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An Evaluation of Geological and Geochemical Data on the

SHARP POINT HOT SPRINGS

MAQUINNA PROVINCIAL PARK

for

B.C. Ministry of Parks
South Coast Regional Office
1610 Indian River Drive
North Vancouver, B.C.
V7G 1L3

by

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dated
1 December 1988

SUMMARY

The well-known hot spring at Sharp Point is situated within Maquinna Provincial Park on the southern tip of Openit Peninsula, approximately 33 km northwest of Tofino, B.C. The mid-1970's saw a growing interest in alternative energy sources which spawned a number of investigations of the Refuge Cove area as a potential geothermal site. This report evaluates geological and hydrogeochemical data assimilated from six different studies on the springs area, and incorporates contemporary data recently obtained on behalf of the Ministry of Parks.

The region surrounding Maquinna Provincial Park is underlain by a complex sequence of metamorphic and volcanic rocks which have been subjected to both intensive plutonism and tectonism. A major north-northwesterly trending fault divides the rocks on opposite sides of Refuge Cove and probably serves as a conduit for circulating geothermal fluids. The spring issues at a temperature of 50-52°C from a steeply inclined fracture in a quartz diorite phase of the West Coast Complex. The springs flow at an estimated 5-8 L/s and bubble profusely in the immediate vicinity of the vent. The small stream draining the vent area flows 75 m westward before reaching Refuge Cove. A series of pools formed along the rocky beach are popular with hot springs visitors. A recently discovered warm spring on Mate Islands and a gas vent some 100 m off its southeast shore appear to be closely related to the hot springs.

An evaluation of numerous physical and geochemical data indicates that there has been little variation in either the chemical or physical properties of the Sharp Point hot springs since it was first documented some 90 years ago. Both temperature and estimated flow rate have remained essentially constant, and major chemical components of the spring water exhibit only minor fluctuations. A bacterial determination on the 1988 water samples identified low total and fecal coliform counts, which, while unacceptable for drinking water, fall well within acceptable standards for recreational waters.

With an increasing popularity, there will be a growing necessity to protect the natural aesthetic qualities of Maquinna Provincial Park. In order to monitor the quality of the spring water, collection of samples on a semi-annual basis is recommended. Sampling of the more popular bathing pools for the purpose of monitoring bacterial populations should also be considered. An ongoing program of semi-annual sample collection and routine geochemical and environmental analyses could probably be contracted for $2,500 to $3,500 per year.

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1.0 INTRODUCTION

1.1 Terms of Reference

At the request of the B.C. Ministry of Parks, Nevin Sadlier-Brown Goodbrand Ltd., consulting geologists and engineers (NSBG) has prepared the following report on geological and hydrogeochemical data on the Sharp Point hot springs, situated in Maquinna Provincial Park. Historic data for this report has been assimilated from a considerable volume of information assembled by NSBG during its involvement with studies on the hot springs since 1975. Contemporary data was acquired by the author during the course of a one-day site visit to the springs on 17 October 1988, in the company of Mr. Rik Simmons, of the South Coast Regional Office.

The report is intended as:

a) a brief description of the location and geology of the spring area;
b) a description of the recent field examination of the springs and the results of re-sampling conducted during the visit;
c) a compilation of existing physical and chemical data on the hot springs; and
d) an evaluation of the available data for the purpose of identifying variations or trends in any of the chemical or physical parameters.

1.2 Location and Access

Maquinna Provincial Park is situated on the southern tip of the Openit Peninsula, approximately 33 km northwest of Tofino, B.C. (Fig. 1). The well-known hot spring at Sharp Point, the southern tip of the

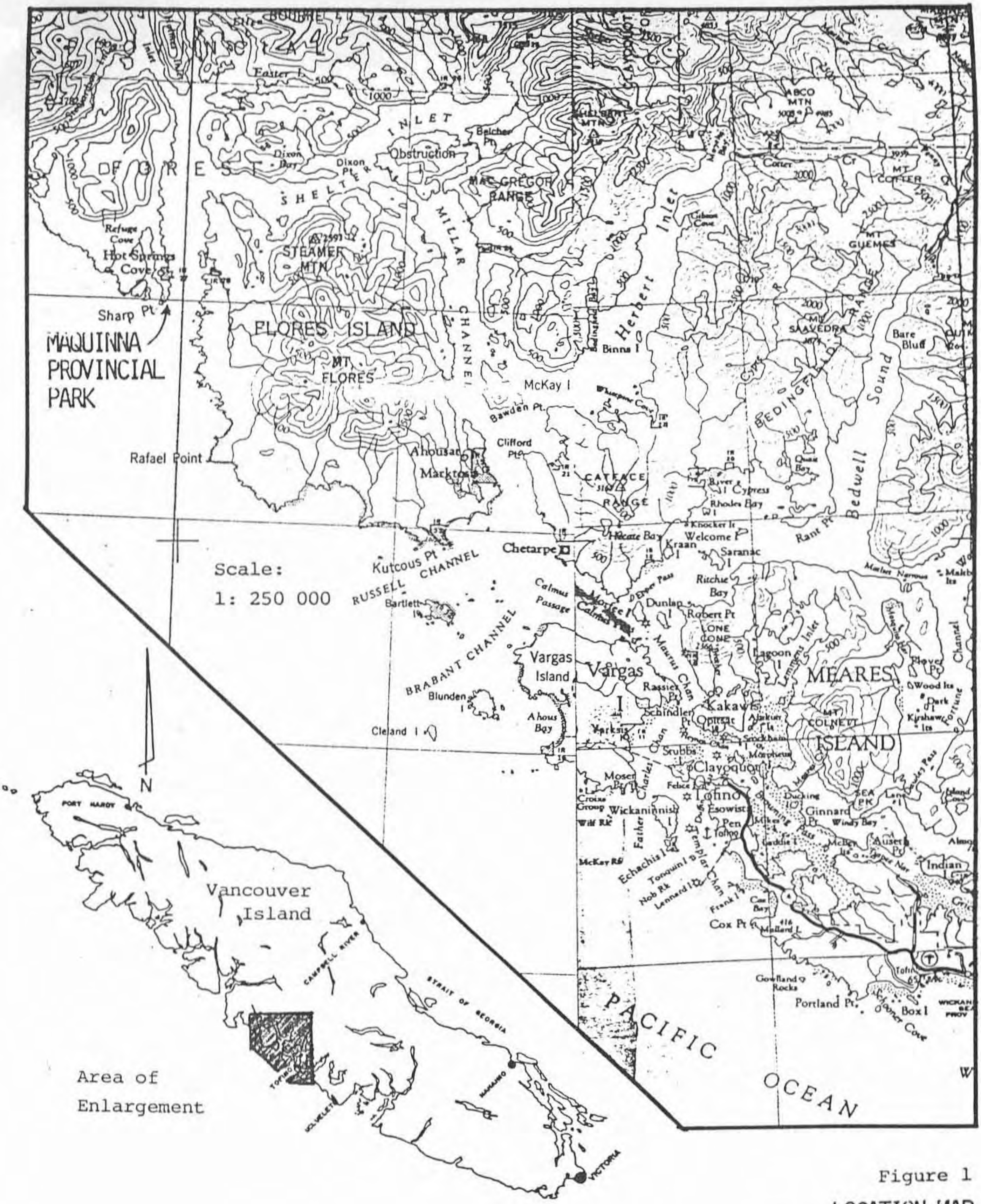
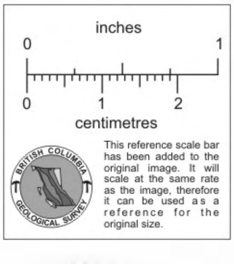


