.C. which performed nearly all of the analyses. Mr. Greg Shore, of Deep Grid Analysis, Ltd. designed the self-potential procedure and analyzed the results.

We would like to acknowledge the scientific and technical guidance given the project by Dr. J.G. Souther, the Scientific Authority for the project. Dr. R.G. Agarwal, Department of Supply and Services, Ottawa, served helpfully as the Science Procurement Manager. Many workers in mineral exploration, prospectors, geologists, and pilots, supplied information on hot spring locations and directions for finding them.

2.0 PRINCIPLES AND PROCEDURES

2.1 General Statement

The backbone of the report lies in the tables of original analytical data (Tables 2, 5, 7 and 8). With these, and the transcribed field notes (Appendix A), the reader can construct his own interpretations.

Table 2 summarizes basic field data. For purposes of this study, we have given each sampled spring a serial reference number. The same reference numbers are used throughout the report. We took the name of the spring from existing geologic or geographical literature, where such a name existed, or from common use in the community, where none was officially assigned. In about half of the instances, the springs had no recognized names. These we refer to using a geographic or descriptive basis.

In most cases, a thermal spring consists of several discharge points of varying temperature, sometimes occurring over a considerable area. Some springs discharge from one or two well-defined vents. Other springs, however, well up through porous materials and the water trickles downslope toward a major drainage without coalescing into a stream. The estimated discharge in these cases is subject to considerable error.

Generally, we attempted to sample the hottest pool available (to sample the water least-mixed with cooler ground and surface waters); however, this was not always practical.

Low mean ambient air temperatures and pervasive permafrost in the study area influence surface temperatures of the springs to an unknown degree. Table 3, 'Classification of Thermal Springs by Temperature', is a strictly empirical categorization to present the range of temperatures and a frequency distribution of the springs sampled. Since such temperatures may not necessarily bear a direct relationship to underlying reservoir temperatures, they should not be taken as an index of potential geothermal resources.

2.2 Field Procedure

Field work was conducted continuously from July 7, 1976 through September 21, 1976. Transportation was by truck, fixed-wing aircraft, and helicopter.

The examinations were performed by a two-man team which made notes on the geology, examined and sampled tufa deposits, estimated the rate of the discharge, measured the temperature, collected water samples and ran electrical self-potential profiles.

The chemical sampling of thermal and mineral waters involves a specialized procedure described as follows. Polyethylene bottles of 500 or 250 ml size are used. (Glass bottles are not acceptable since concentrations of silica may nucleate and precipitate out of solution onto the interior of the bottle between the time of sampling and laboratory analysis). Samples are generally filtered through a 0.45 micron filter for the purpose of removing organic matter or mineral precipitates which may alter the composition of the fluid prior to analysis. A sample of thermal or mineral water consists of three separate bottles numbered 1, 2 and 3. Sub-sample 1 is analyzed for anions and anion complexes (bicarbonate, carbonate, sulphate and chloride), and given a semiquantitative spectrographic scan for other elements. Sub-sample 2 is diluted with 9 parts distilled water, in order to preserve any possible metastable concentrations of silica, and it is analyzed for SiO2. Sub-sample 3 is for light cation analysis (sodium, potassium calcium and magnesium) and is treated with 5 ml, or 1% of concentrated nitric acid in order to preserve these ions in solution.

Samples of tufa and sinter were taken from springs where there was deposition. They were labelled R1 with the spring serial number as prefix.

2.3 Analytical Procedure

Analyses presented in this report were all conducted by Chemex Labs Ltd., North Vancouver, B.C. with the exception of one duplicate check sample. Sodium, potassium, calcium, and magnesium determinations were made by flame atomic absorption methods using a Varian Techtron AA-5. Mercury was determined by flameless atomic absorption procedure. Bicarbonate and carbonate concentrations were tested using a potentiometric titration with a standard sulphuric acid solution. Sulphate concentrations were determined using a titration with a standard barium perchlorate solution using thorin as an indicator. For chloride concentrations less than 10 ppm, a colourmetric test with mercuric thiocyanate was used.

For chloride concentrations greater than 10 ppm the sample was titrated with a standard silver nitrate solution using chromate as an indicator. A colourmetric method was used for the silica determination. pH was tested in the laboratory using a pH meter. An emission spectrograph produced the 30-element semiquantitative analyses.

Selected sinter and tufa samples were examined using microscope oil immersion techniques. Subsequently four sinters were tested on an x-ray diffractometer by Joe Nagel, Department of Geological Sciences, University of British Columbia, to detect the presence of amorphous silica.

2.4 Interpretation of Spring Water Chemistry

The Piper diagram is plotted in "equivalents per million", a measure of chemical equivalence derived as shown in Appendix B. The diagram makes no distinction between concentrated and dilute solutions. If enough data are available, a cluster of points may indicate a class of related waters, or a row of points may indicate samples taken from a water at different stages of a chemical change e.g. mixing with another water or reacting with reservoir rocks.

Several methods, based on temperature-dependent mineral equilibria in dilute aqueous solutions, have been developed for estimating subsurface reservoir temperatures from chemical constituents in thermal springs. As a general rule these methods are best suited to intensive study of a given geothermal system, since variables and basic assumptions are complex, and do not apply rigorously to regional programmes such as this. The leading methods are based on silica content and sodium-potassium-calcium ratios.

The silica estimator (Fournier and Rowe, 1966) makes use of the fact that the solubility of silica is almost directly proportional to the temperature of the reservoir water. Upon elevation of the water to the surface, the reverse reaction, the precipitation of silica, is somewhat sluggish. Therefore, a fluid from a hot reservoir may arrive at the surface containing a metastable amount of silica, indicating some memory of a hotter point with depth. The formula for temperature estimating based on silica content is given in Appendix B.

In rocks of granitic or intermediate volcanic composition, the equilibrium constants for sodium, potassium and calcium feldspars and these dissolved ions are temperature-dependent. Provided the aqueous fluid rises rapidly to the surface without re-equilibration of the light cations, their relative proportions in a hot spring water may give an indication of the temperature at depth in the reservoir (Fournier and Truesdell, 1973). The formula for this is also given in Appendix B.

The temperature estimators are applied only to those thermal springs in granitic terranes (Tables 4, 5). Their validity is impaired in cases where the spring waters pass through thick sequences of carbonate rocks.

2.5 Electrical Self-Potential (SP)

"Self-Potential" is one of the earliest geophysical methods used in exploration for near-surface metal deposits. The method is passive and consists of reading the voltage between two porous pot electrodes placed in the ground, and continuing to traverse between points on a regular or irregular spacing. In metal exploration, where it detects electrolysis, the method has been generally supplanted by more advanced techniques. With the new world-wide interest in geothermal exploration it has been applied as a reconnaissance tool with some success.

Of the many mechanisms known to generate natural electrical fields, the predominant process in geothermal areas is related to fluid movement (Anderson and Johnson, 1976). Laboratory studies, theory, and field studies (Appendix D, particularly Zohdy et al., 1973) indicate that a column of ascending water becomes enriched in cations through selective adsorption of anions by the conduit rock. The net surplus of cations accumulates near the top of the flow producing a local positive charge. SP anomalies have been recorded over a number of known geothermal systems. Some examples:

Mud Volcano Geothermal Reservoir, Yellowstone National Park:	+45 millivolts
Dunes Geothermal Anomaly, Imperial Valley, California:	+250 millivolts
Unnamed geothermal system in north-central Nevada:	+70 millivolts

In addition, anomalies to the order of +250 to +350 millivolts have been observed in association with geothermal activity at Meager Mountain, B.C. in a granitic environment (Nevin et al. 1975).

Significant operational virtues of the SP method are that it is rapid, inexpensive, and needs little equipment. Our survey, for example, used a light, hand-held, high input impedence digital voltmeter, a 1000 ft. (305 m) wire, and two $CuSO_4$-filled porous porcelain pots. Our experience in previous projects is that the SP response can identify extensions of known reservoirs, or anomalies, in suspected geothermal areas, to a degree sufficient to design a survey by an active method such as electrical resistivity. The latter would offer more discrete resolution and deeper penetration.

3.0 OBSERVATIONS

3.1 Chemistry of Spring Waters

Table 5 gives the quantitative analytical data on the springs sampled. Values for pH tend to be slightly basic with only one spring, Glacier L., proving acidic with a pH of 6.4. The predominant cation is calcium although sodium is important in some spring waters. Bicarbonate and sulphate are the dominant ions except in the case of one brine (Ekwi). Silica concentrations were found to be generally low.

Table 6 recapitulates similar data on a few of the same springs and several others as reported by Brandon (1965) and Gabrielse et al. (1973).

Table 7 presents the semiquantitative spectrographic analyses of the spring waters. The concentrations are reported as parts per million or per cent relative to the insoluble residue, the amount of which varies from sample to sample.

Table 8 presents the standardized semiquantitative spectrographic analyses. Concentrations are shown as parts per billion of the original samples and as such may be compared with one another. Strontium is the most consistently abundant metal. Comparisons throughout the various groups of springs show that the Cantung and Atlin groups are relatively low in strontium while the Mountain-Ekwi, Broken Skull and Redstone groups are relatively high. These latter groups are underlain by largely Devonian carbonate sequences.

The relative compositions of all the spring waters are displayed graphically on the Piper tri-linear plot shown in Dwg. 8. Empirical limits of four classes of water chemistry ($Ca(HCO_3)_2$, $CaSO_4$, NaCl, $NaHCO_3$) are drawn to include the points on the plot. These classes tend to enclose geographic groups. A two-fold classification is apparent based on the character of the water and geographic-geologic similarities. (Table 4). Tighter sample density and more rigorous control of individual samples would be needed to permit valid use of the tri-linear plot to ascertain, for example, extent of mixing and reaction with host rocks.

3.2 Sinter and Tufa Deposits

Chemical precipitates are present in all but a few of the springs. They range in size from massive accumulations of tufa (Mountain 1, South Redstone) to thin sinters on rock pebbles (McArthur, Nahanni Headwater). The deposits can be spectacular terraced formations (Rabbitkettle), terraced pools (Coal R., Redstone Jct 1), series of small terraces containing numerous riffles, pisolites and calcareous skins on gas bubbles (Portage Brule) or simple sponge textured masses (Morin North). Each deposit is, in some aspect singular.

Springs issuing from sedimentary terranes form deposits distinct from those which issue from granitic terranes. The former ($Ca(HCO_3)_2$ and $CaSO_4$ in character) tend to produce calcium and magnesian carbonate (travertine) deposits in which aragonite is a common mineral. Of the eight springs issuing from definite or inferred granitic terranes, five deposited precipitates on pebbles in the outwash zone. Oil immersion and x-ray diffraction examination (Nagel, personal commun. 1976) of four of these identified the major constituents:

McArthur	:	Opaline silica (only)
Nahanni Headwater	:	Opaline silica, calcite and perhaps fluorite
Nahanni North	:	Calcite (only)
Hole-in-the-wall	:	Opaline silica, calcite

An analysis of water from the Redstone River, near the Redstone Jct. complex of springs, falls well within the concentration ranges of the thermal waters sampled in the survey.

3.3 Electrical Self-Potential

Self-potential survey traverses were operated over 13 selected springs in an attempt to identify some of the important variables and to test the method in subarctic regions. A summary of the resulting responses is presented in Table 9 and traverse profiles are plotted on Dwgs. 9, 10, and 11.

Of the four strongest, best correlated SP responses, three are from springs issuing from granitic terranes (Nahanni North, Hole-in-the-wall, McArthur). The fourth is the briny Ekwi spring.

At Rabbitkettle the response is distinct but its relationship to background values is unresolved and would require further detailed survey. Contrast is approximately +40mV although correlation with the three seeps of the system is not clear.

Of those springs characterized as having weak or unclear responses, all four are located on flat or gentle slopes and the traverses may be too short to establish background response. West Cantung, in a granite environment and with several vents shows only minor SP variation and no direct correlation of positive inflections to the springs. It should be noted, however, that the overburden in the area has been disrupted by bulldozers. Larsen South, Pool Cr. and McPherson L. yield almost flat SP responses. In the case of Pool Cr. a normal cation accumulation may be continuously or cyclically removed by the purging effects of the nearby river. This assumes however, that the cation enrichment mechanism described in Section 2.5 is active.

The Coal River spring exhibits strong negative SP at and near the vent in a pattern unique among the surveyed springs. The immediate area remains interesting but work on a broader scale would be required to resolve positive trends on both profile flanks.

3.4 Recent Volcanic Terranes

The affiliation between thermal springs and centres of recent or contemporaneous volcanic activity is well established. In the Cordilleran Region of western North America a number of examples exist. Among them are Mt. Baker, just south of the United States border, the Meager Mountain volcanic complex 165 km north of Vancouver, B.C., and Mt. Edziza in the Stikine R. area of Northern B.C. A number of late Tertiary and Quaternary volcanic centres have been reported in the Yukon and an effort was made to determine whether or not thermal springs are associated with them. Three areas were considered: The Wrangell volcanic terrane of the western Yukon; the Selkirk terrane of the central Yukon; and the Miles Canyon terrane of the southern Yukon.

The Wrangell terrane has recently been mapped in detail by the Geological Survey (Souther, 1975) and, although evidence of Tertiary to Quaternary volcanic activity is present, no thermal springs have been reported.

The Selkirk Series consists of a sequence of basaltic flows, tuffs, and agglomerates which erupted during Tertiary and Quaternary time in the general area near the confluence of the Yukon and Pelly Rivers. A number of basaltic volcanic centres were examined during this study. Most are considered to be pre-glacial, the exception being Volcano Mountain, a young cone enclosing two breached craters from which very recent basalt flows have emerged. The area was examined from the air and on the ground but no manifestation of contemporaneous geothermal activity was observed.

The Miles Canyon basalts have their origin in the area west of the Yukon Valley and southwest of the town of Whitehorse. (Wheeler 1961). Several apparent centres were examined including the Golden Horn area, the Ibex Mountain area, and the Alligator Lake - Friday Creek area. Of these the most extensive flows emerge from one or more pre-glacial centres west of Alligator Lake. Although no hotsprings were observed in the immediate area its proximity to the Takhini spring 40 km to the north may be of geological significance.

4.0 DISCUSSION

4.1 General Statement

During the course of the present investigation it became apparent that certain thermal springs could be grouped together on the basis of geographical location and geological and chemical similarities. Seven groupings comprising thirty-two springs resulted. Eight other springs do not fit readily into any of these groups although they may or may not belong with other springs located outside the study area. For purposes of this report, however, they have been considered separately as non-grouped individuals.

Of the seven distinct groups, three lie within the broad area roughly comprising the Southern Mackenzie Mountains. They contain a total of fourteen springs which are included in the Broken Skull, Nahanni, and Cantung groups. Two groups, the Mountain-Ekwi and the Redstone, comprising ten springs, lie within the Northern Mackenzie Mountains area. The Larsen group is situated in the Liard Plateau area. The Atlin group is physiographically located in the southern part of the Yukon Plateau, a vast area which also contains most of the non-grouped springs.

The geological and physical settings of the various springs and groups of springs are briefly described below. Detailed data, including location, temperature, water chemistry, and geophysical observations are shown on the tables and in the field notes (Appendix A).

4.2 Broken Skull Group (Dwg. 2)

Broken Skull
Grizzly Bear

The primary structural feature in the area is the Broken Skull Fault. This is a steeply dipping, northwest-southeast trending break which divides a sedimentary terrane to the north-east, hosting the Broken Skull group, from a sedimentary-intrusive terrane. The Nahanni and Cantung groups of springs occur within the latter. The two springs which make up the Broken Skull group are situated immediately east of the fault in folded limestone of Ordovician to Devonian age. Temperatures are 45° C for the Broken Skull spring and 44° C for the Grizzly Bear spring. Both are characterized by $CaSO_4$ waters. They lie in a remote area, conveniently accessible only by helicopter, and are presently in their natural state.

