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STUDY OF ENVIRONMENTAL ISOTOPES OF PERMAFROST RELATED
WATERS ALONG THE ALASKA HIGHWAY PIPELINE ROUTE

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Abstract

Water has been extracted from a number of cores collected by Foothills Pipelines along the Alaska Highway and has been analyzed for stable isotopes. The results to depths of 15 m indicate the waters to be isotopically similar to present ground-water in the region and it is concluded that the permafrost waters tested are young in age and hence the permafrost is post-Hypsithermal in age.

Résumé

On a extrait l'eau d'un certain nombre de carottes prélevées par la Foothills Pipelines le long de la route de l'Alaska, puis on en a analysé la teneur en isotopes stables. Les résultats obtenus jusqu'à des profondeurs de 15 m indiquent que ces eaux sont semblables, du point de vue isotopique, aux eaux souterraines actuelles de la région. L'auteur conclut que les eaux du pergélisol qui ont été analysées sont récentes et, par conséquent, que le pergélisol est postérieur à l'optimum climatique post-glaciaire.

OFFICE OF RESEARCH ADMINISTRATION
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Study of the Environmental Isotopes of Permafrost Related Waters along the Alaska Highway Pipeline Route

Contract Serial No. OSU81-00116

FINAL REPORT

Prepared for

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By

F. Michel
P. Fritz

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I

INTRODUCTION

1.1 PREVIOUS STUDIES

Initial investigations into the natural variations of stable isotopes in permafrost waters were undertaken by the authors in 1976 (W.R.I. contract #606-12). That study involved an examination of cores made available by Foothills Pipe Lines Ltd. for the Mackenzie Valley, and by Polar Gas Ltd. for their proposed pipeline route through the central Keewatin (Fritz and Michel 1977, Michel and Fritz 1978b). During the 1977-81 period, a program of laboratory experimentation was conducted in order to simulate the natural variations detected within the original cores. To supplement the laboratory work and to increase the natural data base, an extensive field program was undertaken in May of 1979 and 1980 at an experimental lake site (named Illisarvik) in the Mackenzie Delta. A total of 23 continuous cores were collected at this site from within and adjacent to the lake bed. The year by year progress of these studies has been described in a series of reports (Michel and Fritz 1978a, 1979, 1980, 1981, in press) which have been compiled and summarized by the senior author as a Ph.D thesis (Michel 1982).

1.2 TERMS OF REFERENCE

As part of the ongoing investigation of groundwater in permafrost regions of Canada, this study was undertaken in order to examine the isotope contents of permafrost water extracted from cores collected along the proposed Alaska Highway pipeline route. Specifically, the objectives of this study were:

a) to collect core material from the proposed Alaska Highway pipeline route in order to provide a better understanding of the history of these waters and their relationship to the discontinuous permafrost of the southern Yukon, and

b) to continue to quantify the effects creating the isotope variations in permafrost related waters described previously in order to permit a more detailed discussion of the formation and stability of permafrost.

1.3 SCOPE OF THIS REPORT

This report describes the work completed and presents the data acquired during the contract period. Preliminary interpretations of these data are presented in conjunction with the results of other isotope studies being conducted on active groundwater flow systems along the Alaska Highway. Finally, the report suggests a course along which further work could be pursued.

II

WORK COMPLETED

Most of the work completed during the period of this contract has involved the extraction and analysis of water from core samples collected by Foothills Pipe Lines (Yukon) Ltd. during drilling programs in 1980 and 1981. The samples examined represent material from along the entire length of the Alaska Highway within the Yukon (Figure 1). Detailed subsampling of several cores was undertaken to examine minor fluctuations in more detail. In addition, a set of 7 groundwater samples were collected by the second author during a visit to the area during July of 1981. The oxygen-18 contents of all samples have been determined. One wood sample has been radiocarbon dated to provide information on the age of the sediments examined within the borehole.