Figure 1

LOCATION MAP
Hot Springs Cove



Peninsula, is accessed by way of a 2 km hiking trail leaving the Government wharf at "Hot Springs Cove", an abandoned settlement approximately half way up the east side of Refuge Cove. The Hesquiaht Indian Band have established a community of approximately 100 residents on the west side of Refuge Cove which offers a sheltered anchorage for the numerous commercial and recreational vessels that visit the area. Because the springs are a popular destination with visitors to the West Coast, Refuge Cove has recently seen a substantial increase in tourism and, accordingly, in marine and floatplane traffic.

The Openit Peninsula area is typical of coastal Vancouver Island terrain, being characterized by irregular, rugged topography but only moderate relief. Vegetation is dense, coastal rain forest comprising thick undergrowth beneath a canopy of stunted cedar and fir. Immediately inland, however, mountainous terrain with mature coniferous forest prevails.

1.3 History and Previous Work

The Geological Survey of Canada first investigated the Sharp Point hot spring in 1898 when a water sample collected by a prospective resort developer was submitted for analysis. Clapp's (1914) investigation corroborated the earlier data, and speculated on the origins of the thermal waters. No further data were documented until the mid-1970's when interest in geothermal energy saw a province-wide evaluation of major thermal manifestations, including the springs at Sharp Point. In a discussion of the geothermal potential of western Canada, Souther (1975) included Sharp Point in an inventory of data on thermal springs in the Canadian Cordillera. At roughly the same time NSBG (1975), under contract to B.C. Hydro, conducted the preliminary investigation of geothermal resources of western Vancouver Island. The

NSBG program began with an airborne infrared scanning survey of several areas along the west coast of the island, including the Sharp Point Hot Springs, and was followed up by a field examination of both known and suspected thermal anomalies. In favour of the Meager Creek geothermal project, the Hot Springs Cove site was identified as a significant but low priority site for further investigation. NSBG conducted a second evaluation for B.C. Hydro in 1981 (NSBG, 1982) although again, the scope of this investigation was limited to an examination of the springs and its hydrogeochemical constituents. A 1984 study on the springs was conducted by NSBG in conjunction with Crippen Consultants Ltd. (Crippen/NSBG, 1985) as part of an investigation of energy conservation options for the Hesquiaht Indian Band community at Refuge Cove. In addition to further sampling of the springs, the study confirmed both the presence of a warm spring on Mate Islands, situated near the entrance to Refuge Cove, and a gas vent approximately 100 m off its southeast shore. The gas vent is postulated to be an expression of a submarine hot spring. The report's findings were sufficiently encouraging to warrant recommendations for further exploration for low-grade geothermal resources. To date, no such work has been conducted.

The most recent investigation focussed on the feasibility of development of an aquaculture facility at Refuge Cove. The report, prepared in association with Northern Thermal Aquatech (NSBG/NTA, 1986), concluded that an aquaculture facility could be viable provided that the accessibility, quality and temperature of the geothermal resource could be assured. The conceptual model of the geothermal system was further refined by analysis of the heat generating capacity of the reservoir host rocks.

2.0 GEOLOGY

2.1 Regional Setting

The region surrounding Maquinna Provincial Park is underlain by a complex sequence of metamorphic and volcanic rocks which have been subjected to both intensive plutonism and major faulting (Figure 2).

The oldest rocks are the West Coast Metamorphic Complex, comprising an assemblage of schists, amphibolites, metasediments, metavolcanics and intrusive rock, principally quartz diorite. These rocks form the peninsula west of Refuge Cove as well as the southern portion of the Openit Peninsula. They are Paleozoic to Mesozoic in age (on the order of 150-250 My [million years old]) and host all of the known geothermal manifestations in the area.

The rocks of the West Coast Complex are intruded north of Refuge Cove by Island Intrusions comprising granodiorite, quartz diorite and granite of Jurassic age (140-180 My). Both the Island Intrusions and the West Coast Complex have been intruded by an irregularly shaped pluton of Tertiary age (32-36 My) termed the Hot Springs Stock (Muller et al, 1981). The Hot Springs Stock underlies the northern part of the Openit Peninsula and the region at the head of Refuge Cove as well as a 1 km wide belt extending southwesterly to Flores Island.