4.3 Nahanni Group (Dwg. 2)

Glacier L.
North Cantung
Rabbitkettle
Flat Fruit
Wild Mint
Caesar L.
McPherson L.

The Nahanni group comprises seven sampled springs emerging from Proterozoic to Silurian carbonates and clastics lying around and between extensive exposures of Cretaceous granitic intrusives to the west and south of the Broken Skull Fault. The waters are $Ca(HCO_3)_2$ in character with the exception of Glacier L. which is $CaSO_4$ and returned the highest iron analysis in the survey as well as the only acid pH. Three "iron" springs in the vicinity of the Flat Fruit spring were not sampled (Appendix A). Also not sampled were two springs associated with the Wild Mint spring. These were sampled previously (Gabrielse et al., 1973, Table 6). The

McPherson L. spring, about 75 km west of Tungsten, is well separated from the main grouping but is in a similar terrane. The most spectacular member of the group is the Rabbitkettle spring which forms a terraced, flat-topped deposit of tufa, roughly circular in plan, about 60 m in diameter and rising some 25 m above the Rabbitkettle R.

The SP response at Rabbitkettle was distinct (contrast +40mV) but correlation with the three seeps of the system was not clear. The SP data from McPherson L. were weak and unclear (Dwg. 10).

Three springs, those at Glacier L., Caesar L., and McPherson L. are accessible by float plane. The others, however, are best reached by helicopter. Some of them lie within the boundaries of Nahanni National Park and all are in a natural state.

4.4. <u>Cantung Group</u> (Dwg. 2)

Nahanni Headwater
Nahanni North
West Cantung
East Cantung
Hole-in-the-Wall

These springs lie to the west and southwest of the Broken Skull Fault and are either directly or closely associated with granitic intrusive rocks of Cretaceous age. Water temperatures range from 29° C to 64° C (Nahanni Headwater, which was also the highest spring temperature recorded during the survey.). The waters are uniformly characterized by NaCO3 and both silica and Na-K-Ca geothermometers have been applied to them with no correction for mixing.(Table 5).

The silica thermometer is consistently higher than the Na-K-Ca thermometer. Mixing with ground or surface water will lower the indicated temperature obtained from the silica estimator and a re-equilibration of the composition of the thermal fluid en route to the surface will influence the Na-K-Ca estimator in a variety of ways (Fournier et al., 1973). At this early stage we have no explanation for the disparity other than a preliminary conclusion that the cation concentrations are not wholly dependent upon feldspar equilibria in these instances.

Of the three SP surveys conducted within this group, (Dwg. 9) two showed strong positive contrasts in potential and good correlation with spring location (Nahanni North: +60mV, Hole-in-the-wall: +100mV). The third, West Cantung, gave a weak and unclear response.

None of the springs in this group have generated large tufa deposits. Solid precipitation is limited to encrustations of sinter on pebbles in outwash zones. Sinters from Nahanni Headwater and Hole-in-the-wall consist of opaline silica and calcite (Section 3.2).

The only settlement in the area is the town and minesite of Tungsten, N.W.T. on the Flat River. The East and West Cantung springs are just south of the townsite and are readily accessible by road. West Cantung is used locally for recreation. Other springs in the group are remote and are best reached by helicopter, except for Hole-in-the-wall which is accessible by float plane.

4.5 Mountain-Ekwi Group (Dwg. 3)

Mountain 1
Mountain 2
Mountain 3
Deca East
Deca West
Ekwi

The six springs of the Mountain-Ekwi group lie in a terrane of Proterozoic to Mid Devonian limestone and dolomite and are apparently related to extensive and repetitive thrust faulting in the area. The faults trend northwest-southeast and thrusting is from the southwest. From northwest to southeast the surface temperature of the springs increases from 8.5° C at Mountain 3 to 47° C at Ekwi. In the same direction the water compositions change from $CaSO_4$ to NaCl. The Ekwi water is the densest encountered in the survey with 1.6% dissolved solids. It is also the only NaCl brine and contains the largest concentrations of boron and strontium (Table 8) found in the survey.

An SP traverse across the Ekwi spring area produced a strong response of +75mV which corresponded well with the spring location. (Dwg. 11).

The Mountain-Ekwi group lies in a remote area and the only convenient access is by helicopter. None of the springs is presently utilized.

4.6 Redstone Group (Dwg 5)

North Redstone
South Redstone
Redstone Jct 1
Redstone Jct 2

The springs of the Redstone group issue from deformed Proterozoic through lower Paleozoic carbonate rocks on the limbs of the Marten Syncline, a broad northwest-southeast trending structure in the eastern part of the Mackenzie Mountain Belt. The North and South Redstone springs lie on the west limb of the syncline in the vicinity of the North Redstone and Rouge Thrust Faults. The South Redstone spring, at 54° C, is the warmest in the group. It also has the most extensive surface expression and highest discharge rate of any spring examined in the course of the project. The Redstone Junction complex is a cluster of four springs which occur in the canyon of the Redstone River adjacent to the Redstone Thrust Fault. Two of these springs were sampled. The composition of the group waters is predominantly $CaSO_4$.

An SP traverse across the South Redstone spring yielded a distinct positive potential contrast of +25mV which correlated well with the spring location (Dwg. 11).

The springs in this group are all located on or near the Redstone River in an uninhabited area and no use is presently made of any of them.

4.7 Larsen Group (Dwg. 5)

Larsen North
Larsen South
Pool Creek

The Larsen group of springs lies on the eastern margin of the Liard Plateau. Three springs issue from sedimentary rocks in the western part of the Beaver River Basin and another is reported to occur on the Crow River further south but could not be found.

The known springs are situated on or near the contact of Mid Devonian to Earlier carbonates and Devonian to Mississippian shales and sandstones which may include equivalents of the Nahanni Formation. Structure is characterized by north-south trending thrust faulting with moderate to steep easterly dips. Surface temperatures are 43° C to 53° C. Water composition is intermediate between $Ca(HCO_3)_2$ and $CaSO_4$ with Mg the secondary prominent ion.

SP surveys over Larsen South and Pool Cr. gave weak and unclear responses. (Dwg. 11).

The Mid Devonian carbonates of the Nahanni Formation which are apparently important aquifers in the Liard Plateau area are encountered at depth further east in the Mackenzie Valley. There, Sproule Associates Ltd. (1976) have compiled data from wells testing the Pointed Mountain and Beaver River Devonian gas fields (Dwg. 1, Section KK'), some 100 km to the east of the Larsen Group. They report the main unit of interest is the Mid Devonian Nahanni carbonate reef containing zones of excellent porosity which have been enhanced by faulting. This unit is overlain at depths in excess of 3660 m by Devonian-Mississippian shales. They conclude that there appear to be potential sources of water with temperatures well over 150° C in the Devonian sequence in the Pointed Mountain area at depths of about 4270 m. The waters are rich in Na, Cl and Ca.

The springs in this group are in a natural state and are remote from any settlements. Convenient access is only by helicopter.

4.8 Atlin Group (Dwg. 1)

Atlin
Morin North
Morin Middle
Morin South
Jones L.

The springs of the Atlin group occur in a sedimentary-intrusive terrane near the southern limit of the Yukon Plateau. They appear to be confined to a Late Paleozoic carbonate formation within the Cache Creek Group and their locations are evidently influenced by faulting. The dominant structure in the area is the Nahlin Fault which passes near those springs at Warm Bay on Atlin Lake. All water samples are $Ca(CO3)2$ in character and temperatures range from 9.5° C to 29° C with the warmest being the Atlin spring at Warm Bay.

SP traverses across the Atlin spring gave a distinct contrast in potential of +65mV with good correlation with the spring location. (Dwg. 10).

The Atlin spring is readily accessible by road from the town of Atlin and casual recreational use is made of it. The other springs can be reached by boat or float plane.

4.9 Liard (Dwg. 1)

The Liard springs emerge from the west limb of an anticline in Upper Palaeozoic clastic rocks at a point near their contact with an underlying limestone of Mid Devonian age. The waters are $CaSO4$ in character and temperatures of the two vents tested are 21° C and 54° C. The spring has been developed as a provincial park and is extensively used for public bathing.

About 14 kilometers northeast of the Liard springs is the Deer River spring which was not visited. It is reported to have a temperature of 42° C.

4.10 Portage Brule (Dwg. 1)

The Portage Brule spring consists of a zone of eight seeps issuing from fractured pelitic limestone of Cambro-Ordovician age. The warmest temperature measured is 48° C and the waters are $Ca(HCO_3)_2$ in character.

An SP traverse over the area gave a distinct +20mV response which correlates with some of the seeps. (Dwg. 11).

The springs are located on the north bank of the Liard River near the mouth of the Coal River about 2 km from the Alaska Highway. They remain undeveloped.

4.11 Coal River (Dwg. 1)

The Coal River spring is in a Silurian-Devonian limestone and dolomite unit between two northerly trending faults. The water is $Ca(HCO_3)_2$ in character and emerges at a temperature of 13° C.

An SP traverse produced an anomalous apparent negative response with a contrast potential of -95mV. (Dwg. 10).

The tufa deposit at Coal R. is also unique. It consists of a steep bluff at the east edge of the Coal River Valley. Deep, narrow, arcuate pools are developed in terraces over a vertical distance of about 12 m. The spring is best reached by helicopter although a mineral exploration winter road passes 5 miles to the west. No use is made of the spring.

4.12 Takhini (Dwg. 6)

The Takhini spring rises in unconsolidated glacial sediments which overlie the Triassic limestones and clastic sedimentary rocks of the Lewes River Group. It appears to be spatially related to a limestone unit within this group and is just west of a vertically dipping north-south striking fault. Water temperature is 47° C and character is $CaSO_4$.

The spring is readily reached by road from Whitehorse and is situated on private land. It has been developed for public swimming and is extensively used for this purpose. The owner is attempting to raise trout in an outflow pool.

4.13 Versluce (Dwg. 6)

This spring flows from glacial till overlying volcanic and sedimentary rocks of the Lewes River Group which are locally cut by granitic intrusions. Water emerges at 12.5° C and is $Ca(HCO_3)_2$ in character. The spring is on residential land, privately owned, and used as an ice-free domestic water supply.

4.14 McArthur (Dwg. 7)

The McArthur spring issues from valley fill underlain by Triassic (or Earlier) slates and quartzites which are intruded by Mesozoic granitic rocks. It is about 10 km northeast of the Tintina Fault, a major northeast trending structure, and 7 km east of a small Tertiary granitic pluton. The temperature of the water is 54° C characterized by $Na HCO_3$, and groups with the granitic thermal waters (Table 4). The springs are depositing a thin sinter, consisting of opaline silica (Section 3.2), on boulders in the outwash.

A very well correlated, strong SP response of +80mV was obtained over the vent area. (Dwg. 9).

The spring is in mountainous terrain 60 km south of the town of Mayo and no use is presently made of it.

4.15 Mayo Well (Dwg. 7)

The Mayo Municipal Well penetrates 244 m of fluvial silt and produces water at a temperature of 15° C from a gravel aquifer lying on bedrock. This is inferred, from the regional geology, to consist of a Mid Palaeozoic metaclastic sequence. The water is $Na HCO_3$ in character, which could imply a granitic association (Table 4).

The water will be used by the town to augment the municipal water system and is expected to significantly reduce the amount of fossil fuel required to keep the system from freezing.

4.16 Jarvis Creek (Dwg. 1)

The Jarvis Cr. spring rises in several small pools in the creek valley at a point near the middle of the Shakwak Trench. The area is till-covered but lies near the north limit of a wedge of Dezadeash Group clastic sedimentary rocks approximately on the major zone of reverse faulting which brings them into contact with the crystalline terrane to the northeast. (Campbell et al. 1975; Eisbacher 1975). The water temperature varies from pool to pool but the maximum observed is 16° C. The spring is $NaHCO_3$ in character, suggesting a granitic affiliation (Table 4), and is located 30 km northwest of Haines Junction. A bush road passes to within 2 km of it.

5.0 CONCLUSION

5.1 Feasibility of Future Use

Present uses of geothermal energy fall into two general categories: 1) electrical generation from geothermal steam and 2) space or process heating from either steam or hot water. The second category could, in fact, be broadened to include warm water.

Thermal springs are assigned by Souther (1975-B) into three classes 1) those related to deep flow systems in layered rocks, predominantly carbonates; 2) those originating in fractured metamorphic or intrusive terranes; and 3) those occurring in and near areas of Quaternary volcanic activity.

All of the springs examined during the course of the present survey fall into either class 1 or 2. Several areas exist in the Yukon where class 3 springs might be expected to occur but none were found during this study and none have been reported. As the springs of class 3 are the ones most commonly associated with electrical power generation the data on hand suggest that the important future uses of geothermal energy in the Yukon and N.W.T. will be in the field of space or process heat. It should be noted, however, that of the springs for which reservoir temperature estimates were calculated, 6 gave values greater than 100° C using the SiO_2 indicator with no provision for mixing. Of these, 3 gave values below, but approaching 100° C using the Na-K-Ca indicator. These springs are Nahanni Headwater, Nahanni North and McArthur. Hole-in-the-wall and the East and West Cantung springs also produced anomalously high estimates. The temperature estimates are below what might be considered an economic goal for power generation (say +200° C) but they do not exclude the possibility of steam at depth. The above localities then, are presently considered to be the best targets for any future research into geothermal steam in the study area.

Space and process heat remain the most likely short range applications for geothermal energy in the study area. Both are dependent upon proximity of the geothermal source to the user of the energy, which would normally be a community or plant. In the sparsely populated Yukon and District of Mackenzie this would seem to require a remarkable coincidence yet in several instances thermal springs are in fact located near population centres or possible future population centres. Among these are the East and West Cantung springs located near the settlement of Tungsten and the Takhini spring near Whitehorse. The Nahanni Headwater and Nahanni North springs, while presently remote from any population centres, are located about 50 km east of a major mining development project being undertaken by Placer Development at Howards Pass.

The concept of using naturally warm water (15° - 20° C) to augment municipal water supplies is being developed in the Yukon and both Mayo and Whitehorse benefit to some degree from exploitation of this form of geothermal energy. Other communities might be able to do the same if their populations reach sufficient size to warrant it. Haines Junction for instance is located in the same structural and geological terrane as the Jarvis Creek springs 30 km to the northwest.

5.2 Suggestions For Further Research

Geological and economic considerations point to 5 areas which are felt to warrant more detailed evaluation. Of these the two most important are the Whitehorse-Takhini areas and the Cantung springs area. Both should be studied with the objective being the location of a reservoir of hot water of sufficient size to be used in space heating or as process heat (drying of mineral concentrates for example).

The Nahanni Headwater and Nahanni North springs are situated near a developing area and any overall resource evaluation of this region should include studies of them both from the point of view of energy production and as possible sources of space and process heat.

The McArthur spring is somewhat remote from present or planned growth areas. Nevertheless its geological setting near an area of Tertiary (Bostock 1947) granitic activity, the general chemical makeup of its waters and precipitate (opaline silica sinter), and a distinct, well correlated SP response combine to make it a unique and possibly valuable subject for detailed study.

Respectfully submitted,

J.T. Crandall

T.L. Sadlier-Brown

TABLE 1.- METEOROLOGICAL DATA

	MEAN ANNUAL DAILY TEMPERATURE (°C)	MEAN ANNUAL TOTAL PRECIPITATION (mm)
YUKON		
Watson Lake	-2.9	432.1
Whitehorse	-0.9	260.3
Haines Jct	-3.2	282.5
Mayo	-3.8	293.4
Ross River	-5.2	..
NWT		
Tungsten	-4.7	..
Norman Wells	-6.3	334.3
Wrigley	-5.1	323.5
B.C.		
Atlin	-0.2	283
Lower Post	-2.2	..

REFERENCE: Environment Canada (1975) Canadian Normals, Volumes 1-SI, 2-SI

TABLE 2.- BASIC DATA ON THERMAL SPRINGS

Discharge rates of "-1" read "less than 1". Generally the spring having the highest temperature in the surface system was sampled.