A major north-northwesterly trending fault divides the rocks on opposite sides of Refuge Cove and is probably responsible for the topographic depression which created both the inlet and the valley of the creek which empties into it from the north. Numerous other distinctive fault related lineations are apparent in aerial photography of the region.

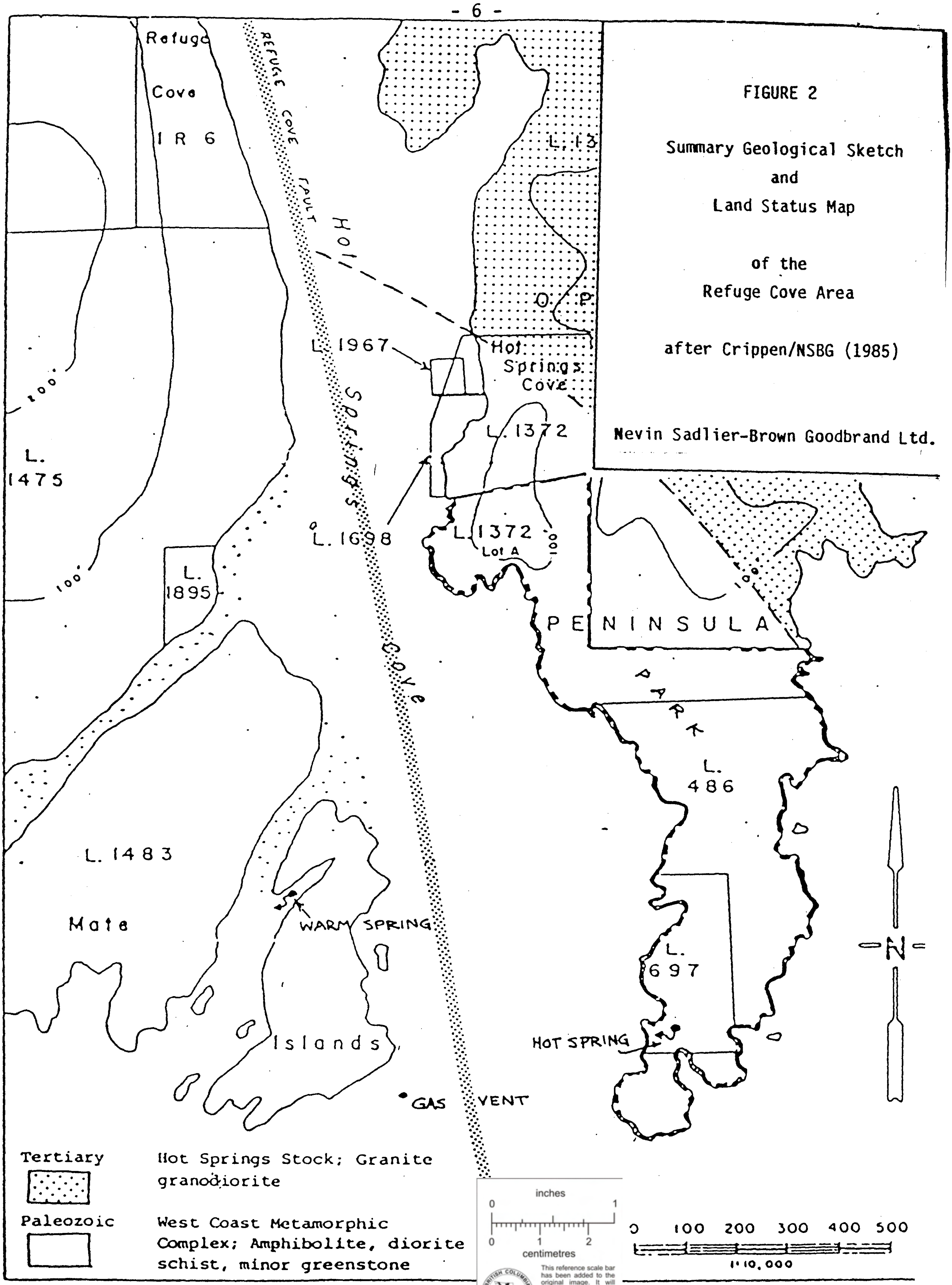


FIGURE 2

Summary Geological Sketch and Land Status Map of the Refuge Cove Area

after Crippen/NSBG (1985)

Nevin Sadlier-Brown Goodbrand Ltd.

2.2 Thermal Manifestations at Sharp Point

The Sharp Point hot spring issues at a temperature of 50-52°C from a steeply dipping to vertical fracture striking approximately 110° in a quartz diorite phase of the West Coast Complex. The water in the spring contains a considerable gas component, bubbling profusely in the vicinity of the spring vent. Periodic surges (20-40 seconds apart) resulting in markedly increased gas flow for 2-3 seconds, are observed. At an estimated 5 L/s to 8 L/s (80 gal/min to 125 gal/min), the discharge from the Sharp Point springs is among the largest in B.C. A distinct, weakly sulphurous odour pervades the immediate vicinity of the vent area.

From the vent, situated an estimated 10 m above the high tide mark, a small stream drains westward, flowing approximately 75 m towards tidewater. A fragile carbonate precipitate forms a thin white coating on rocks in the stream bed immediately below the vent, while further downstream, wispy, dark green algal growth dominates. The stream flows over a 3 m cliff before reaching a rocky beach where several natural pools popular with springs visitors are formed.

The 1975 airborne infrared survey (NSBG, 1975) identified a small but distinct thermal anomaly near the head of a small inlet on Mate Island (800 m west of Sharp Point). Subsequent follow-up surveys located a warm spring which vents at an elevation only slightly above the low low-tide level. While somewhat limited in scope, subsequent investigations have confirmed that, even while submerged, the seawater in the immediate area is at least 6°C above a 14°C ambient (October) temperature.

In addition to the two known thermal springs, Sadlier-Brown (Crippen/NSBG, 1985) also documents the occurrence of an underwater gas vent approximately 100 m off the south shore of Mate Island. Known for years by local residents and fishermen, the vent may be an expression of an underwater spring. Analyses of samples collected from both the offshore vent and Sharp Point hot spring (Table 1) indicate that the gas is virtually identical at each site, and is composed principally of nitrogen and oxygen. The gas analysis is consistent with that of an oxygen depleted air, and is interpreted to indicate a common, atmospheric, source for both the hot spring fluids and the offshore gas. (See Appendix B for further details of the hypothesized geological model).

Table 1 (from Crippen/NSBG, 1985)

Location	Nitrogen (%)	Oxygen (%)	Methane (%)	SiO_2 (ppm)	Hydrocarbons (ppm)
Sharp Point hot spring	91.73	8.13	0.14	57.8	34.8
Mate Islands gas vent	88.41	10.78	0.60	2100	73.4

The three features, namely the hot and warm springs, and the gas vent, are all hosted by rocks of the West Coast Complex and are clustered within a kilometer of one another near the projected sub-marine extension of the Refuge Cove fault.

2.3 1988 Sampling Program

Two water samples were collected during the course of a one-day site examination of the Sharp Point hot spring conducted on 17 October 1988. The first (labelled "Vent Oct 17" in Appendix A) was collected at the fissure where the springs issue from the quartz diorite; the second sample (labelled "Upper Pool") was obtained from a shallow pool immediately upstream from the small cliff (the "waterfall") approximately 40 m downstream from the vent. The temperatures of the water at the sample sites were recorded as 52.0°C and 46.0°C for the vent and the upper pool respectively. Weather conditions in the two days immediately prior to the site visit had been cool and moist, with some heavy rain, although precipitation had been slight through the earlier part of the Autumn.

The analyses of the samples (Appendix A) are virtually identical. Significant changes in the concentration of certain ions, notably carbonate/bicarbonate, silica, chloride and ammonia, are probably attributable to the decreased temperature between the sample sites and the resulting precipitation of various compounds. Little or no mixing with cool, surface runoff is apparent.

The 1988 samples were the first to have been analysed for bacterial content. Total and fecal coliform counts from the vent sample were 2 Cfu/100mL and 1 Cfu/100mL respectively, while 40 m downstream at the upper pool, the coliform counts had risen markedly (total: 10 Cfu/100mL, fecal: 3 Cfu/100mL). Although these levels exceed acceptable limits for drinking water, they remain well below the "objective levels" for "direct contact recreation" waters as set out in Federal water quality guidelines (GWQOS, 1972).

2.4 Data Compilation

Table 2 represents a compilation of data from analyses for physical parameters and major chemical constituents within water samples collected from the Sharp Point hot spring. With the recent sampling, conducted on behalf on the Ministry of Parks, a data set spanning 90 years is available.

Table 2. Compilation of Geochemical Analyses from Sharp Point Hot Spring

	Clapp (1914)	Souther (1975)	NSBG/BCH (1975)	NSBG/BCH (1981)	NSBG/DSS (1984)	NSBG/MoP (1988)
Physical Properties						
Sample date	1898	1975	1975	11/81	10/10/84	17/10/88[1]
Flow rate (L/s)	7.5	7.5	-	-	-	5 to 8[2]
Temperature (°C)	52	50.5	50.5	50.5	50.5	52.0
pH	-	8.38	-	-	6.5-7	9.0
Conductivity (μmhos)	-	-	-	-	1230	1200
Major Geochemical Constituents						
Na (mg/L) sodium	137	141.2	144	150.0	170.0	160
K (mg/L) potassium	2.0	2.0	2.1	1.50	2.0	2.0
Ca (mg/L) calcium	20	17.7	16.5	17.0	16.0	17.0
Mg (mg/L) magnesium	1.0	0.05	0.05	1.5	<0.1	<0.2
Cl (mg/L) chloride	217	206.0	224	150.0	212.0	160.0
HCO_3 (mg/L) bicarb'ate	-	22.3	32.1	21.7	7.7	4.7
CO_3 (mg/L) carbonate	-	-	-	0.5	19.6	20.4
SO_4 (mg/L) sulphate	47	36.0	28.5	33.0	29.0	29.0
NH_3 (mg/L) ammonia	-	-	-	-	0.26	0.600
SiO_2 (mg/L) silica	59	52.8	49.0	36.0	24.0	40.0
Sr (μg/L) strontium	-	10	2000[3]	-	-	170
B (mg/L) boron	-	-	20	2.20	1.20	-
F (mg/L) fluoride	-	1.32	-	11.00	1.16	-
Li (mg/L) lithium	-	0.072	-	<0.05	0.08	-
Fe (mg/L) iron	-	-	-	0.060	<0.02	<0.2
Hg (ppb) mercury	-	-	-	0.3	-	<0.1
Total Diss. Solids (mg/L)	-	-	-	-	470	485
Coliform Count						
total (Cfu/100ml)	-	-	-	-	-	2
fecal (Cfu/100ml)	-	-	-	-	-	1

\- denotes "not reported"

[1] Weather was warm and dry, 2 days following the first significant rainfall of the autumn.

[2] Visually Estimated; flow through a V-notch weir calculated at 4 L/s though significant leakage around the dam (20% to 40% of the total flow) was evident.

[3] The validity of this determination is questionable.

Since observations began at the turn of the century, both the temperature and the flow rate of the springs have remained essentially constant. Measured temperatures (between 50.5°C and 52.0°C) show the least variation of any of the spring's physical or chemical parameters, while the estimated flow rates fall consistently around 7.5 L/s (100 gal/min).