REFERENCE NUMBER	NAME OF SPRING	NTS MAP SHEET	LAT	LONG	ESTIMATED DISCHARGE (litres/sec) TOTAL SYSTEM	SPRING SAMPLED	MAXIMUM SYSTEM TEMPERATURE (°C)
1	Liard 1	95M Rabbit R	59°25'	126°05'		30	21
2	Liard 2	95M Rabbit R	59 25	126 05	+ 70	40	54
3	West Cantung	105H Frances L	61 55	128 15		-1	41
4	East Cantung	105H Frances L	61 55	128 15	30	seep	29
5	Takhini	105D Whitehorse	60 52	135 22	15	4	47
6	Versluce	105D Whitehorse	60 46	135 09	-1	-1	12.5
7	McArthur	105M Mayo	63 04	135 42		5	54.5
8	McArthur	105M Mayo	63 04	135 52	30	5	50
9	Mayo	105M Mayo	63 36	135 53	5	5	15
10	Ekwi	106A Mt Eduni	64 03	128 15	30	10	46
11	Deca East	106A Mt Eduni	64 10	128 25	7	7	22
12	Deca West	106A Mt Eduni	64 10	128 28	-2	-2	16
13	Mountain 1	106A Mt Eduni	64 32	129 15	15	8	10
14	Mountain 2	106A Mt Eduni	64 31	129 15	-3	seep	10
15	Mountain 3	106A Mt Eduni	64 38	129 13	25	20	8.5
16	North Redstone	95M Wrigley L	63 43	126 25	-1	seep	9
17	Grizzly Bear	95L Glacier L	62 40	127 55	30	20	44
18	Nahanni Headwater	105I Nahanni	62 49	128 50	60	20	64
19	Atlin	104N Atlin	59 24	133 35	45	20	29
20	Morin North	104M Skagway	59 59	134 13	25	25	9.5
21	Morin Middle	104M Skagway	59 58	134 13	20	seep	15
22	Jones L	104N Atlin	59 53	134 00	45	45	13
23	Morin South	104M Skagway	59 58	134 13	-1	seep	17
24	McPherson L	105H Frances L	61 52	129 37	20	20	16
25	South Redstone	95N Dahadinni	63 24	125 52	120	15	54
26	Redstone Jct 1	95N Dahadinni	63 32	125 42	25	28	15
27	Redstone River water	95N Dahadinni	63 32	125 42			5
28	Redstone Jct 2	95N Dahadinni	63 33	125 44	4	2	8
29	North Cantung	105I Nahanni	62 07	128 25	5	seep	32
30	Nahanni North	105I Nahanni	62 22	128 40	40	15	58
31	Broken Skull	105I Nahanni	62 45	128 08	35	25	45
32	Glacier L	95L Glacier L	62 05	127 35	25	25	3
33	Wild Mint	95E Flat R	61 25	126 35	50	30	29
34	Rabbitkettle	95E Flat R	61 57	127 11	-2	seep	21
35	Hole-in-the-Wall	95E Flat R	61 42	127 17	30	10	47
36	Flat Fruit	95E Flat R	61 40	127 35	-3	seep	11
37	Caesar L	95E Flat R	61 25	127 52	40	40	3
38	Coal R	95D Coal R	60 08	127 25	45	45	13
39	Larsen North	95C La Biche R	60 12	125 30	40	40	53
40	Larsen South	95C La Biche R	60 12	125 30	30	20	43
41	Pool Cr	95C La Biche R	60 23	125 32	3	3	54.5
42	Portage Brule	94M Rabbit R	59 38	126 57	15	seep	48
43	Jarvis Cr	115A Dezadeash	60 54	137 57	5	-1	16

TABLE 3.- CLASSIFICATION OF THERMAL SPRINGS BY TEMPERATURE

COLD Less than 5° C	COOL 5-20° C	WARM 20-35° C	HOT More than 35° C
Glacier L	Versluce	East Cantung	Liard 2
Caesar L	Mayo	Deca East	West Cantung
	Deca West	Atlin	Takhini
	Mountain 1	North Cantung	McArthur
	Mountain 2	Wild Mint	Ekwi
	Mountain 3	Rabbitkettle	Grizzly Bear
	North Redstone	Liard 1	Nahanni Headwater
	Morin North		South Redstone
	Morin Middle		Nahanni North
	Morin South		Broken Skull
	Jones L		Hole-in-the-Wall
	McPherson L		Larsen North
	Redstone Jct 1		Larsen South
	Redstone Jct 2		Pool Cr
	Flat Fruit		Portage Brule
	Coal R		
	Jarvis Cr		

TABLE 4.- APPARENT CLASSES OF THERMAL AND MINERAL SPRING SYSTEMS, CORDILLERAN YUKON, N.W.T., AND ADJACENT B.C.

Water chemistry and geographic proximity suggest groups of springs as shown below (Nahanni, Cantung, etc.). The NaHCO3-rich springs also correlate with granite terranes. In some instances a spring has a secondary prominent ion which is shown in brackets. These apparent classes are developed in Drawing 8 and the text.

CLASSES BASED ON WATER CHEMISTRY

CLASSES BASED ON GEOGRAPHY AND GEOLOGY	$Ca(HCO_3)_2$	$CaSO_4$	$NaCl$	$NaHCO_3$
SOUTHERN MACKENZIE MOUNTAINS	**NAHANNI** 29 North Cantung (Mg) 34 Rabbitkettle 36 Flat Fruit 33 Wild Mint 37 Caesar L 24 McPherson L	**NAHANNI** (cont.) 32 Glacier L		**CANTUNG** 18 Nahanni Headwater (SO4) 30 Nahanni North (SO4) 3 West Cantung (SO4) 4 East Cantung (SO4) 35 Hole-in-the-Wall
SOUTHERN MACKENZIE MOUNTAINS		**BROKEN SKULL** 31 Broken Skull (HCO3) 17 Grizzly Bear (HCO3)		
NORTHERN MACKENZIE MOUNTAINS		**MOUNTAIN-EKWI** 15 Mountain 3 14 Mountain 2 13 Mountain 1 11 Deca East 12 Deca West	**MOUNTAIN-EKWI** (cont.) 10 Ekwi	
NORTHERN MACKENZIE MOUNTAINS		**REDSTONE** 16 North Redstone (Mg) 25 South Redstone (NaCl) 26 Redstone Jct 1 (Nacl) 28 Redstone Jct 2		
LIARD PLATEAU	**LARSEN** 39 Larsen North (Mg) 40 Larsen South (Mg) 41 Pool Cr (Mg)			
ATLIN	**ATLIN** 19 Atlin 20 Morin North 21 Morin Middle 23 Morin South 22 Jones L			
NON-GROUPED INDIVIDUALS	6 Versluce (Mg, SO4) 38 Coal R 42 Portage Brule	1 Liard 1 2 Liard 2 5 Takhini		7 McArthur 8 McArthur 9 Mayo (Ca, Mg) 43 Jarvis Cr
NATURE OF GEOLOGIC TERRANES	SEDIMENTARY ROCKS	SEDIMENTARY ROCKS	SEDIMENTARY ROCKS	GRANITIC

NATURE OF GEOLOGIC TERRANES

TABLE 5.- QUANTITATIVE CHEMICAL DATA ON THERMAL SPRING WATERS

pH values are from laboratory, not field examinations. Figures such as "-0.1" read "less than 0.1". A blank means that no determination was made. Temperatures are estimated from SiO2 content by the method of Fournier and Rowe (1966) and from Na-K-Ca following Fournier and Truesdell (1973) where appropriate (see also Appendix B).

GROUP AND SPRING	T°C	pH	SiO2	Na	K	Ca	Mg	ppb/Hg	HCO3	CO3	SO4	Cl	ESTIMATED TEMPERATURE IN °C SiO2	Na-K-Ca
			ANALYSES IN PPM OR Mg/LITRE (Hg IS IN PPB)											
NAHANNI														
32 Glacier L	3	6.4	48	1.2	0.8	58	11	0.05	30.4	-0.06	169	-0.1	..	..
29 North Cantung	32	7.39	21	0.8	0.7	19	12.9	0.05	64.7	-0.06	17.5	-0.1	..	..
34 Rabbitkettle	21	7.26	40	3.85	4.84	200	39.8	-0.02	404	-0.06	36	0.7	..	..
36 Flat Fruit	11	7.06	43	24	5.98	470	49	0.03	897	-0.06	36	1.7	..	..
33 Wild Mint	29	7.33	45	1.4	2.54	125	25.5	0.02	240	-0.06	33	0.2	..	..
37 Caesar L	3	7.41	31	12	1.36	110	7.5	0.09	201	-0.06	36	1.5	..	..
24 McPherson L	16	7.27	34	3.25	0.48	47	10.1	0.08	109	-0.06	12.2	0.2	..	..
BROKEN SKULL														
31 Broken Skull	45	7.27	56	52	33.8	140	50.2	0.05	240	-0.06	351	21.4	..	..
17 Grizzly Bear	44	7.73	54	22	23.8	105	25.5	0.2	123	-0.06	195	1.9	..	..
CANTUNG														
18 Nahanni Headwater	64	9	109	56	1.68	2.8	-0.2	0.1	20.7	19.9	34	9.7	142	77
30 Nahanni North	58	9.25	78	67	1.36	1.9	-0.2	0.05	17.3	31.1	61	2.1	125	80
3 West Cantung	41	8.2	58	47	1.24	7.6	1.2	-0.02	50.3	-0.06	23.4	6.1	109	42
4 East Cantung	29	8.94	68	64	1.36	3.6	0.5	-0.02	39.3	18.6	28.5	10	117	66
35 Hole-in-the-Wall	47	9.09	83	28	0.7	1.2	-0.2	0.05	27.9	19.2	8.	1.9	127	60
MOUNTAIN-EKWI														
15 Mountain 3	8.5	7.88	34	2.8	0.7	270	60	0.1	78.7	-0.06	827	1.8	..	..
14 Mountain 2	10	7.87	34	82	1.6	390	112	0.17	98.9	-0.06	1368	122	..	..
13 Mountain 1	10	7.9	34	80	1.6	350	102	0.1	106	-0.06	1182	114	..	..
11 Deca East	22	7.3	38	420	6.2	285	65	0.1	102	-0.06	1007	535	..	..
12 Deca West	16	7.4	34	200	3.64	155	58.8	0.17	77.5	-0.06	555	263	..	..
10 Ekwi	46	7.5	54	5850	80	260	66	0.28	278	-0.06	1191	8312	..	..
REDSTONE														
16 North Redstone	9	7.92	40	12.4	0.92	39	34.5	0.17	86.6	-0.06	214	16	..	..
25 South Redstone	54	7.43	58	49	1.46	72	21	0.12	72.6	-0.06	180	74.4	..	..
25 Check sample by Bondar Clegg Lab	54	..	35	44	1.7	90	24		48	nil	173	..	..	..
26 Redstone Jct 1	15	7.64	47	88.5	2.54	88	34.1	0.14	109	-0.06	224	143	..	..
28 Redstone Jct 2	8	7.61	31	5.3	0.48	69	35.2	0.06	125	-0.06	136	6.4	..	..
LARSEN														
39 Larsen North	53	7.4	60	5.6	3.74	72	19.1	0.05	115	-0.06	108	5.	..	..
40 Larsen South	43	7.12	55	5.50	3.74	74	18.2	0.08	115	-0.06	114	5.2	..	..
41 Pool Cr	55	7.32	68	9.15	4.18	76	31	0.05	160	-0.06	100	5.5	..	..
ATLIN														
19 Atlin	29	8.23	..	3.4	0.7	67	18.5	-0.02	150	-0.06	12.8	0.2	..	..
20 Morin North	9.5	7.53	32	1.65	0.8	61	13	0.14	134	-0.06	5.4	0.2	..	..
21 Morin Middle	15	7.29	39	2.85	1.04	68	15.8	0.03	122	-0.06	7.5	0.1	..	..
23 Morin South	17	7.59	34	1.8	0.7	59	13.8	-0.02	138	-0.06	5	0.1	..	..
22 Jones L	13	7.6	39	2.4	1.14	58	9.8	-0.02	114	-0.06	8.9	0.1	..	..
NON-GROUPED														
1 Liard 1	21	7.3	85	16.2	10.4	210	34.2	-0.02	93.9	-0.06	558	19.	..	..
2 Liard 2	54	7.84	54	8	5.2	155	22	-0.02	141	-0.06	273	9.1	..	..
5 Takhini	47	7.25	98	34	8.2	575	75	0.02	64.7	-0.-6	1768	1.5	..	..
6 Versluce	12.5	7.79	44	5.3	1.36	47	13.5	-0.02	90.3	-0.06	32.1	0.9	..	..
7 McArthur	54	9.09	67	48.1	1	1.25	-0.2	0.06	19.8	22.8	8.7	1.7	116	76
8 McArthur	..	8.8	87	44.4	1	1.25	-0.2	0.02	28.9	12	9.4	1.2	130	75
9 Mayo	15	8.09	45	62.5	1.82	38.8	20	0.6	148	-0.06	39.5	2.1	97	31
43 Jarvis Cr	16	7.74	34	150	6.6	12.8	9.8	-0.02	205	-0.06	36	27.6	84	142
38 Coal R	13	7.48	34	1.2	0.7	76	16.4	0.06	175	-0.06	22.7	0.2	..	..
42 Portage Brule	48	7.15	72	42.5	35.6	210	74.5	0.03	525	-0.06	78.8	64.7	..	..
27 Redstone River water (control)	4	7.89	53	7.25	0.36	32	13.3	0.09	65.3	-0.06	48.4	9.6	..	..

TABLE 6.- COMPILED ANALYSES OF THERMAL SPRING WATERS AFTER BRANDON (1965) AND GABRIELSE ET AL. (1973)

			ANALYSES IN PPM OR Mg/LITRE									
LOCATION	DATE SAMPLED	T^{o} C	pH	SiO2	Na	K	Ca	Mg	HCO3	SO4	Cl	REFERENCE
* Liard	July 1960	47.7	8.1	52	15	9.8	234	34	182	566	18.5	L.V. Brandon (1965)
* Portage Brule	Aug. 1961	32 to 44.4	7.3	40	40.6	34	125	76.5	725	77	63.6	" " "
* Atlin	July 1961	26.6	7.7	14	2.6	0.7	55.1	17.3	253	11.3	0.8	" " "
* Takhini	July 1961	46.6	7.5	41	30.1	7.7	586	95.1	132	1721	1.5	" " "
Roche-qui-trempe-a-l'eau, A	Aug. 1960	21 to 31	7.7	24	3220	34.5	925	223	184	2810	5226	" " "
Roche-qui-trempe-a-l'eau, B	Aug. 1960	21 to 31	7.8	..	3075	32.5	895	215	185	2744	5033	" " "
Roche-qui-trempe-a-l'eau, C	Aug. 1960	21 to 31	7.7	24	3420	33.0	946	215	188	2832	5200	" " "
Creek one mile north of Roche-qui-trempe-a-l'eau	Aug. 1960	21 to 31	8.0	17	2500	27.0	743	174	222	2198	3980	" " "
Old Fort Island	Aug. 1960	11.6	7.9	6.6	27.5	2	250	64	223	683	36.9	" " "
Clausen Cr, A	Sept. 1960	35 to 36.6	6.8	26	1176	73.5	470	116	271	660	2277	" " "
Clausen Cr, B	Sept. 1960	35 to 36.6	6.9	28	1066	72.5	460	117	263	738	2231	" " "
Clausen Cr, C	Sept. 1960	35 to 36.6	7.1	28	1076	75	470	116	283	732	2271	" " "
Clausen Cr, D	Sept. 1960	35 to 36.6	7.4	29	1054	72.5	452	120	308	698	2208	" " "
* McArthur	Nov. 1939	53.3	9.5	..	50	..	10	5	..	5	2	Bostock, cited by L.V. Brandon (1965)
NE side of Flat R, 4½ mi. (7.4 km) NE of mouth of McLeod Cr	July 13/64	11.6	7.3	21	1.6	3.2	158	21	580	15.7	0.4	H. Gabrielse et al. (1973)
SE side of Flat R, 5½ mi. (8.9 km) NE of mouth of McLeod Cr.												
a) 5 ft (1.5 m) above river	July 14/64	10.6	7.3	22	2.	3.5	151	33	563	54.3	0.2	H. Gabrielse et al. (1973)
b) 125 ft (38 m) above river	July 14/64	17.2	7.3	21	1.9	5.2	96	34	391	60.4	0.3	H. Gabrielse et al. (1973)
c) 125 ft (38 m) above river, 70 ft (21 m) downstream from (b)	July 15/64	17.2	7.4	22	2.0	3.2	152	33.6	558	61.3	0.1	H. Gabrielse et al. (1973)
* 7 mi.(11.3 km) ENE of Seaplane L (Wild Mint)**	June 15/63	26.1	8.0	14	1.1	2.1	36.1	20.4	184	24.2	1.7	H. Gabrielse et al. (1973)
* 1 mi.(1.6 km) SW of Caesar Lakes (Caesar L)**	July 15/63	3.3	7.9	5.4	11.0	1.2	38.8	7.7	142	34.9	0.5	H. Gabrielse et al. (1973)
* Rabbitkettle	July 26/63	20.5	7.9	15	3.9	4.9	44.8	41.2	317	32 2	41	H. Gabrielse et al. (1973)

* re-sampled by Crandall et al., 1976

** Spring designation used in this report

TABLE 7.- SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSES OF THERMAL SPRING WATERS

Original analytical data reported by Chemex Labs Ltd., North Vancouver. A blank means that concentration is below level of detection. In addition to values shown, analyses indicated that all samples contained less than 5 ppm each of Be and Bi, 20 ppm Cd and Ge, 50 ppm Sb and Nb, 100 ppm Th and 200 ppm Ta and Te.