Although they exhibit a broader fluctuation than the physical characteristics, the major chemical constituents of the hot spring water are also reasonably consistent. Figure 3a depicts the trend in levels of sodium and chloride ions since 1898. While the Na concentration exhibits a modest long-term increase, Cl tends to vary between highs around 200 to 220 mg/L and lows of 150 to 160 mg/L. The cause of the chloride variation is unclear. Figure 3b depicts a very stable long-term calcium concentration, while levels of sulphate and silica each appear to be decreasing slightly. Silica in particular exhibits the most pronounced decline, although the data for 1984 are considered to be anomalously low.

It is notable that even between the two samples collected in 1975 there is significant disparity between the chemical determinations. Except for calcium, it is apparent that seasonal variations in the levels of the various chemical constituents may be more significant than the changes resulting from a long-term trend. Should ongoing monitoring of the spring hydrogeochemistry be contemplated, it would be valuable to collect samples at approximately the same time (or times) each year in order to minimize the effect of this variation.

Fig. 3a Comparison of Na and Cl
at Sharp Point Hot Springs

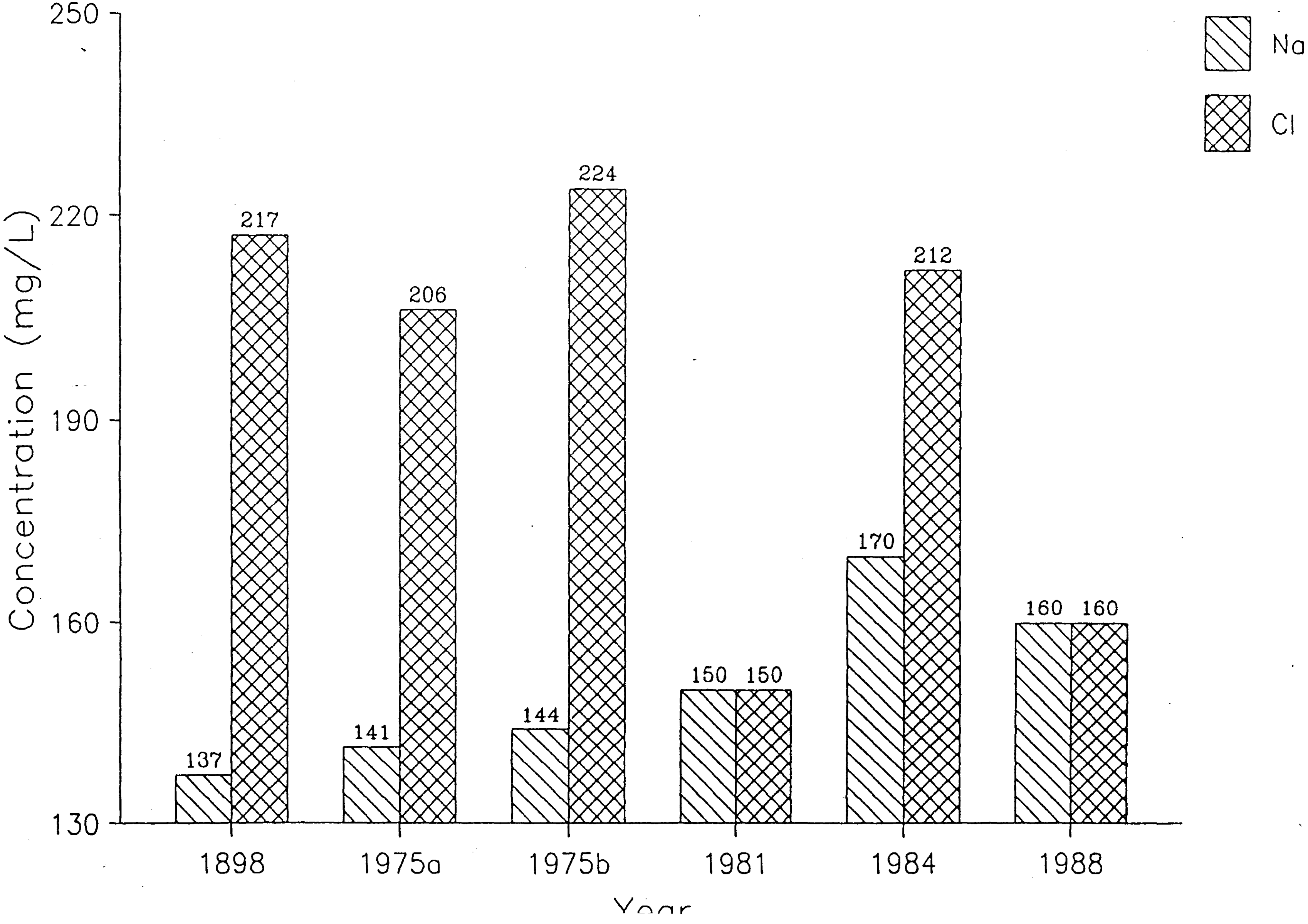
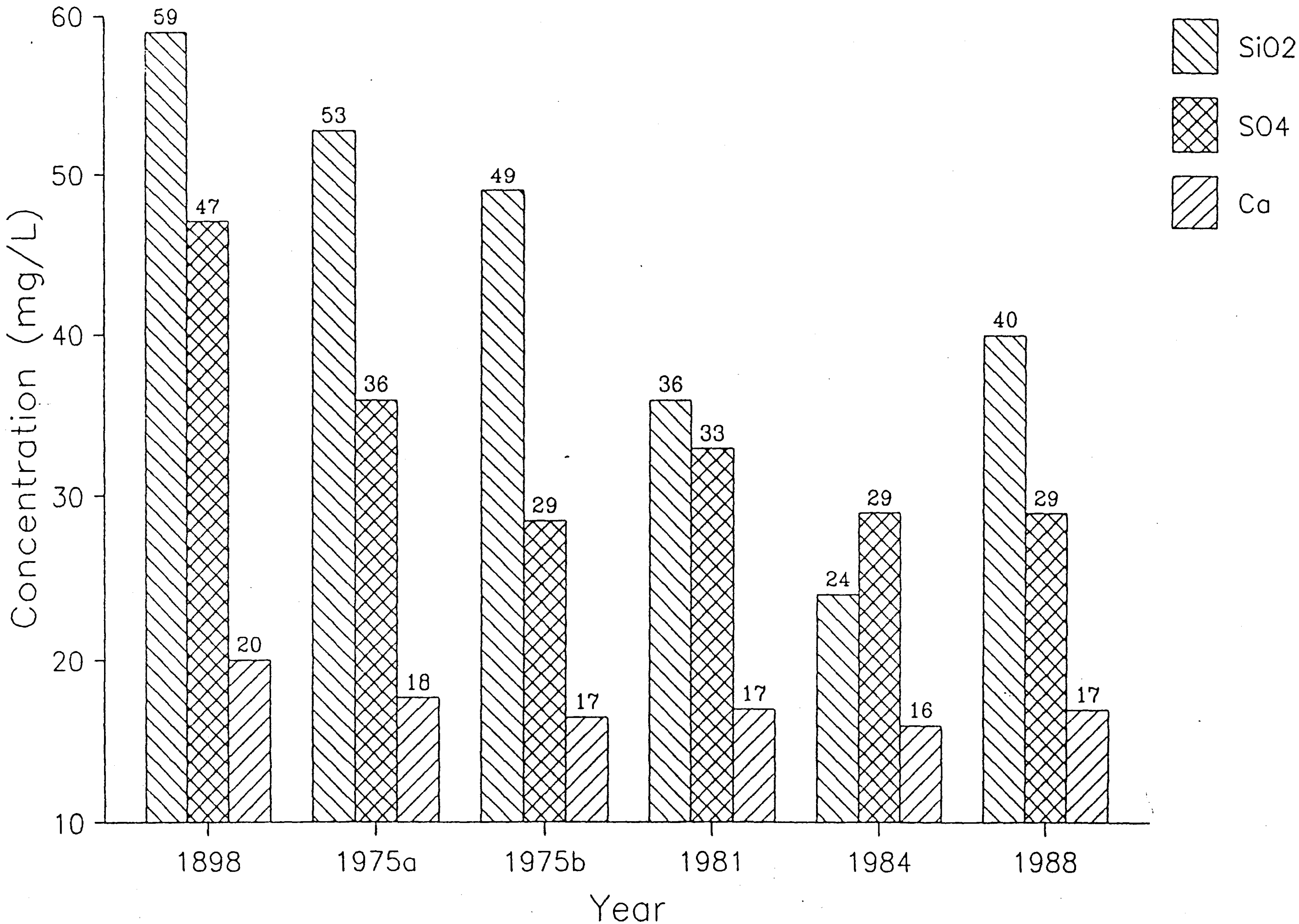


Fig. 3b Comparison of SiO2, SO4 and Ca
at Sharp Point Hot Springs



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3.0 DISCUSSION AND CONCLUSIONS

3.1 Discussion

The hot springs and the gas vent in the vicinity of Sharp Point and Mate Island all issue from fractured crystalline rocks of the West Coast Metamorphic Complex. Their relative proximity and a chemical similarity in gas samples between Sharp Point and Mate Island vents (Crippen/NSBG, 1985) suggests a common origin. Although Clapp (1914) postulated that ocean water is circulated deeply and returned to surface, evidence gathered to date favours a meteoric source for the water. NSBG/NTA (1986) proposes a geological model (see full description in Appendix B) whereby surface water is collected in one or more catchment basins situated along the trace of the Refuge Cove fault, and conducted to depth along a zone of permeability produced by the fault. The fuilds are heated, transported southward, and vented through cross-fractures and splay faults in the crystalline rocks of the West Coast Complex in the vicinity of the north tip of Mate Islands. An estimate of the heat generation capacity of the Hot Springs Stock indicates that the intrusive would be incapable of producing either an estimated reservoir temperature of 90°C to 105°C, or observed spring water temperatures of 52°C. However, because of several morphological similarities between Sharp Point hot springs and the Ahousat warm spring on Flores Island (i.e., thermal springs proximal to Tertiary granitic intrusions), the possibility that the Hot Springs Stock contributes a significant amount of heat to relatively shallow (<2 km) rocks cannot be discounted.

An evaluation of numerous physical and geochemical data indicates that there has been little variation in either the chemical or physical properties of the Sharp Point hot springs since it was first documented some 90 years ago. Temperature and estimated flow rate have remained essentially constant during the course of the past century. Analyses of the major chemical components of the spring water indicate that consistent levels in most elements, particularly calcium, are being maintained. While some components appear to have established a modest increasing (sodium) or decreasing (silica and sulphate) trend, this variation is considerably less pronounced than short term differences apparently resulting from seasonal chemical fluctuations. A larger database will be required before the causes and magnitude of seasonal hydrogeochemical variations can be ascertained.

The 1988 water samples were the first to have been subjected to bacteriological determinations. A single sample from the vent identified low total and fecal coliform counts, although the analysis suggests that the water would be unacceptable from a domestic consumption standpoint. The second sample, collected immediately above the "waterfall" exhibited a marked increase in both total and fecal coliform counts. Again, based on the single analysis, the water fails drinking water standards. Both samples, however, fall well within the acceptable bacterial standards for "recreational waters", a category probably best suited to the hot spring fluids. It would be informative to conduct coliform counts on a series of samples collected over several days in order to obtain a statistically valid profile of bacteria populations in the pools most frequented by springs visitors.

3.2 Recommendations

The "baseline study" of data collected from analyses of water samples should be continued, and should be augmented by periodic re-sampling of the springs in order to monitor the water quality, and to provide a basis for action if necessary. The sampling should be conducted semi-annually; with one sample collected during the peak-use period in mid-summer. Chemical analyses need only be conducted on water collected from the immediate vicinity of the hot springs vent. However, consideration should be given to expanding the monitoring of bacterial populations in the lower, cooler pools frequently used for bathing. Careful note of the physical parameters should also be made and periodic chemical checks should be conducted.