GROUP AND SPRING	INSOLUBLE RESIDUE/ g/litre	CONCENTRATION IN INSOLUBLE RESIDUE IN PARTS PER MILLION EXCEPT WHERE NOTED AS PERCENT																				
		As	Ba	B	%Ca	Cr	Co	Cu	Ga	%Fe	Pb	%Mg	Mn	Mo	Ni	Ag	Sr	Sn	Ti	V	Zn	Zr
NAHANNI																						
32 Glacier L	0.35	..	20	20	15	50	70	20	..	5	100	5	1000	..	300	..	500	..	15	50	1000	..
29 North Cantung	0.11	..	500	70	15	70	..	20	..	0.05	200	10	10	..	10	..	500	..	15	30	..	..
34 Rabbitkettle	0.265	..	500	70	10	..	..	7	..	..	20	10	5	..	..	..	1000	..	10	30	..	..
36 Flat Fruit	0.22	..	200	200	10	30	..	5	..	0.05	70	10	5	..	..	..	2000	..	7	20	..	..
33 Wild Mint	0.245	..	200	50	15	50	..	20	..	0.05	150	10	10	..	..	..	2000	..	20	50	..	..
37 Caesar L	0.155	..	200	300	20	30	..	7	15	0.05	200	5	5	..	..	..	5000	..	..	100	..	..
24 McPherson L	0.075	..	100	50	15	100	..	20	..	0.07	500	7	20	..	10	..	1500	..	70	70	..	..
BROKEN SKULL																						
31 Broken Skull	0.79	..	50	500	15	..	..	7	..	..	70	10	..	..	..	..	5000	..	10	50	..	..
17 Grizzly Bear	0.564	..	100	150	10	..	..	7	..	0.05	10	5	30	10	..	..	2000	..	30	50	..	..
CANTUNG																						
18 Nahanni Headwater	0.198	70	10	5000	2	50	..	15	30	0.05	20	0.1	5	100	50	..	300	..	10	..	..	..
30 Nahanni North	0.25	..	..	1000	2	20	..	20	50	0.05	300	0.1	5	70	..	..	100	..	20	..	..	..
3 West Cantung	0.19	50	500	..	20	..	..	50	..	0.5	150	7	10	..	20	..	1000	..	100	300	..	..
4 East Cantung	0.341	..	30	..	1	..	..	20	50	0.1	150	0.5	5	..	..	..	50	50	50	..	..	..
35 Hole-in-the-Wall	0.13	..	10	2000	1	20	..	20	30	0.05	150	0.1	5	70	..	..	50	..	20	20	50	..
MOUNTAIN-EKWI																						
15 Mountain 3	1.64	..	5	..	10	..	..	2	..	..	..	2	15	..	..	..	500	..	5	10	..	..
14 Mountain 2	2.75	..	10	20	10	..	..	..	..	..	..	2	..	10	..	..	700	..	..	..	..	..
13 Mountain 1	2.28	..	5	20	10	..	..	1	..	..	..	2	..	..	..	..	700	..	..	..	..	..
11 Deca East	2.42	..	15	50	10	..	..	5	..	..	10	2	..	10	..	..	1500	..	15	10	..	..
12 Deca West	1.48	..	15	50	10	..	..	7	..	..	5	3	..	..	..	..	700	..	15	..	..	..
10 Ekwi	16.9	..	10	70	2	..	..	1	..	..	..	0.7	..	..	..	..	300	..	5	..	..	..
REDSTONE																						
16 North Redstone	0.607	..	30	20	10	..	..	7	..	0.05	50	3	20	10	..	..	1000	..	20	..	..	..
25 South Redstone	0.56	..	100	30	15	30	..	10	..	..	70	7	5	..	5	..	7500	..	20	70	..	..
25 Check sample by Bondar-Clegg Lab																						
26 Redstone Jct 1	0.735	..	100	30	15	20	..	10	..	..	50	7	..	..	..	..	5000	..	10	70	..	..
28 Redstone Jct 2	0.375	..	50	20	15	30	..	15	..	..	150	10	5	..	..	..	1000	..	10	30	..	..
LARSEN																						
39 Larsen North	0.27	..	500	200	15	..	..	5	20	..	70	5	5	..	..	..	3000	..	..	50	..	..
40 Larsen South	0.31	..	300	200	20	20	10	10	..	..	100	5	100	..	10	..	3000	..	..	70	..	..
41 Pool Cr	0.33	..	500	200	10	..	..	5	10	..	150	7	..	..	..	..	1000	..	..	50	..	..
ATLIN																						
19 Atlin	0.182	..	150	70	20	20	..	15	..	0.05	10	7	15	20	20	..	700	..	10	100	..	..
20 Morin North	0.085	..	700	50	20	70	..	50	..	0.05	200	7	20	..	10	..	500	..	100	70	50	..
21 Morin Middle	0.225	..	300	30	20	70	..	20	..	0.07	300	7	15	..	..	..	700	..	50	70	..	..
23 Morin South	0.15	..	500	20	20	50	..	10	..	0.05	100	5	15	..	..	..	500	..	70	100	..	..
22 Jones L	0.165	..	1000	20	20	50	..	7	..	0.05	100	5	10	..	..	..	700	..	70	100	..	..
NON-GROUPED																						
1 Liard 1	1.23	..	100	..	20	..	..	20	..	0.1	50	5	10	..	..	..	2000	..	..	..	..	..
2 Liard 2	0.782	50	1000	..	20	..	..	20	..	0.1	20	5	10	..	20	..	1000	..	..	..	..	50
5 Takhini	3.43	..	20	..	20	..	..	10	..	0.1	20	5	5	..	..	..	1000	20	..	..	..	..
6 Versluce	0.354	..	700	..	20	..	..	50	..	0.5	100	7	10	..	10	..	1000	50	500	..	..	..
7 McArthur	Insufficient sample																					
8 McArthur	Insufficient sample																					
9 Mayo	Insufficient sample																					
43 Jarvis Cr	0.47	..	150	500	2	..	..	7	5	..	20	2	..	70	..	..	700	..	..	..	..	..
38 Coal R	0.19	..	300	50	20	20	..	10	5	0.05	100	5	5	..	..	..	700	..	5	100	..	..
42 Portage Brule	0.615	..	500	500	10	..	..	5	5	..	70	10	..	..	..	2	2000	..	..	30	..	..
27 Redstone River water (control)	0.165	..	200	70	15	70	..	20	..	0.07	150	10	20	..	10	..	2000	..	20	50	50	..
Lower Limit of Detection	..	50	5	20	0.05	10	10	1	2	0.05	5	0.02	5	10	5	1	20	10	5	10	50	20

NOTE: Precision of analyses is described as follows: 5000 ppm means 2500-10000 ppm, 2000 ppm means 1000-4000, 1000 means 500-2000, 500 means 250-1000, 200 means 100-400, 100 means 50-200, 50 means 25-100, 20 means 10-50, 10 means 5-20, 5 means 2-10, 2 means 1-4, 1 ppm means 0.5-2 ppm.

TABLE 8.- STANDARDIZED SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSES OF THERMAL SPRING WATERS

Standardizing means multiplying the concentration of the element, reported in the previous table as a fraction of the insoluble residue, times the concentration of the residue in the sample water. Formulas are, for example: 700 ppm Sr x 0.225 g/litre residue = 158 ppb Sr in sampled water; or 0.5% Fe x 0.354 g/litre residue x 10^4 = 1770 ppb Fe in sampled water. Precision greater than 1 or 2 significant digits is not implied by 3 digit values presented here. Ca and Mg were not standardized, because quantitative values were obtained.

	PARTS PER BILLION IN WATER SAMPLE																		
GROUP AND SPRING	As	Ba	B	Cr	Co	Cu	Ga	Fe	Pb	Mn	Mo	Ni	Ag	Sr	Sn	Ti	V	Zn	Zr
NAHANNI																			
32 Glacier L	..	7	7	18	25	7	..	17500	35	350	..	105	..	175	..	5	18	350	..
29 North Cantung	..	55	8	8	..	2	..	55	22	1	..	1	..	55	..	2	3	..	..
34 Rabbitkettle	..	133	19	..	..	2	..	..	5	1	..	..	..	265	..	3	8	..	..
36 Flat Fruit	..	44	44	7	..	1	..	110	15	1	..	..	..	440	..	2	4	..	..
33 Wild Mint	..	49	12	12	..	5	..	123	37	2	..	..	..	490	..	5	12	..	..
37 Caesar L	..	31	47	5	..	1	2	78	31	1	..	..	..	775	..	..	16	..	..
24 McPherson L	..	8	4	8	..	2	..	53	38	2	..	..	..	113	..	5	5	..	..
BROKEN SKULL																			
31 Broken Skull	..	40	395	..	..	6	..	..	55	..	..	..	..	3950	..	8	40	..	..
17 Grizzly Bear	..	56	85	..	..	4	..	282	6	17	..	..	..	1128	..	17	28	..	..
CANTUNG																			
18 Nahanni Headwater	14	2	990	10	..	3	6	99	4	1	20	10	..	59	..	2	..	..	..
30 Nahanni North	.	..	250	5	..	5	13	125	75	1	18	..	..	25	..	5	..	..	..
3 West Cantung	10	95	..	..	..	10	..	950	29	2	..	4	..	190	19	57	..	..	..
4 East Cantung	..	10	..	..	..	7	17	341	51	2	..	..	..	17	17	17	..	..	..
35 Hole-in-the-Wall	..	1	260	3	..	3	4	65	20	1	9	..	..	7	..	3	3	7	..
MOUNTAIN-EKWI																			
15 Mountain 3	..	8	..	..	..	3	..	..	..	25	..	..	..	820	..	8	16	..	..
14 Mountain 2	..	28	55	..	..	..	..	..	..	..	28	..	..	1925	..	..	..	..	..
13 Mountain 1	..	11	46	..	..	2	..	..	..	..	..	..	..	1600	..	..	..	..	..
11 Deca East	..	36	121	..	..	12	..	..	24	..	24	..	..	3630	..	36	24	..	..
12 Deca West	..	22	74	..	..	10	..	..	7	..	..	..	..	1040	..	22	..	..	..
10 Ekwi	..	169	1180	..	..	17	..	..	..	..	..	..	..	5070	..	85	..	..	..
REDSTONE																			
16 North Redstone	..	18	12	..	..	4	..	304	30	12	6	..	..	607	..	12	..	..	..
25 South Redstone	..	56	17	17	..	6	..	..	39	3	..	3	..	4200	..	11	39	..	..
26 Redstone Jct 1	..	74	22	15	..	7	..	..	37	..	..	..	..	3680	..	7	52	..	..
28 Redstone Jct 2	..	19	8	11	..	7	..	..	56	2	..	..	..	375	..	4	11	..	..
LARSEN																			
39 Larsen North	..	135	54	..	..	1	5	..	19	1	..	..	..	810	..	..	15	..	..
40 Larsen South	..	93	62	6	3	3	..	..	30	30	..	3	..	930	..	..	22	..	..
41 Pool Cr	..	165	66	..	..	2	3	..	50	..	..	..	..	330	..	..	17	..	..
ATLIN																			
19 Atlin	..	27	13	4	..	3	..	91	2	3	4	4	..	127	..	2	18	..	..
20 Morin North	..	60	4	6	..	4	..	43	17	2	..	1	..	43	..	9	6	4	..
21 Morin Middle	..	68	7	16	..	5	..	158	68	3	..	..	..	158	..	11	7	..	..
28 Morin South	..	75	3	8	..	2	..	75	15	2	..	..	..	75	..	11	15	..	..
22 Jones L	..	165	3	8	..	1	..	83	17	2	..	..	..	116	..	12	17	..	..
NON-GROUPED																			
1 Liard 1	..	123	..	..	..	25	..	1230	62	12	..	..	..	2460	..	..	..	..	..
2 Liard 2	39	782	..	..	..	16	..	782	16	8	..	16	..	782	..	..	..	..	39
5 Takhini	..	69	..	..	..	34	..	3430	69	17	..	..	..	3430	69	..	..	..	..
6 Versluce	..	248	..	..	..	18	..	1770	35	4	..	4	..	354	18	177	..	..	..
7 McArthur	insufficient sample																		
8 McArthur	insufficient sample																		
9 Mayo	insufficient sample																		
43 Jarvis Cr	..	71	235	..	..	3	2	..	9	..	33	..	..	329	..	..	..	..	..
38 Coal R	..	57	10	4	..	2	..	95	19	1	..	..	..	133	..	1	19	..	..
42 Portage Brule	..	308	308	..	..	3	3	..	43	..	..	..	1	1230	..	..	18	..	..
27 Redstone River water (control)	..	33	12	12	..	3	..	116	25	3	..	2	..	330	..	3	8	8	..

TABLE 9.- SUMMARY OF SELF-POTENTIAL RESPONSES

RESPONSE	SPRING GROUP	SPRING	CONTRAST IN POTENTIAL (mV)	DRAWING NO.
A. Strong, correlates with spring location	Cantung	30 Nahanni North	+ 60	9
	Cantung	35 Hole-in-the-Wall	+100	9
	Mountain-Ekwi	10 Ekwi	+ 75	11
	Non-Grouped	7-8 McArthur	+ 80	9
B. Distinct, correlates with spring location	Redstone	25 South Redstone	+ 25	11
	Atlin	19 Atlin	+ 65	10
	Non-Grouped	42 Portage Brule	+ 20	11
C. Distinct, correlation not clear	Nahanni	34 Rabbitkettle	Approx. + 40	10
D. Weak or unclear	Nahanni	24 McPherson L	Approx. + 10	10
	Cantung	3 West Cantung	Approx. + 10	9
	Larsen	40 Larsen South	Approx. + 10	11
	Larsen	41 Pool Cr	Approx. + 5	11
E. Apparent negative response	Non-Grouped	38 Coal R	- 95 ?	10

APPENDIX A

Transcribed Field Notes

The springs are described in the chronological order in which they were visited. Locations are given according to National Topographic System (NTS) map sheet, latitudes and longitudes to the nearest minute, and geographic setting.

Elevations are recorded as feet above sea level with the rounded off metric equivalent in brackets. Determinations were taken from 1:250,000 scale topographic maps.