The study will prove to be particularly important should rumoured exploration and development of geothermal resources at Refuge Cove proceed. As noted in Crippen/NSBG (1985):

> There is evidence that the Sharp Point Hot Spring as well as the Mate Island warm spring and the gas vent offshore near Mate Island, are derived from a common reservoir. Although the size of this reservoir and its productive capability are unknown it is possible that extraction of reservoir fluid from a drillhole could affect flows at one or more of these three known natural sites. As far as exploration drilling is concerned no adverse effects are anticipated provided drilling is done in a manner which would permit the hole to be permanently sealed if required. If production from the reservoir were found to have an adverse effect on the existing flow rate at the Sharp Point Hot Spring and/or other natural vents it could be necessary to restrict fluid extraction from any well or wells to a level consistent with satisfactory sustained flow at the natural spring.

For lack of data on the inferred geothermal system, it is impossible to accurately predict the effect that drilling might have upon the flow dynamics of the Sharp Point springs. As considerable additional work is required before the size and nature of this geothermal resource at

Refuge Cove can be determined, the Parks Branch should be concerned only with the establishment and maintenance of data pertinent to the Sharp Point spring and probably of the other related naturally occurring thermal phenomena. An ongoing program of sampling involving semi-annual collection and routine geochemical and environmental analyses could probably be contracted for $2,500 to $3,500 per year.

Consideration should be given to investigation of the offshore gas vent. If indeed the vent is an expression of an underwater hot spring, it may represent a valuable, unique resource.

Of academic (and possibly economic) significance would be clarification of the "history" of the hot springs fluids. A study involving isotopic chemical analyses and hydrogeologic mapping would be well justified if a foreseeable change in the springs' flow regime is threatened. Such an evaluation of the Sharp Point Hot Springs is estimated to cost $12,000 to $15,000.

With the number of visits to the Sharp Point hot spring growing progessively, it will become increasingly important to protect the natural aesthetic qualities of Maquinna Provincial Park. As important as maintaining the integrity of the "wilderness" setting of the springs will be preservation of the quality of the spring water itself.

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APPENDIX A

<u>RESULTS OF 1988 SAMPLING</u>

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CERTIFICATE A8825800

NEVIN SADLIER-BROWN GOODBRAND LTD.
PROJECT :
P.O.# : NONE

Samples submitted to our lab in Vancouver, BC.
This report was printed on 24-OCT-88.

SAMPLE PREPARATION

CHEMEX CODE	NUMBER SAMPLES	DESCRIPTION
221	2	Water sample

* NOTE 1:

The 32 element ICP package is suitable for trace metals in soil and rock samples. Elements for which the nitric-aqua regia digestion is possibly incomplete are: Al, Ba, Be, Ca, Cr, Ga, K, La, Mg, Na, Sr, Ti, Tl, W.

ANALYTICAL PROCEDURES

CHEMEX CODE	NUMBER SAMPLES	DESCRIPTION	METHOD	DETECTION LIMIT	UPPER LIMIT
63	2	Mo ug/l: Water samples	ICP-AES	2	10000
64	2	W ug/l: Water samples	ICP-AES	20	10000
65	2	Zn ug/l: Water samples	ICP-AES	2	10000
68	2	P ug/l: Water samples	ICP-AES	20	10000
69	2	Pb ug/l: Water samples	ICP-AES	4	10000
70	2	Bi ug/l: Water samples	ICP-AES	4	10000
71	2	Cd ug/l: Water samples	ICP-AES	1	10000
72	2	Co ug/l: Water samples	ICP-AES	2	10000
73	2	Ni ug/l: Water samples	ICP-AES	2	10000
74	2	Ba ug/l: Water samples	ICP-AES	20	10000
75	2	Fe mg/l: Water samples	ICP-AES	0.2	2000
76	2	Mn ug/l: Water samples	ICP-AES	2	10000
77	2	Cr ug/l: Water samples	ICP-AES	20	10000
78	2	Mg mg/l: Water samples	ICP-AES	0.2	2000
79	2	V ug/l: Water samples	ICP-AES	2	10000
80	2	Al mg/l: Water samples	ICP-AES	0.2	2000
81	2	Be ug/l: Water samples	ICP-AES	1	10000
82	2	Ca mg/l: Water samples	ICP-AES	0.2	2000
83	2	Cu ug/l: Water samples	ICP-AES	2	10000
84	2	Ag ug/l: Water samples	ICP-AES	1	10000
85	2	Ti mg/l: Water samples	ICP-AES	0.2	2000
86	2	Sr ug/l: Water samples	ICP-AES	2	10000
87	2	Na mg/l: Water samples	ICP-AES	0.2	2000
88	2	K mg/l: Water samples	ICP-AES	0.2	2000

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Page No. : 1-A
Tot. Pages: 1
Date : 24-OCT-88
Invoice # : I-8825800
P.O. # : NONE

CERTIFICATE OF ANALYSIS A8825800

SAMPLE DESCRIPTION	PREP CODE		Mo ug/L	W ug/L	Zn ug/L	P ug/L	Pb ug/L	Bi ug/L	Cd ug/L	Co ug/L	Ni ug/L	Ba ug/L	Fe mg/L	Mn ug/L	Cr ug/L	Mg mg/L
UPPER POOL OCT17	221	--	24	40	< 2	< 20	< 4	< 4	< 1	< 2	< 2	< 20	< 0.2	< 2	< 2	0.2
VENT OCT 17	221	--	20	40	< 2	< 20	< 4	< 4	< 1	< 2	< 2	< 20	< 0.2	< 2	< 2	< 0.2

CERTIFICATION : B. Cargill

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Comments: ATTN: STUART A.S. CROFT, P. ENG.

Date : 24-OCT-88
Invoice # : I-8825800
P.O. # : NONE

CERTIFICATE OF ANALYSIS A8825800

SAMPLE DESCRIPTION	PREP CODE		V ug/L	Al mg/L	Be ug/L	Ca mg/L	Cu ug/L	Ag ug/L	Ti mg/L	Sr ug/L	Na mg/L	K mg/L
UPPER POOL OCT17	221	--	< 2	< 0.2	< 1	17.0	< 2	< 1	< 0.2	170	160	2.0
VENT OCT 17	221	--	< 2	< 0.2	< 1	17.0	< 2	< 1	< 0.2	170	160	2.0

CERTIFICATION : B. Cargill

Chemex Labs Ltd.
Analytical Chemists * Geochemists * Registered Assayers
212 BROOKSBANK AVE., NORTH VANCOUVER,
BRITISH COLUMBIA, CANADA V7J-2C1
PHONE (604) 984-0221

To: NEVIN SADLIER-BROWN GOODBRAND LTD.,

401 - 134 ABBOTT ST.
VANCOUVER, B.C.
V6B 2K4

Comments: ATTN: STUART A.S. GROFT, P. ENG.

A8825802

CERTIFICATE A8825802

NEVIN SADLIER-BROWN GOODBRAND LTD.,
PROJECT :
P.O.# : NONE

Samples submitted to our lab in Vancouver, BC.
This report was printed on 2-NOV-88.

SAMPLE PREPARATION

CHEMEX CODE	NUMBER SAMPLES	DESCRIPTION
221	2	Water sample

RECEIVED NOV - 9 1988

ANALYTICAL PROCEDURES

CHEMEX CODE	NUMBER SAMPLES	DESCRIPTION	METHOD	DETECTION LIMIT	UPPER LIMIT
688	2	Total Coliform (Cfu/100ml)	MILLIPORE	2	200000
689	2	Fecal Coliform (Cfu/100ml)	MILLIPORE	2	200000
664	2	Chloride ppm	COLORIMETRIC	0.1	100000
662	2	Sulfate/SO2/SO3 mg/l	TURBIDITY	1.00	10000
679	2	Silica mg/l SiO2	HETERO-POLY BLUE	0.2	10000
673	2	Ammonia mg/l N	NESSLERIZATION	0.001	10000
659	2	pH	POTENTIOMETER	0.1	14.0
653	2	Alkalinity mg/l CaCO3	TITRA-ACID-BASE	0.5	10000
605	2	Hg ppb: Total, H2SO4 digestion	AAS-FLAMELESS	0.1	10000
657	2	Total dissolved solids mg/l	OVEN	1	100000
682	2	Bicarbonate mg/l CaCO3	TITRA-ACID-BASE	0.5	10000
683	2	Carbonate mg/l CaCO3	TITRA-ACID-BASE	0.5	10000

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CERTIFICATE OF ANALYSIS A8825802

PARAMETER DESCRIPTIONS	SAMPLE UPPER POOL OCT17	SAMPLE VENT OCT 17								
Sample preparation code	221	221	---	---	---	---	---	---	---	---
Sample preparation code	---	---	---	---	---	---	---	---	---	---
T. Col. (Cfu/100ml)	10	2								
Fec. Col. (Cfu/100ml)	3	1								
Chloride (ppm)	120.0	160.0								
Sulphate/SO2/SO3 (mg/L)	30.0	29.0								
Silica (mg/L SiO2)	36.0	40.0								
Ammonia (mg/L N)	0.240	0.600								
pH	8.5	9.0								
Alkalinity (mg/L CaCO3)	19.0	25.1								
Hg ppb (total)	< 0.1	< 0.1								
Tot diss solids (mg/L)	489	485								
Bicarbonate (mg/L CaCO3)	10.6	4.7								
Carbonate (mg/L CaCO3)	8.4	20.4								

CERTIFICATION : [signature]

APPENDIX B

GEOLOGICAL MODEL FOR THE REFUGE COVE GEOTHERMAL SYSTEM

(Excerpted from NSBG/NTA, 1986)

In our proposed geological model, surface water at ambient temperature (5°-15°C) from a catchment area north of Hot Springs Cove enters the fault structure (which, over much of its length, is followed by stream courses) and is conducted to depths in excess of 3 km where it is heated by a normal geothermal gradient (approximately 25°C/km) to between 90-105°C. The heated fluid contains dissolved air which at high hydrostatic pressure is kept in solution even at elevated temperatures. It moves along the fault in a southerly direction through granodiorite which does not appear to sustain open fractures, then into the older, more fractured rocks of the West Coast Complex in the vicinity of the north tip of Mate Islands. The fracturing in the metavolcanics which are cut by the fault south of this point provides access for the return of the now heated fluid to the surface. Reduced near-surface pressures allow the gas to exsolve, producing strong bubbling in the Sharp Point spring and the submarine gas vent off Mate Islands, which may also be a hot spring. During its upward passage through cooler near-surface rocks, the water loses about 50% of its heat and emerges at the hot spring at a tempeature of 50.5°C flowing at about 7.5 L/s. Temperatures at the warm spring are unreliable and flow rates could not be measured because of seawater dilution at the vent which is in a tidal pool. Neither temperatures nor flow rates have been obtained at the offshore gas source.

The model does not preclude the possibility that significant heat may be derived nearer the surface from the granitic rocks of the Hot Springs Stock, where it may be produced by radioactive decay of elements such as uranium, thorium and potassium. Measurements of radioactivity in three samples of this material collected by the study team were made at the Pacific Geoscience Centre, Sidney, B.C. to test this possibility. Radioactive element concentrations were determined to be:

Sample No.	Uranium (ppm)	Thorium (ppm)	Potassium (%)
1	1.8	4.7	1.62
2	1.7	5.0	1.76
3	2.5	6.3	2.07

These values are consistent with heat production to the order of one micro-watt per cubic meter. This is not considered sufficient to account for either the estimated reservoir temperature of 90-105°C, or the observed water temperature of 50.5°C at the Sharp Point spring. The favoured model is thus deep circulation in the fault system with a zone of upwelling along a segment of the fault cutting rocks of the West Coast Complex near the entrance to the Cove.