Rates of discharge are visual estimates.

Comments respecting plant and animal life are of a general nature only. No distinction for instance is made between algae and bacterial growths in the spring waters.

1/2 LIARD

MAX. TEMP : 54^{o} C
SAMPLES : 01-1,-2,-3
02-1,-2,-3
01-R1

NTS : Rabbit River (95M)
COORDINATES : 59^{o} 25'; 126^{o} 05'
ELEVATION : 1400' (425 m)
ACCESS : Road
DATE : 18 July, 1976

The Liard spring is in a provincial park on the north side of the Liard R. near kilometer 800 on the Alaska Highway. There are four vents : three form pools at the base of slope and a fourth venting into a small stream at an undetermined point above the base of slope. The hottest vent is used extensively for bathing.

The water in the main pool (02-1,-2,-3) is clear and there is a pronounced H2S odour. Gas bubbles rise in the vent. Flow is of the order of 40 l/s. Pale grey-white algae grows in the vent. The other two pools are very slow flowing with white algae and vegetation growing on the surface. Outwash from the pools drains through bush into a broad swamp where small fish live in the active water and moose feed on water plants.

Uphill from the hot pool is a warm stream of water (21^{o} C, 01-1,-2,-3) which forms a porous tufa mound (01-R1) with a rude terracing. Flow is of the order of 30 l/s.

GEOLOGY : The spring issues from Devonian-Mississippian clastics which overlie Mid-Devonian limestones exposed on a northerly trending anticline. South, several kilometres, are two northwesterly trending thrust faults, dipping southwest.

3 WEST CANTUNG

MAX. TEMP : 41° C
SAMPLES : 03-1,-2,-3

NTS : Frances Lake (105H)
COORDINATES : 61° 57'; 128° 13'
ELEVATION : 3500' (1070 m)
ACCESS : Road
DATE : 21 July, 1976

The spring issues from the base of slope on the southwest side of the Flat R. about a kilometre southeast of the town of Tungsten. During construction of the airstrip adjacent to the spring, gravel and sand fill was piled over the vent(s) and the discharge controlled with weeping tile. A large pool which is used for bathing has been dug in this fill. To the north 150 m is a series of seeps of which are covered with small plywood bathing chambers.

The water is clear, there is no gas discharge although there is a slight H_2S odour in places. Green algae grows in some of the seeps. The warmest of the seeps was sampled.

There is no precipitate from the spring.

GEOLOGY : The spring emerges from a Cretaceous granite intruding Cambrian carbonates and clastics. There are small east-west faults in the area.

4 EAST CANTUNG

MAX. TEMP : 29° C
SAMPLES : 04-1,-2,-3
04-R1 (misplaced)

NTS : Frances Lake (105H)
COORDINATES : 61° 57'; 128° 12'
ELEVATION : 3500' (1070 m)
ACCESS : Road
DATE : 21 July, 1976

A small seep issues from granite boulder rubble at the base of slope on the northeast side of the Flat R. opposite the West Cantung spring. There are also cold soil seeps mixing with the warm seep.

The water is clear. There is a slight H_2S odour and sporadic gurgles coming from under the boulders near the source of the seep. Green, yellow and cream algae are growing in the outwash.

A thin white crust rims pebbles in the outwash (04-R1).

GEOLOGY : Similar to West Cantung.

5 TAKHINI

MAX. TEMP : 47^{o} C
SAMPLES : 5-1,-2,-3
5-R1

NTS : Whitehorse (105D)
COORDINATES : 60^{o} 52'; 135^{o} 22'
ELEVATION : 2400' (730m)
ACCESS : Road
DATE : 23 July, 1976

The spring rises into an excavated pit on the flats north of the Takhini R. a kilometre from the base of a series of low hills. It is about 30 road kilometres north of Whitehorse. The spring is privately owned and used for public bathing.

The water is clear with a very slight H2S odour. There is a gas bubbling into the pool as well as sporadic accumulations rising back up the pipe which conducts water into the bathing facility. The vent pool overflows slightly promoting the growth of an ochre-reddish brown algae. The vent pool is covered and no algae grows within. The vent flows at about 4 l/s.

Sample 5-R1 consists of material precipitated at the outflow of the bathing pool as well as some of the clayey material piled up around the spring vent.

GEOLOGY : The spring rises in unconsolidated glacial sediments which overlie the Triassic Lewes River Group limestones and clastics. It appears to be spatially related to a limestone unit within this group and is just west of a normal north-south striking fault.

6 VERSLUCE

MAX. TEMP : 12.5° C
SAMPLES : 6-1,-2, -3
6-R1

NTS : Whitehorse (105D)
COORDINATES : 60° 46'; 135° 09'
ELEVATION : 2400' (730m)
ACCESS : Road
DATE : 24 July, 1976

The Versluce spring is the largest of a series of seeps near the top of a glacial till bench lying to the west of Porter Cr. within the limits of the municipality of Whitehorse. It is used as an ice free water supply by the owner.

The water is clear and potable. There is no H2S odour. Bubbles rise from the bottom of the small pool. Watercress flourishes in the water. Flow is less than 1 l/s.

At present there is a minimal seep downslope. However, before domestication, the spring formed an irregular porous deposit of tufa downslope incorporating humus, moss and cobbles (6-R1).

GEOLOGY : The glacial till overlies Lewes River Group rocks in an area where they have been intruded by Mesozoic granodiorite.

9 MAYO (Municipal Well)

MAX. TEMP : 15° C
SAMPLES : 9-1,-2,-3

NTS : Mayo (105 m)
COORDINATES : 63° 36'; 135° 53'
ELEVATION : 1900' (580 M)
ACCESS : Road
DATE : 27 July 1976

The town of Mayo has recently drilled for water about a kilometre north of the Stewart River. The hole encountered 244 m of unconsolidated silt and made water from a 3 m thick gravel aquifer lying on bedrock. Preliminary tests with a 20 h.p. pump have produced about 15 l/s with a drawdown of 52 m. Further testing is to proceed this winter with the intention of introducing the well water into the municipal water supply to augment it and to warm it slightly in order to reduce the quantity of fossil fuels required to keep it from freezing during the winter.

The water is clear and potable with a slight H2S odour. While drilling was in progress a spark reportedly flared gas ascending from the drill hole. Green algae is growing in the overflow. An artesian flow from the well head is about 5 l/s.

GEOLOGY : The bedrock is inferred from the regional geology to consist of a Mid Paleozoic metaclastic sequence (Bostock 1947).

10 EKWI

MAX TEMP : 46° C
SAMPLES : 10-1,-2,-3
10-R1,-R2

NTS : Mt. Eduni (106A)
COORDINATES : 64° 03'; 128° 15'
ELEVATION : 2300' (700 m)
ACCESS : Helicopter
DATE : 29 July 1976

The Ekwi vents are on the southern bank of the Godlin R. immediately upstream from the mouth of the Ekwi R. There are three vents within several metres of each other. No's. 1 and 2 are on the lip of the bank, a small cliff, while No. 3 is at the base of the bank, at and below river level.

Vent No. 1 is a seep, T = 32° C with green algae growing in the outflow. Vent No. 2 was sampled. Its temperature is 40° C. Its water is clear and salty with ochre, red, and green algae growing in the water in the short outflow channel above the river. There is no H2S odour. Flow is 5-10 l/s. There is no tufa deposit per se associated with vent No. 2. The surface of the limestone host has been irregularly changed into a reddish, friable mush where it is in contact with spring water but this is only a centimetre or two deep. Sample 10-R1 is a piece of host rock in its unaffected state and a piece in a partially affected state.

Vent No. 3 has the highest temperature. It is flowing vigorously and directly into the river, a significant portion of it below river level. There are no gas bubbles or odour. Flow is of the order of 25 l/s. Small white stalactitic deposits (10-R2) up to 10 cm long are developed on a weeping overhang above the vent. They taste very salty. In the mixing zone between spring and river waters, there is a small amount of banded carbonate (10-R2) in conjunction with carbonate nodular crystals.

GEOLOGY : Vents 1 and 2 are hosted by a locally flat lying limestone, finely banded with numerous solution and redeposition channels and vugs, most lying within individual or contiguous bedding planes. From the river southwards the limestone warps upwards forming a rounded hill. The flat lying portion forms a broad, smooth convex surface before the upwarp and is traversed in a northerly direction by two deep cuts which could have been formed by fissuring and/or dissolution. Vent 2 is near the end of one of these cuts but no association is obvious. The limestone is breaking off in great chunks at the edges. Strike/dip relationships in the mountains around are variable. Vent No. 2 is within a conglomerate at its contact with the overlying limestone. The conglomerate is made of metasedimentary pebbles within a hard brown matrix.

Aitken and Cook (1974) place Ekwi in the Helikian Little Dal carbonate formation between two major thrust faults, upthrust from the southwest.

11 DECA EAST

MAX. TEMP : 22° C
SAMPLES : 11-1,-2,-3
11-R1,-R2

NTS : Mt. Eduni (106A)
COORDINATES : 64° 10'; 128° 25'
ELEVATION : 2800' (850 m)
ACCESS : Helicopter
DATE : 29 July, 1976

Deca East is on the north bank of the Twitya R. about a kilometer from the river and three kilometers west of the mouth of Deca Cr. There is one vigorous spring filling a pool about 6 m in diameter and a meter or two deep. Outflow from this pool has built a large tufa mound. About 150 m uphill to the north is a cold seep. At the foot of the tufa mound is another cold seep.

The spring water is clear and has no disagreeable taste. There are fresh-water 'shrimp' in the pool. Gas bubbles well up in the pool but have no odour. Flow is of the order of 10 l/s.

The spring waters have produced a large tufa mass measuring 300 m by 225 m, elongate downslope. The spring and pool have remained in the same place for a long time and outflow has anastamosed over the tufa. The deposit is not terraced but is a massive mound petering out on a forested outwash floor. Locally small terraces have been formed in stream channels. Vegetation is beginning to creep onto the thinning lower 15 m of the mound. None of the meandering streams traverse the mound to the bottom but dissipate about three quarters of the way down. It would appear that present flow is not as great as it may have been in the past. The surface of the mound is flakey and loose and degraded. Sample 11-R1 consists of four fragments of tufa numbered 1, 2, 3, 4 and were taken from the top to the bottom of the mound.

There is a mossy growth on the surface of the pool but there is no algae growth in the outflow system.

The temperature of the seep uphill from the pool is 4.5° C, the water is clear and there is an occassional bubble of odourless gas coming from the vent. Pebbles in the outwash are encrusted with white carbonate crystals (Sample 11-R2 (UP)) in addition to a rusty stain. There is also a rusty algae growth.

The temperature of the seep at the foot of the tufa mound is 14° C. Outwash pebbles have a white carbonate encrustation (11-R1 (DOWN)). There is no rust stain or algae.

GEOLOGY : Locally there is no outcrop. Surface float consists of quartzite, shale and a few gneissic erratics. Aitken and Cook (1974) map the springs within the carbonate Little Dal Formation (Helikian?) and on or near the locus of a major NW-SE thrust fault downthrown on the NE.

12 DECA WEST

MAX. TEMP : 16° C
SAMPLES : 12-1,-2,-3
12-R1

NTS : Mt. Eduni (106A)
COORDINATES : 64° 10' ; 128° 28'
ELEVATION : 2800' (850 m)
ACCESS : Helicopter
DATE : 29 July, 1976

Deca West lies about a kilometer west of Deca East at the same elevation. There are two tufa mounds - the western one hosts three seeps, including the most vigorous, situated on the eastern margin of the mound. The smaller eastern mound has one active seep.

The most vigorous seep was sampled. Its temperature is 12° C and has no odour. Varicoloured (white, yellow, green, tan) algae grows in the outwash. The seep to the west is 11° C, with no algae but carbonate rocks in its outwash are coated with white carbonate crystal precipitate (12-R1 (1)). The westernmost seep is the warmest at 16° C, is very feeble and hosts varicoloured algae. The seep on the eastern mound was very sluggish with limy algae and green mossy growth.

The large western tufa mound (12-R1 (2)) is about 60 x 100 m, elongate downhill. It has cavities conforming to the sheeted nature of the deposit and has a hollow ring in many places. The seeps are located well downhill from the top of the mound and it is very apparent that they wander in space and time. The eastern mound is a smaller replica of the western one.

GEOLOGY : Between the two mounds is a carbonate (dolomite) and quartzite boulder train. Deca West is in the same geological environment as Deca East.

13 MOUNTAIN 1

MAX. TEMP : 10° C
SAMPLES : 13-1,-2,-3
13-R1

NTS : Mt. Eduni (106A)
COORDINATES : 64° 32'; 129° 15'
ELEVATION : 2500' (760 m)
ACCESS : Helicopter
DATE : 30 July, 1976

Mountain 1 presently consists of one vigorous spring and three seeps about 30 m above the Mountain River on its east bank about 13 km south of Mountain 3. Its large distinct tufa deposit is readily seen from the air.

The water is clear but unpleasant tasting, like slightly salty epsom salts. The spring is the most southerly vent. Its temperature is 9° C, it gives off a slight H2S odour and its rate of flow is 15 to 20 l/s. The temperature of the seep north of the spring is 10° C and it gives off a slight H2S odour as well. The two northernmost seeps have temperatures of 9° C and have no discernable odour.

The tufa deposit is large, measuring roughly 150 m by 225 m not including a large southerly lobe which shows no spring activity at present. The spring and seeps are along the top of the deposit and their flows form anastomosing paths down the gentle slope of the tufa and then fall over its western edge , a cliff 15 - 20 m high. Laterally the competent tufa ledge is bounded by chaotic zones of tufa blocks which have 'calved' off the main mass. The surface of the ledge is granular and flakey smooth due to frost action. Some pebbles of tufa have been selectively stained deep red. Spring vent locations have changed with time.

Chartreuse and orange algae is sparsely distributed in the stream channels.

GEOLOGY : Locally the float is carbonate, conglomerate (with metasedimentary cobbles) and shale. Up the hill to the east are rock exposures which appear to be dipping gently easterly. They trend NW-SW conforming to the fabric imposed by the many thrust faults in the area. Mountain 1 appears to lie on or near a thrust fault extension as shown by Aitken and Cook (1974) on or near the contact of the Mid Devonian Hume and Bear Rock carbonates.

14 MOUNTAIN 2

MAX. TEMP :	10^{o} C	NTS :	Mt. Edune (106A)
SAMPLES :	14-1,-2,-3 (unfiltered)	COORDINATES :	64^{o} 31'; 129^{o} 15'
	14-R1 (lost in transit)	ELEVATION :	2500' (760 m)
		ACCESS :	Helicopter
		DATE :	30 July, 1976

Mountain 2 is presently represented by three small seeps close together at the top of a large tufa mound/ledge less than a kilometer south of Mountain 1 on the east side of the Mountain River.

The water is clear and similar in taste to Mountain 1. There is, however, no H2S odour. Combined flow of the three seeps is less than three l/s.

The tufa deposit is roughly 90 m downslope by 160 m across slope in a north-south direction. It is developed on and conforms to a steep talus/outcrop slope. The lower edge is a jumble of broken material. The seep waters drain down one side of the deposit but dissipate before they reach the river. At the foot of the deposit the streams precipitate a black coating on pebbles.

Algae of chartreuse and very yellow-green colour grow in the flow channels.

GEOLOGY : Immediately uphill from the seeps is an outcrop of meta-sedimentary pebble conglomerate with a hard brown mud matrix overlain by a solution leached carbonate (similar to Ekwi). This outcrop is dipping about 30^{o} W. To the east, uphill on the ridge are sediments striking northwesterly and apparently dipping gently east. Relation to the map by Aitken and Cook (1974) is the same as Mountain 1.

15 MOUNTAIN 3

MAX. TEMP : 8.5° C
SAMPLES : 15-1,-2,-3
15-R1

NTS : Mt. Eduni (106A)
COORDINATES : 64° 38'; 129° 13'
ELEVATION : 2500' (760 m)
ACCESS : Helicopter
DATE : 30 July 1976

There is one large spring and a series of seeps draining west into the Mountain R. immediately south of its confluence with Cache Cr. Spring water rises into a 6 m diameter pool, flows west for 100 m through spruce forest and falls 5 m over a steep overburden/ bedrock slope to the Mountain R. A series of seeps along a soil slump scarp extend 100 - 150 m south along the river bank.

The water is clear and potable with no unpleasant taste/smell. Sporadic clusters of odourless gas bubbles rise from the bottom of the pool. Spring flow is equal to or less than 20 l/s.

In the mid to upper reaches of the stream white carbonate crystallizes as thin skins and nodules on pebbles. In the lower reaches and especially where the water debouches onto the river bank the deposition of carbonate forms a steep sheeted deposit with the stream anastomosing over the face of it. The tufa has no riffle terraces. Its surface has been flaked by ice action.

A yellow-green algae is present in small quantities in the stream channels on the tufa.

GEOLOGY : Outcrop exposed near the tufa is a flat lying arkosic sediment poorly cemented with carbonate with an intercalation of a metasedimentary pebble conglomerate with a hard reddish brown matrix. It is quite similar to the conglomerate exposed at Mountain 1 and Ekwi. North of the pool, on the south side of Cache Creek, is an exposure of finely banded limestone which strikes 290° and dips 70-80° S.

Aitken and Cook (1974) place Mountain 3 in the Mid Devonian Hume Formation in a tight syncline-anticline system trending NW-SE.

16 NORTH REDSTONE

MAX. TEMP : 9^{o} C
SAMPLES : 16-1,-2,-3 (unfiltered)
16-R1

NTS : Wrigley L. (95 M)
COORDINATES : 63^{o} 43'; 126^{o} 25'
ELEVATION : 2500' (760 m)
ACCESS : Helicopter
DATE : 30 July, 1976

Over a distance of 800 m there are four seeps emerging from the base of an overburden covered slope about a kilometer north of the North Redstone R. 15 km southwest of Wrigley L.

The water is clear and tastes very bitter with a hint of salt. Combined flow is at most a few l/s. There is a small amount of green/brown algae well away from the vents. Vegetation has been inhibited in three elongate zones in an area 40 m downslope by 100 m across slope.

Spring deposits (16-R1) consist of small nodular white carbonate crystals on pebbles near the vents and small accumulations of porous flakey tufa in and around outwash pebbles well removed from the vent.

GEOLOGY : There is no local outcrop. Float is dolomite and quartzite. The spring rises from undivided Mid to Lower Devonian dolomites of the Arnica and Sombre Fms (Gabrielse et al. 1973) They are exposed on an anticline trending 330^{o} and plunging northerly. The North Redstone Thrust Fault, dipping steeply east, passes 2 km to the east while to the west is the southern end of the Nainlin Thrust Fault and the northern extension (?) of the Rouge Thrust Fault.

17 GRIZZLY BEAR

MAX. TEMP : 44.5° C
SAMPLES : 17-1,-2,-3
17-R1

NTS : Glacier Lk. (95L)
COORDINATES : 62° 40'; 127° 55'
ELEVATION : 4000' (1220 m)
ACCESS : Helicopter
DATE : 31 July, 1976

The Grizzly Bear spring is a series of four pools, one below another, lying about 15 m up on the southern bank of a juvenile drainage about three and a half kilometers west of the western margin of Grizzly Bear Lake. The active spring and outwash zone is roughly 40 m x 80 m and is devoid of trees although partially covered with grasses.

The water is clear and bubbles into the top pool. There is no H2S odour. Green algae grows in the waters. Flow is about 20 l/s.

The top pool is about 3 m in diameter and is sunk less than a meter into the old porous tufa (17-R1) surrounding it. This pool drains under the tufa into two small, slightly lower, irregularly shaped pools. The water then flows over a partially riffled tufa mound with small terraces and in part fills a fourth lower pool. The flow then wanders to the creek over an area of calcareous muck. There is a band of old tufa, now vegetation covered, to the south and west of the upper pool. On the south east margin of the spring area is a cold seep.

GEOLOGY : Local float is dolomite and well rounded quartzite. The spring is underlain by the Sunblood Formation, a Mid Ordovician limestone and dolomite unit (Gabrielse et al., 1973), exposed on the eastern limb of the Grizzly Bear Anticline. To the west several kilometers is the north westerly trending Broken Skull Fault. To the east is the similarly trending, west dipping Grizzly Bear Thrust Fault which defines the western margin of the Redstone Plateau.

18 NAHANNI HEADWATER

MAX. TEMP : 64^{o} C
SAMPLES : 18-1,-2,-2 (unfiltered)
18-R1

NTS : Nahanni (105 I)
COORDINATES : 62^{o} 49'; 128^{o} 50'
ELEVATION : 4500' (1370 m)
ACCESS : Helicopter
DATE : 31 July, 1976

Nahanni Headwater consists of three major vents flowing from and down granite boulder trains on a steep slope above a creek draining east and then southwest into the South Nahanni R. The boulder trains are clear of vegetation and are readily visible from the air. The northern most spring was sampled. To the south about 20 m is the second vent. Some 400 m further south separated by bush is the third vent.

The water is clear. There is a slight odour of H2S. Green, orange and cream to buff algae is growing in the outwash. The flow of the northern vent is less that 20 l/s. The system flow could be 60 l/s.

There is no tufa accumulation merely a white encrustation (non calcareous) on boulders in the outwash (18-R1).

GEOLOGY : The springs issue from a Cretaceous granite which intrudes a Devonian-Mississippian clastic (unit 10, Green et al., 1968). The mountain is capped with a rusty, horizontally layered meta-sediment.

19 ATLIN

MAX. TEMP : 29° C
SAMPLES : 19-1,-2,-3
19-R1

NTS : Atlin (104N)
COORDINATES : 59° 24'; 133° 35'
ELEVATION : 2500' (760 m)
ACCESS : Road
DATE : 3 August, 1976

The spring rises from the side of a hill about a kilometer south and east of Warm Bay on Atlin Lake. A small bathing pool has been dug and is used casually.

The water is clear, has no odour although there are gas bubbles rising sporadically from the pool. Watercress is ubiquitous and green algae grows in the outflow, not in the pool. Flow from the pool is about 20 l/s.

The outflow area is large, about 100 m x 300 m. The outflow is both channeled and diffused and produces small accumulations of tufa (19-R1) and widespread areas of calcareous ooze/mud. There are some terraces where the water flows over a 6 m drop.

To the north and west of the sampled vent, across the road, above Warm Bay near an old homestead is a similar spring (T=29° C, flow about 20 l/s). A kilometer and a half further south along the road towards the O'Donnel River is "The Grotto", a large volume spring (T=9°C) emerging from limestone. The creek draining "The Grotto" is rumoured to have a few warm springs near its mouth on Atlin Lake.

GEOLOGY : The Atlin spring is in overburden overlying a limestone member of the Late Paleozoic Cache Creek Group. The Nahlin Fault, a northwesterly striking feature, passes nearby to the west.

20 MORIN NORTH

MAX. TEMP : 9.5° C
SAMPLES : 20-1,-2,-3
20-R1

NTS : Skagway (104M)
COORDINATES : 59° 59'; 134° 13'
ELEVATION : 2200' (670 m)
ACCESS : Float plane, boat
DATE : 6 August, 1976

Morin North is the northernmost of a series of at least 6 cool seeps and springs spread along four miles of the western shore of Tagish Lake from northeast of Mt. Morin, to opposite Talaha Bay. The peak of Mt. Cloutier lies on a bearing of 150° from the spring which rises into a 5 m diameter pool about 15 m above lake level.

The water is clear and odourless. Small gas bubbles rise constantly in the pool with a larger accumulation from time to time. Grey-green and grey-white algae are floating on the pool which is surrounded by trees and low plants. Flow is of the order of 25 l/s. The water flows into the lake along a channel lined with a porous tufa covered with moss. Where the flow empties into Lake Tagish there is no tufa. About 60 m south, however, is an old tufa deposit which extends some distance up the bank. It is white and associated with a calcareous mud. It is the only feature by which one may identify the spring from the lake. Sample 20-R1 is from both old and contemporary deposits.

GEOLOGY : The spring issues from overburden underlain by a limestone unit of the Late Paleozoic Cache Creek Group (Christie, 1957; Aitken, 1959) within the vicinity of the possible northern extension of the Nahlin Fault.

21 MORIN MIDDLE

MAX. TEMP : 15° C
SAMPLES : 21-1,-2,-3
21-R1

NTS : Skagway (104M)
COORDINATES : 59° 58'; 134° 13'
ELEVATION : 2175' (663 m)
ACCESS : Boat, float plane
DATE : 6 August, 1976

Morin Middle is a series of seeps extending for 120 m along the western shore of Tagish L. The peak of Mt. Cloutier lies on a bearing of 110°. The seeps are along the base of a clay bank from 3 to 8 m above lake level.

The waters are clear but they seep into a calcareous ooze/ mud which gives them a clouded appearance. There are small amounts of a light green algae present. Grasses grow and water insects live in the smaller puddles. Locally the seeps and attendant mud discourage tree growth. Tufa does not develop around the seeps. There is a very small sheeted deposit (21-R1) at the lake's edge which would have formed as a result of a different vent configuration. Total flow is estimated at around 20 l/s.

GEOLOGY : Same as Morin North

22 JONES L.

MAX TEMP. : 13° C
SAMPLES : 22-1,-2,-3
22-R1

NTS : Atlin (104N)
COORDINATES : 59° 53'; 134° 00'
ELEVATION : 2400' (730 m)
ACCESS : Boat & foot, float plane
DATE : 7 August, 1976

The Jones L. spring rises into a 9 m diameter pool and flows some 50 0 m south into Jones L. just east of a low, prominent penninsula. A hundred metres or so north of the spring is a tote road used in winter access between Carcross and Atlin via Tagish and Atlin Lakes.

The water is clear and potable. There are bubbles rising in the pool but no H2S odour. The pool is covered with water cress, there is no algae. The water flows into a channel lined with porous tufa (22-R1) through lush sparsely treed meadow. The meadow grows on old tufa. Flow is about 45 l/s.

GEOLOGY : The spring rises in overburden. To the north in the vicinity of Mt. Minto, undifferentiated rocks, mainly volcanic of uncertain age are probably underlain by rocks of the Cache Creek Group. Both are intruded by Jurassic granitic material (Aitken, 1959).

23 MORIN SOUTH

MAX. TEMP : 17° C
SAMPLES : 23-1,-2,-3
23-R1

NTS : Skagway (104M)
COORDINATES : 59° 58'; 134° 13'
ELEVATION : 2160' (658 m)
ACCESS : Boat, float plane
DATE : 7 August, 1976

Morin South is a seep issuing from a limestone point opposite the mouth of Talaha Bay.

The water is clear and issues from soil and moss overlying rock. The seep is about 3 m in from the shore and 1.5 m above lake level. A small sheeted mound of tufa is forming above the lake surface. A thin sheet of tufa incorporating lake bottom gravel extends underwater for about 6 m. (23-R1).

GEOLOGY : The limestone is a unit of the Cache Creek Group. It is well fractured.

24 McPHERSON LAKE

MAX. TEMP : 16° C
SAMPLES : 24-1,-2-3
24-R1

NTS : Frances Lake (105H)
COORDINATES : 61° 52'; 129° 37'
ELEVATION : 2750' (840 m)
ACCESS : Float plane
DATE : 11 August, 1976

The spring rises into a 4 m diameter pool which drains westwards about 100 m into McPherson Lake at a point about 2 km north of the southern tip of the lake. The pool is surrounded by forest and the outflow stream has incised a small gully into the overburden. There is a small fan-like meadow where it debouches onto the lake. There is soil seepage for a short way on either side of this fan.

The water is clear and potable. Bubbles rise in the pool but there is no odour. The pool is choked with watercress, moss and wild mint; there is no algae.

In the lower portions of the stream disconnected 'heads' of porous tufa incorporating moss etc. are forming (24-R1). These become more frequent and connected towards the lakeshore,

GEOLOGY : To the north of the mouth of the outflow channel are several outcrops of carbonate, probably flat lying, thinly bedded, showing solution and precipitation features. One outcrop was quite well fractured. This limestone may be a member within a Cambrian or Earlier clastic unit (Unit 1, Map 6-1966, Blusson, 1966). It appears to lie on a northwesterly trending anticline. To the southeast are extensive granitic intrusions.

25 SOUTH REDSTONE

MAX TEMP : 54° C
SAMPLES : 25-1,-2,-3
25-R1, R2

NTS : Dahadinni R (95N)
COORDINATES : 63° 24'; 125° 52'
ELEVATION : 2600' (790 m)
ACCESS : Helicopter
DATE : 13 August, 1976

South Redstone lies about 1 km south of the South Redstone River on the eastern slope of the Rouge Range. There are two main vent areas about a half kilometer apart. The northern one is the most active and extensive with numerous vents and tufa deposition over an area roughly 250 m across slope and 300 meters downslope with an elevation difference, top to bottom, of about 50 m. The southern area is much smaller with one or more vents.

The warmest vent is in the centre of the northern spring area and has two cooler (20° C) flows mixing almost immediately with it. These waters flow over a portion of the tufa mound and form a series of riffled terraces in the process. The sampled vent (53° C) near the uphill forest margin of the spring areas fills a shallow 6 m x 9 m. boulder filled pool. Its outwash flows towards the northern edge of the area and produces some local riffled terraces. Six flows (40° C - 50° C) emerge near the upper margin of the zone and one large vent/pool (46°C) lies at the base of the tufa. There are numerous streams of cooler (15° C - 36° C) mixed waters.

The hot water is clear, with a slight odour that is not H2S. There are sporadic bubbles in several of the vents. System flow is of the order of 120 l/s; the vent sampled was flowing about 15 l/s. Algae in the hot running water is a dark vivid green to a light shiny bright green. On the surface of pools and where exposed to the air the algae is mustard to ochre in colour. In the cooler, mixed streams of water, the algae is buff beige.

The northern vent area is developed on a moderate to steep slope. The tufa forms a large steep-faced mound the face of which is almost a cliff with a vertical drop of about 20 m. The tufa is massive and most of it is at present dry and grey-black. Sample 25-R1 is a piece of the main deposit as well as an encrustation taken from the sampled vent.

The southern vent zone consists of one or more springs. The one visited has a temperature of 50° C, a flow of about 15 l/s and is developing a flexible, cardboard-like tufa bound up with vegetal matter 20 m or so down from the vent (25-R2).

25 SOUTH REDSTONE (Cont'd)

GEOLOGY : The south Redstone spring is within a sequence of Proterozoic to Devonian sediments on the western limb of the north-northwesterly trending Marten Syncline. The spring likely emerges from the Devonian Delorme and Camsell carbonate formations. Several kilometres to the west are the North Redstone and Rouge Faults, major northwesterly features, dipping easterly (Douglas et al., 1963).

REDSTONE JUNCTION AREA

In the canyon of the Redstone R. adjacent to the Redstone Fault are four springs. Two of these springs were sampled (Redstone Jct 1, 2) Water sample 27-1,-2,-3 was taken from the Redstone R. just upstream from Redstone Jct 1. The water is very silty. The Rapitan Group of iron rich clastics underlies much of the headwaters of the South Redstone River. The rocks in the area are the same succession exposed on the western limit of the Marten Syncline.

26 REDSTONE JCT 1

MAX. TEMP : 15° C
SAMPLES : 26-1,-2,-3
26-R1

NTS : Dahadinni R. (95N)
COORDINATES : 63° 32'; 125° 42'
ELEVATION : 1700' (518 m)
ACCESS : Helicopter
DATE : 13 August, 1976

The spring and a seep issue from shallow overburden cover on a steep slope, then fall several meters over a dolomite scarp into a semicircular series of shallow terraced pools, down a steep fan outwash and thence into swampy ground on the south bank of the Redstone R.

The water is clear and has no unpleasant taste or smell. Flow is about 23 l/s. Grass, snails and shrimp live in the terraced pools. The outwash from the pools hosts a dark green-brown fibrous algae.

The terraced pools (26-R1) (less than or equal to 0.6 m deep) form a semicircle (12 m x 20 m) at the base of the waterfall against the scarp. Overflow fans down steep sheeted tufa mass (about 20 m high). Old, broken tufa flanks the presently forming deposits.

GEOLOGY : The scarp is dolomite, part of the Proterozoic Tigonankweine Fm. or the Ordovician-Silurian Whittaker Fm. The spring is immediately east of the easterly dipping, northerly trending Redstone Fault.

28 REDSTONE JCT 2

MAX. TEMP : 8° C
SAMPLES : 28-1,-2,-3
28-R1, -R2

NTS : Dahadinni R (95N)
COORDINATES : 63° 33'; 125° 44'
ELEVATION : 1700' (520 m)
ACCESS : Helicopter
DATE : 13 August, 1976

Redstone Jct 2 comprises three small springs issuing from craggy outcrop on the north shore of the Redstone R.

The water is similar to Redstone Jct 2. The spring sampled was flowing at about 2 l/s. The other two flanking springs have a combined flow of about 2 l/s. There is dark green-brown algae in the outwash.

The tufa deposit is about 12 m x 30 m and is developed as a domed cap (28-R1) on a jutting outcrop. It is layered and hollow in places. To the east of the sampled vent is a perched deposit of glacial granite boulders well cemented with tufa. 28-R2 is a few pieces of old tufa including laminated calcite/aragonite cementing fragments of host rock.

GEOLOGY : The craggy outcrops are very well fractured silty and dolomitic limestone of either the Delorme or Whittaker Fm. A subsidiary thrust fault to the Redstone Fault lies immediately to the west.

29 NORTH CANTUNG

MAX. TEMP : 32° C
SAMPLES : 29-1,-2,-3
29-R1

NTS : Nahanni (105I)
COORDINATES : 62° 07'; 128°25'
ELEVATION : 4250' (1295 m)
ACCESS : Helicopter
DATE : 14 August 1976

North Cantung is an area of seepage of thermal waters, some 200 m in diameter lying about 400 m south of the headwater of the Flat R. at the base of the northern nose of the Ragged Range. Boulders in the outwash are rimmed with a white precipitate readily visible from the air.

The waters are clear and there is no odour. Temperatures range from 12° C to 32° C. with the hottest seep being the one sampled. Orange algae grows in the outwash and wild mint is abundant. Overall flow could be about 5 l/s.

There is no tufa accumulation, merely white calcareous encrustations and crystals on boulders in the outwash (29-R1).

29 NORTH CANTUNG (Cont'd)

GEOLOGY : The seeps rise on a gentle overburden slope underlain by the Cambrian Sekwi Formation (Green et al., 1968) in a largely clastic terrane. The sediments are trending northwesterly and are dipping strongly west. The seeps are on the western limb of an anticline. To the east 10 km is an exposure of Cretaceous granite.

30 NAHANNI NORTH

MAX. TEMP :	58^{o} C
SAMPLES :	30-1,-2,-3 30-R1
NTS :	Nahanni (105I)
COORDINATES :	62^{o} 22'; 128^{o} 40'
ELEVATION :	4000' (1220 m)
ACCESS :	Helicopter
DATE :	14 August 1976

Nahanni North consists of two springs and a few seeps in a zone roughly 60 m wide and forming a noticeable outwash devoid of trees about 400 m to the east of a creek flowing north to join the South Nahanni R.

The water is clear. There is a pronounced H2S odour in the vent area. The two vents were 56^{o} C and 58^{o} C in temperature. The latter was sampled. There are several cool streams from the forest just above the vent area. Dark to yellow green and orange to rusty algae grows in the outwash. Wild mint, ferns and flowers abound. The vent sampled flows at approximately 15 l/s; total flow is about 40 l/s.

There is a white calcareous encrustation (30-R1) on boulders in the outwash and a small tufa accumulation (6 m x 20 m) several meters below the hottest vent.

GEOLOGY : The springs issue from a heap of rounded granite boulders and angular to subangular fragments of schist. The spring is underlain by a Cambrian to Earlier clastic sequence (unit 2, Green et al., 1968). Up the hill to the east is the Rabbitkettle (Cambrian-Ordovician) carbonate trending northwest, dipping strongly northeasterly and in contact with an exposure of Cretaceous granite.

31 BROKEN SKULL

MAX. TEMP : 45° C
SAMPLES : 31-1,-2,-3

NTS : Nahanni (105I)
COORDINATES : 62° 45'; 128° 08'
ELEVATION : 3500' (1066 m)
ACCESS : Helicopter
DATE : 14 August 1976

The spring issues from two vents, a cooler one in a pool (9m x 18m) at the base of slope on the western bank of a creek flowing southeast into the Broken Skull R. and a hotter one at the edge of the tufa which encloses the pool.

The water in the pool is a murky grey reflecting the green-grey algal growth and mud in the bottom. There are bubbles but no odour. Temperature of the water is 38° C. The water in the main vent at the base of the pool's tufa wall is clear, 45° C with no odour. There is green algae growing in this vent which is discharging at about 25 l/s. There is no overflow from the pool.

The tufa enclosing the pool (31-R1) is built out from the base of the slope and reaches a maximum height of 2 m and forms a flat surface on top around the pool with a maximum width of about 6 m. Below is a wide, elongate shallow pool catching some of the outflow. Ultimately the outwash enters a shallow portion of the creek and forms irregularly spaced and stepped tufa terraces (31-R2).

GEOLOGY : The spring issues from overburden at the base of slope. It is probably underlain by the Mid Devonian Headless Fm, a carbonate, within a Late Paleozoic, largely carbonate suite of rocks lying to the east of the Broken Skull Fault. (Green et al., 1960) The fault is immediately to the west of the spring. There is also a northerly subsidiary fault immediately east of the spring.

32 GLACIER LAKE

MAX. TEMP : 3^{o} C
SAMPLES : 32-1,-2,-3
32-R1

NTS : Glacier Lake (95L)
COORDINATES : 62° 05'; 127° 35'
ELEVATION : 2900' (885 m)
ACCESS : Helicopter, float plane
DATE : 14 August 1976

This 'iron' spring issues from the hill above the northern shore of Glacier Lake near its western end. It forms a distinctive red stain.

The water is clear with an unpleasant iron taste. There is no algae. Flow is about 25 l/s

The deposit is a bright rust red. It is botryoidal, made of many small subhorizontal riffles. The surface is slippery. In section the deposit is formed of sheeted black layers.

GEOLOGY : The spring flows from the Road River shale which has been intruded by Cretaceous granitic rocks.

33 WILD MINT

MAX. TEMP : 29^{o} C
SAMPLES : 33-1,-2,-3

NTS : Flat River (95E)
COORDINATES : 61° 25'; 126° 35'
ELEVATION : 2500' (760m)
ACCESS : Helicopter
DATE : 15 August 1976

The Wild Mint spring rises on a gentle slope on the south side of a creek draining into the Flat R. about 11.3 km east northeast of Seaplane Lake. There are three large pools : the upper is about 75 m long by 30 m wide and 3 m deep; the middle is about 175 m long, 15 m to 40 m wide and 2 m deep; the lower is about 30 m by 12 m wide and 1.5 m deep.

The water is clear. The vent is near the hillside in the upper pool. Gas is bubbling up. There is no odour. Lush vegetation grows in the bottoms of the pools. Flow is of the order of 30 l/s.

The pools are dammed by arcuate deposits of tufa (33-R1). The outflow from the pools washes over a considerable area and forms sheets of riffled tufa before it enters the creek.

33 WILD MINT (Cont'd)

GEOLOGY : The spring is in overburden underlain by Mid Ordivician Sunblood carbonate on a northwest trending gentle anticlinal feature with limb dips varying from 25° C to 60° C. Extensive exposures of Cretaceous granite lie to the north and west (Gabrielse et al., 1973)

OTHER SPRINGS : Two other springs sampled by Gabrielse et al., (1973) on the Flat R. a few miles north of Wild Mint were not visited. The Old Pot Mineral Spring 14 km to the north was not visited due to lack of visibility.

34 RABBITKETTLE

MAX. TEMP : 21° C
SAMPLES : 34-1,-2,-3
34-R1

NTS : Flat River (95E)
COORDINATES : 61° 57'; 127° 11'
ELEVATION : 2100' (640 m)
ACCESS : Helicopter
DATE : 15 August 1976

The Rabbitkettle spring comprises three seeps on the southern bank of the Rabbitkettle R. about 2 km upstream from its junction with the S. Nahanni R. They form a broad low deposit and a spectacular flat topped,terraced mound of tufa.

The water is clear with no odour. The seep in the centre of the large terraced deposit was sampled. The pool is about 4 m in diameter, and depth is unknown. It overflows slightly down, across shallow, unknown crenulated terraces, and then over the topmost large terrace (34-R1) and down the side of the deposit. Stalactitic flowstone deposits have accumulated on the sides of the large terraces (34-R1). This main deposit is about 60 m in diameter and rises 25 m above the Rabbitkettle R. There is an orange algae in places on the outflow terraces and sparse vegetation in the pool.

The other two seeps fill small deep pools at either end of a large low mound of tufa and flow for a very short distance over small areas before dissipating. Temperatures in the two seeps is 20° C. Green and reddish algae grows in the outwash. There is some vegetation in the pools.

GEOLOGY : The spring is underlain by the Ordovician-Silurian Road River shale near its contact with the Mid-Ordovician Sunblood carbonate. Cretaceous granite has intruded these rocks to the south.

35 HOLE-IN-THE-WALL

MAX. TEMP : 47° C
SAMPLES : 35-1,-2,-3
35-R1

NTS : Flat River (95E)
COORDINATES : 61° 42'; 127° 17'
ELEVATION : 3800' (1160 m)
ACCESS : Helicopter, float plane
DATE : 15 August 1976

The spring consists of two vent areas about 300 m apart immediately west of Hole-in-the-Wall Lake. Vents and outwash do not support trees.

The western vent is 40°C and discharges at about 10 l/s. The eastern area has two vents, both 47° C and discharging about 10 l/s each. There are a few seeps and cooler surface water mixes with the outwash. The water is clear, there is no H2S odour. Green and some pale orange algae grows in the outwash.

There is no tufa accumulation, merely white encrustations, slightly calcareous, on the boulder strewn outwash zone (35-R1).

GEOLOGY : The spring rises in talus and valley fill closely underlain by a major Cretaceous granitic intrusive. A large lobe of Road River shale lies to the north and east.

36 FLAT FRUIT

MAX. TEMP : 11° C
SAMPLES : 36-1,-2,-3
36-R1, -R2

NTS :Flat River (95E)
COORDINATES : 61° 40'; 127° 35'
ELEVATION : 3000' (915 m)
ACCESS : Helicopter
DATE : 15 August 1976

The Flat Fruit spring rises about a kilometer to the south west of the Flat River at a point some 13 km northwest of the mouth of Pass Cr. It comprises two areas of tufa deposition; one, presently defunct on a steep creek - incised cut into overburden and the other, a low flat deposit, presently active, about 150 m westwards up a gentle slope. A treed area intervenes.

The water is clear and tastes effervescent reminiscent of fruit salts. Abundant gas bubbles are being discharged but there is no odour. The waters bubble up in several small 'blow-holes' in the tufa and may or may not trickle a short way before disappearing. There is a green algae with a buff calcareous skin on some of the vents. It can, in some cases, cover a red muck in the vent. There was an abnormal abundance of mosquitoes around the spring.

FLAT FRUIT (Cont'd)

The tufa deposit is raised only slightly above the surrounding level ground. Flat, round, pisolites with serrated edges (36-R1) are scattered about on the surface. There are small (up to 30 cm in diameter and 10 cm high) 'warts' (36-R1) on the surface which are hollow and contain vuggy, wavy, irregularly banded carbonate of varying colours (orange, pink, purple, green).

The deposit on the 12 m high, steeply incised creek bank downhill to the east of the active seeps is dry at present. It has small riffle terraces (subhorizontal) developed on it. A relatively fresh portion of it is a yellowish colour. Small pisolites are developed in the riffles. (36-R2).

GEOLOGY : The spring is on overburden underlain by Road River shale near its contact with the Rabbitkettle limestone formation. To the east and south are extensive exposures of Cretaceous granite. (Gabrielse et al., 1973)

OTHER SPRINGS: On the southwest side of the Flat R., 6 km northwest of Flat Fruit is a 9° C 'iron' spring which is depositing an extensive tufa from its waters anastamosing through sparse bush. The tufa, where wet, is orange, where dry, is grey to black and is terraced and riffled. The vent is apparently mobile. There is a minor chartreuse algae. Discharge rate is strong, about 40 l/s. It is on overburden underlain by Road River shales.

To the southwest, about 2 km. from the Flat River opposite the mouth of Pass Cr. is a small rusty-red lake. There is no obvious vent, however the seepage and seasonal overflow from the lake has produced a tufa with low grade terracing which in part is retaining the lake waters.

On the same side of the river, some 16 km downstream is an 'iron' spring with a red outwash. It was not visited.

37 CAESAR LAKE

MAX. TEMP : 3° C
SAMPLES : 37-1,-2,-3
37-R1

NTS : Flat River (75E)
COORDINATES : 61° 25'; 127°52'
ELEVATION : 4000' (1220 m)
ACCESS : Helicopter, float plane
DATE : 16 August 1976

The spring emerges from one vent on an east facing hillside about 2 km south of the Caesar Lakes and deposits tufa over an area roughly 70 m x 120 m.

The water is clear and not unpleasant tasting. There is spotty growth of a chartreuse algae. Flow is about 40 l/s.

The water flows for a short distance in a channel lined with chunky, porous tufa. It then spreads out over the terraces and sheeted tufa deposit (37-R1), producing an orange colour. Dry tufa is grey and black. Pisolites develope on some of the shallow, narrow terraces (37-R1). The pisolites are larger nearer the top of the deposit.

GEOLOGY : The spring rises from overburden underlain by a Hadrynian 'Grit Unit'. (Gabrielse et al., 1973)

38 COAL R.

MAX. TEMP : 13^{o} C
SAMPLES : 38-1,-2,-3
38-R1

NTS : Coal R. (95D)
COORDINATES : 60^{o} 08'; 127^{o} 25'
ELEVATION : 2500' (760 m)
ACCESS : Helicopter
DATE : 16 August 1976

The spring is on the east bank of the Coal R., rising into an elongate, shallow pool (15 m x 60 m) on a bench at the base of slope of the hills to the east. It flows about 90 m to the west and falls down through a series of narrow, deep, terraced pools to a slough at the bottom.

The water is clear and potable with no odour. There are infrequent growths of green algae but abundant watercress and moss flourish. Flow is of the order of 45 l/s.

The stream from the source pool to the terraced pools has accumulations of porous tufa along its edges integrated with forest material and moss. The terraced pools are formed on a sharp incline with a 12 - 15 m drop. They are long, narrow and arcuate in plan with crenulated rims (38-R1). They are in many cases deep with submerged 'tufa heads' and shelves. The terrace area is approximately 60 m x 15 - 25 m.

GEOLOGY : The spring issues from talus and glacial overburden overlying Silurian-Devonian limestone and dolomite unit between two northerly trending faults (Gabrielse et al., 1969).

39 LARSEN NORTH

MAX. TEMP : 53^{o} C
SAMPLES : 39-1,-2,-3
39-R1, -R2

NTS : LaBiche R. (95C)
COORDINATES : 60^{o} 12'; 125^{o} 30'
ELEVATION : 2500' (760 m)
ACCESS : Helicopter
DATE : 17 August 1976

Larsen North issues from a partially submerged gravel bar in the centre of a major tributary of Larsen Creek.

The water is clear and is generously mixed with stream waters. There are bubbles but no H2S odour. A red algae grows in the up-welling portions of the gravel and boulder bar and a green and buff (drying) algae grows around and on boulders on the margins of the vent. Flow is difficult to estimate. It could be 40 l/s.

Presently tufa is accumulating in small halos around boulders in the bar (39-R1). On the outcrop across the creek to the north is an old sheeted mound deposit (39-R2).

GEOLOGY : The outcrop is well fractured and brecciated sandstone with quartz crystals in fracture dilations. It could belong to Unit 5 (Douglas, 1959, Map 32-1959). It is adjacent to a Mid Devonian or Earlier dolomite (Unit 4) including the Nahanni Fm (limestone). The region is characterized by repetitive thrust faults trending north-south and dipping easterly.

40 LARSEN SOUTH

MAX. TEMP : 43° C
SAMPLES : 40-1,-2,-3
40-R1,-R2

NTS : La Biche River (95C)
COORDINATES : 60° 12'; 125° 30'
ELEVATION : 2500' (760 m)
ACCESS : Helicopter
DATE : 17 August 1976

Larsen South rises in a pool (7 m in diameter, 3 m deep) situated about 6 m above Larsen Creek on its south bank about a kilometer upstream from the junction with the tributary containing Larsen North.

The water is clear, gas bubbles well up from several spots on the pool floor. There is no odour. The pool bottom is covered with a green growth. The surface has a small amount of green to yellowish green algae growing on it. Flow is of the order of 20 l/s.

The spring is in the curve of an S bend in the creek and the pool, outwash zone and old sheeted mound of tufa (40-R2) cover an area roughly 40 m in diameter. The pool is presently overflowing on the downstream side of the area and producing a pale ochre tufa. The tufa retaining walls of the pool (40-R1) are about half a meter high, incorporate organic matter and are built on tufa. The outflow is contained in crenulated tufa rivulets or washes over algae covering a calcareous muck.

GEOLOGY : The spring issues from a shallow overburden. The local geology is probably similar to that of the Larsen North spring.

41 POOL CREEK

MAX. TEMP : 54.5° C
SAMPLES : 41-1,-2,-3
41-R1,-R2

NTS : La Biche River (95C)
COORDINATES : 60° 23'; 125° 32'
ELEVATION : 1600 - 1700' (490-520m)
ACCESS : Helicopter
DATE : 17 August 1976

The spring rises from the base of a steep tree covered slope and forms a small pool on the river terrace on the south bank of the Beaver River immediately downstream from the mouth of Pool Creek.

The water is clear. It flows from a small vent in a talus accumulation at about 3 l/s. The pool is covered with green algae and is crusted with buff calcareous tufa.

The surface of the pool is not very much above the level of the flat, coarsely graded, river terrace. The tufa retaining the water is very porous and almost ropey (41-R2). Outwards from the present margin of the pool are arcuate, very shallowly stepped down zones of older tufa (41-R1). The pool does not overflow to any great degree.

GEOLOGY : The talus is a granular, porous dolomite and could represent Unit 4 on Map 32-1959 (Douglas, 1959). Regional geology is the same as the Larsen North spring.

42 PORTAGE BRULE

MAX. TEMP : 48° C
SAMPLES : 42-1,-2,-3
42-R1

NTS : Rabbit River (94M)
COORDINATES : 59° 38'; 126° 57'
ELEVATION : 1600' (490 m)
ACCESS : Road & foot
DATE : 18 August 1976

Portage Brule consists of eight seeps over a distance of 260 m, on the north bank of the Liard R. about 3 km downstream from the mouth of the Coal R. They form small tufa mounds and drain directly into the Liard R.

The water is clear, without odour, there is sporadic bubbling, varying rates of flow or seeping and a variety of depositional features. Overall discharge rate is of the order of 15 l/s. The eight areas progressing upstream are listed below:

#1 A flowing seep; T=20° C; green algae with black edges and entrained bubbles of gas (air ?); red-orange calcareous ooze underneath algae; small tufa mound with small riffles; 3 - 4 m above river.

#2 Weak seeps; T=30°, 35°, 40° C; bubbles of gas; green algae with red ooze underneath; mound tufa with small riffle terraces and two small pools 1.5 x 2.5 m with 15 cm high walls.

#3 Several seeps (T=25°, 34°, 41° C) and a minor flowing seep (T=48°C (42-1,-2,-3)); bubbles of gas; green and red algae with calcareous encrustations; several shallow pools about 3 m x 4 m, 1.5 m x 4 m, 3 m x 6 m; pisolites; calcareous coatings on gas bubbles on bottom of small terraced water catchments; delicate calcareous skin on surface of pools which eventually breaks up and falls to the bottom; also riffles on the tufa mound (42-R1)

#4 Active flowing seeps; T=30°, 44° C; mounded, riffled tufa.

#5 Seep; T=35°C; green algae; orange-buff riffled tufa mound.

#6 Actively flowing seep; T=40°C; small pond covered with calcareous algae; red ooze on bottom of flow channel; largest tufa mound.

#7 Seep; T=35°C; two small ponds; well riffled tufa mound.

#8 Active seep; T=40°C; green algae with red ooze underneath; medium size tufa mound about 6 m x 9 m x less than 1.5 m thick.

GEOLOGY : The seeps are issuing directly from bedrock exposed in a narrow strip less than 30 m wide between the Liard R. and a clay scarp. The rock is a well fractured pelitic limestone of Cambro-Ordivician age (Gabrielse, 1961).

43 JARVIS CR.

MAX. TEMP : 16° C
SAMPLES : 43-1,-2,-3

NTS : Dezadeash (115A)
COORDINATES : 60° 54'; 137° 57'
ELEVATION : 2000' (610 m)
ACCESS : Road & foot
DATE : 16 September 1976

The spring is a series of small pools rising in the Jarvis Creek valley at the base of a clay and till bank. They are open in the winter.

The water is clear, has no odour, and is probably potable. The pools bubble sporadically. No flow estimate is possible. There is no algae growing in the water. There is no tufa.

GEOLOGY : The spring is near the middle of the Shakwak Trench in glacial till. The area is near the northern limit of a wedge of Dezadeash Group clastics where a major zone of reverse faulting brings them into contact with the crystalline terrane to the northeast. (Campbell et al., 1975; Eisbacher, 1976)

APPENDIX B

FORMULAE

GEOTHERMOMETERS

(After Fournier and Rowe, 1966; Fournier and Truesdell, 1973; and Fournier, personal communication)

Geothermal investigations make wide use of two chemical systems, which can be measured in a hot spring, and which have memory of the hottest temperature which the fluid may have reached in an underlying reservoir. The basic formula for the first of these, which makes use of the ratio between sodium, potassium, and calcium, is as follows:

$$T^{o}C = \frac{1647}{\log \frac{Na}{K} + \left(B \log \frac{\sqrt{Ca}}{Na}\right) + 2.24} - 273$$

Where Na, K, Ca = molality of ionic species and where the rational number B = 1/3 for equilibrium temperature above 100° C and 4/3 below 100° C.

This relationship is empirical and it is based on the equilibrium constants between the various feldspars under conditions of high pressure and temperature. Because it is a ratio, it is relatively insensitive to dilution of the hot springs by surface waters.

The second chemical thermometer is the absolute silica content, which is based on the equilibrium of the hot water with quartz. It owes its utility to the fact that upon rapid cooling, the reaction which would tend to precipitate excess silica becomes increasingly sluggish. This can lead to an excess amount of silica in meta-stable solution in the hot springs. Absolute silica content is sensitive to dilution of the thermal water by cold surface water.

The principal formula relating silica content to temperature is as follows:

$$T^{o}C = \frac{1309}{5.19 - (\log SiO2)} - 273$$

Where SiO2 = silica content in mg/litre (ppm)

EQUIVALENT WEIGHT UNITS

(excerpted from Hem, 1959, p.32)

A further refinement in units of expression may be desirable for some purposes, to help describe the composition of water and the relationships among the ions in solution. A commonly used system for expressing analyses takes into account not only the weight concentrations of ions but also the concept of chemical equivalence.

Conversion factors: Parts per million to equivalents per million.

Ion	Multiply by	Ion	Multiply by
Bicarbonate (HCO_3^-)	.01639	Magnesium (Mg^{++})	.08224
Calcium (Ca^{++})	.04990	Potassium (K^+)	.02558
Carbonate (CO_3^-)	.03333	Sodium (Na^+)	.04350
Chloride (Cl^-)	.02820	Sulfate (SO_4^{--})	.02082

Chemical equivalence may be introduced into the data by dividing each of the concentration values in parts per million or other units by the combining weight of that ion.[1] The table contains the reciprocals of the combining weights of cations and anions generally reported in water analyses. Parts per million values may be converted to "equivalents per million"(epm) by multiplying ppm by the reciprocals of combining weights of the appropriate ions.

The terms "equivalents per million" is a contraction which has been generally adopted for the sake of convenience. In more exact language, these units are "milligram equivalents per kilogram" if derived from part-per-million data, or "milligram equivalents per liter" if derived from data expressed in milligrams per liter. Equivalent weights may be computed for use with any of the systems of expression of data.

[1] Combining weight = atomic or molecular weight of ion/ionic charge.

APPENDIX C

Bibliography : Regional

Aitken, J.D.
1959: Atlin Map-Area, British Columbia; Geol. Surv. Can., Mem. 307, p.80.

Aitken, J.D., and Cook D.G.
1974: Preliminary Eduni Unedited Geological Maps Showing Bedrock Geology of the Northern Parts of Mt. Eduni (106A) and Bonnet Plume Lake (106B) map-areas, District of Mackenzie, N.W.T., Open File 221, Geol. Surv. Can. Libraries in Ottawa, Calgary, Vancouver.

Atchison, M.E.
1964: A Study of Springs and Spring Deposits in Flat River Map Area: Univ. British Columbia, B.Sc. Thesis.

Blusson, S.L.
1966: Geology, Frances Lake, Yukon Territory and District of Mackenzie; Geol. Surv. Can., Map 6-1966.

Bostock, H.S.
1936: Carmacks District, Yukon; Geol. Surv. Can., Mem 189

Bostock, H.S.
1947: Mayo, Yukon Territory; Geol. Surv. Can., Map 890A

Brandon, L.V.
1965: Groundwater Hydrology and Water Supply in the District of Mackenzie, Yukon Territory, and Adjoining Parts of British Columbia; Geol. Surv. Can., Paper 64-39.

Campbell, R.B. and Dodds C.J.
1975: Operation St. Elias, Yukon Territory; Geol. Surv. Can., P75-1, Part A pp 51-53

Christie, R.L.
1957: Bennett, Cassiar District, British Columbia; Geol. Surv. Can., Map 19-1957.

Douglas, R.J.W. and Norris, D.K.
1959: Fort Liard and La Biche Map-Areas, Northwest Territories and Yukon; Geol. Surv. Can., Paper 59-6.

Douglas, R.J.W. et al
1963: Dahadinni and Wrigley Map Areas, District of Mackenzie, N.W.T.; Geol. Surv. Can., Paper 62-33.

APPENDIX C - Cont'd

Eisbacher, G.H.
1976: Sedimentology of the Dezadeash Flysch and its Implications for Strike-Slip Faulting along the Denali Fault, Yukon Territory and Alaska; Can. Jour. of Earth Sc., Vol. 13, No. 11, Nov 1976.

Environment Canada,
1975: Canadian Normals Temperature; Vol. I-SI, Precipitation; Vol. 2-SI, 1941 - 1970

Gabrielse, H.
1961: Rabbit River Map-Area; Geol. Surv. Can., Map 2-1961

Gabrielse, H. and Blusson, S.L.
1969: Geology of Coal River Map-Area, Yukon Territory and District of Mackenzie (95D); Geol. Surv. Can. Paper 68-38.

Gabrielse, H. Blusson, S.L., and Roddick, J.A.
1973: Geology of the Flat River, Glacier Lake, And Wrigley Lake Map Areas, District of Mackenzie and Yukon Territory; Geol. Surv. Can., Mem. 366.

Green, L.H., Roddick, J.A., and Blusson, S.L.
1968: Geology, Nahanni, District of Mackenzie and Yukon Territory; Geol. Surv. Can., Map 8-1967.

Kindle, E.D.
1953: Dezadeash Map-Area, Yukon Territory; Geol. Surv. Can., Mem. 268.

Souther, J.G.
1975: Operation St. Elias, Yukon Territory, Tertiary Volcanic Rocks; Geol. Surv. Can., P.75-1, Part A, pp.63-70.

Wheeler, J.O.
1961: Whitehorse Map-Area; Geol. Surv. Can., Mem. 312.

APPENDIX D

Bibliography

Geothermal

Fournier, R.O., and Rowe, J.J.
1966: Estimation of Underground Temperatures from the Silica Content of Water from Hot Springs and Wet - Steam Wells; Am. Jour. Sci., Vol. 264, pp. 685-697.

Fournier, R.O , and Truesdell, A.H.
1973: An Empirical Na-K-Ca Geothermometer for Natural Waters; Geochemica et Cosmochemica Acta, Vol. 37. pp.1255-1275.

Fournier, R.O., Sorey, M.L., Mariner, R.H., and Truesdell, A.H.
1976: Geochemical Prediction of Aquifer Temperatures in the Geothermal System at Long Valley, California; U.S. Geol. Surv., Open File report 76-469.

Nevin, A.E., Sadlier-Brown, T.L., and Crandall, J.T.
1975: Report on Detailed Geothermal Investigation at Meager Creek; prepared on behalf of B.C. Hydro and Power Authority.

Nevin, A.E., and Stauder, J.J.
1975: Canada - Early Stages of Geothermal Investigation in British Columbia; Proceedings of the Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, May 1975, pp. 1161-1165

Souther, J.G.
1975: Geothermal Potential of Western Canada; Proceedings of the Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, May 1975.

Sproule Associates Ltd.,
1976: Report on Study of Geothermal Resources in Western Canadian Sedimentary Basins from Existing Data, Phase One, Prepared for Earth Physics Branch, Dept. of Energy Mines and Resources, March 1976.

White, D.E.
1969: Rapid Heat-Flow Surveying of Geothermal Areas, Utilizing Individual Snowfalls as Calorimeters; Jour. Geophys. Res., Vol. 74, No. 22, pp. 5191-5201.

White, D.E., Muffler, L.J.P., and Truesdell, A.H.
1971: Vapour-Dominated Hydrothermal Systems Compared with Hot-Water Systems; Economic Geology, Vol. 66 pp. 75-97.

APPENDIX D - Cont'd

Geochemical

Hem, J.D.
1959: Study and Interpretation of the Chemical Characteristics of Natural Water; U.S. Geol. Surv., Water Supply Paper 1473.

Piper, A.M.
1944: A Graphic Procedure in the Geochemical Interpretation of Water Analyses; Trans., Amer. Geophys. Union, Papers, Hydrology pp. 914-923.

Geophysical

Anderson, L.A., and Johnson, G.R.
1976: Application of the Self-Potential Method to Geothermal Exploration in Long Valley, California; Jour. Geophys. Res., Vol 81, No. 8, pp. 1527-1532.

Combs, J., and Wilt, M.
1975: Telluric Mapping, Telluric Profiling and Self-Potential Surveys of the Dunes Geothermal Anomaly, Imperial Valley, California; Proc. of the Second United Nations Symposium on the Dev. and Use of Geothermal Res., San Francisco, May 1975

Corwin, R.F.
1975: Self-Potential Exploration for Geothermal Reservoirs; Proc. of the Second United Nations Symposium on the Dev. and Use of Geothermal Resources, San Francisco, May 1975.

Meidav, T. and Tonani, F.
1975: A Critique of Geothermal Exploration Techniques; Proc. of the Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, May 1975.

Zablocki, C.S.
1975: Mapping Thermal Anomalies on an Active Volcano by the Self-Potential Method, Kilauea, Hawaii; Proc. of the Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, May 1975.

Zohdy, A.A.R., Anderson, L.A., and Muffler, L.J.P.
1973: Resistivity, Self-Potential, and Induced Polarization of a Vapor-Dominated Geothermal System; Geophysics Vol. 38, No. 6, 1973.