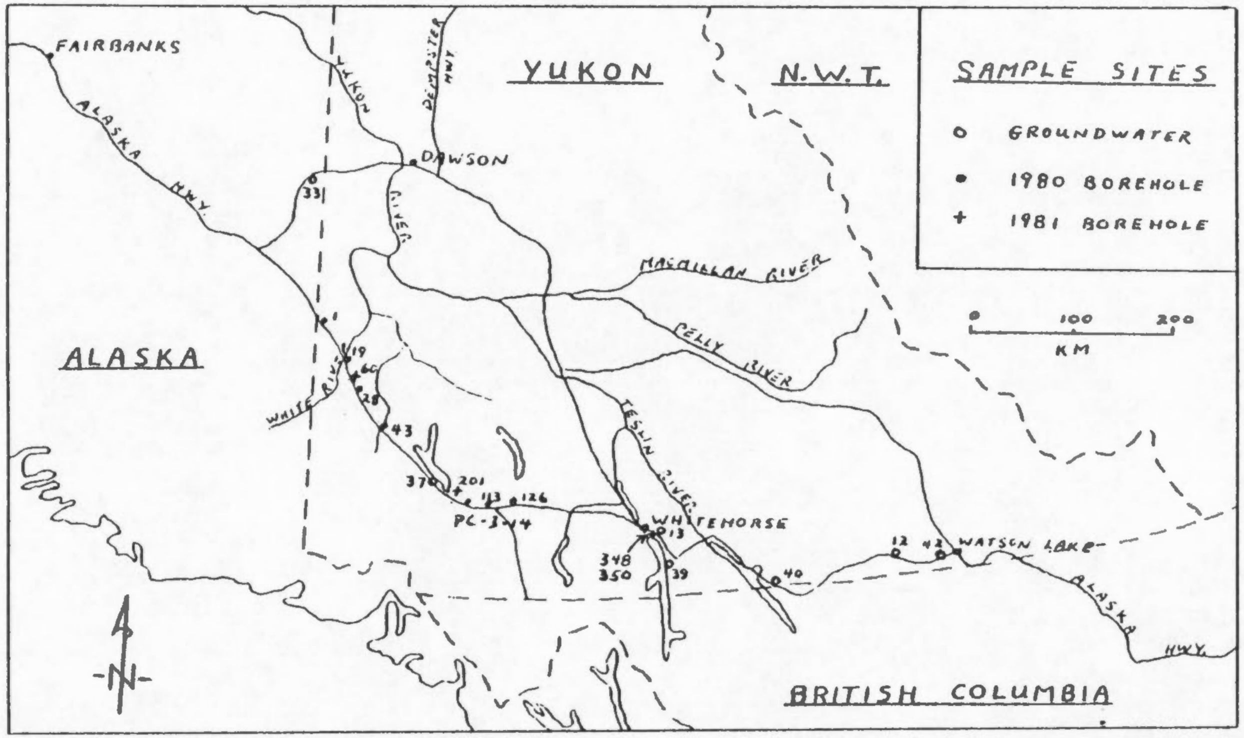

Figure 1 Location map of boreholes and groundwater sampling sites along the Alaska Highway in the Yukon.

III

DISCUSSION OF RESULTS

3.1 INTRODUCTION

The Alaska Highway pipeline route proposed by Foothills Pipe Lines (Yukon) Ltd. would closely parallel the highway along the section between Whitehorse and the Alaska border. The highway follows the base of the St. Elias Mountains which contain several of the highest mountains in Canada. The large differences in elevation result in the formation of large active groundwater flow systems which are expressed by numerous spring discharges along the entire section of highway west of Whitehorse. The elevation differences also result in the rapid accumulation of sediments in valleys subject to large volumes of snowmelt run-off in the spring.

In Figure 1, the known locations for those boreholes analysed during the current contract period are shown. In addition, the locations of groundwater samples are plotted. The proposed routing within the Yukon lies entirely within the discontinuous permafrost zone and in many ways resembles conditions in the central portion of the Mackenzie Valley. All of the isotope data are listed in Appendix A.

3.2 ISOTOPE RESULTS

Shallow groundwater samples, collected by the second author during July 1981, display a range in oxygen-18 contents from -20 to -23 ^{0}/oo. In a related study of spring discharges and icing formation along the proposed route, van Everdingen (personal communication) has determined a range of -19 to -23.5 ^{0}/oo for groundwaters collected at various times of the year over a several year period. These groundwaters include both shallow and more regional flow systems, which indicates that the range in isotope contents is probably valid for all groundwaters along the route.

The core samples examined were collected by Foothills Pipe Lines (Yukon) Ltd. during their 1980 drilling program. During a 1981 program five samples of massive ice were collected and shipped to Waterloo for analysis. In addition, the numbered portion of core PC-3-14 represents a massive ice zone. In an examination of the isotope results it can be seen that all of the samples have oxygen-18 contents in the range of -19 to -24 ^{0}/oo. If minor fractionations as a result of freezing are taken into account, this range can be considered to be the same as that of the active groundwater systems. This would suggest that the waters contained in the permafrost are of a similar age as the groundwaters in adjacent active flow systems.

The data for borehole 19 demonstrate that no variations occur in the upper 7.5 metres of permafrost which cannot be explained as a result of freezing. Although not as complete, the profile for core BH-19 is similar to the core previously studied from the Willowlake River area of the Mackenzie River (Fritz and Michel, 1977). Both localities are similar in that they are situated within the zone of discontinuous permafrost and in areas of active groundwater flow. In such situations, minor changes to the permafrost can result in alteration of the frozen zones by groundwater.

The largest shifts detected during this study were in the massive ice sections of cores PC-3-14 and 81-02-348(2). In both instances, the oxygen-18 contents shift from values of -23.6 to -23.9 $^{0}/oo$ at the top of the interval examined to -21.2 to -21.7 $^{0}/oo$ at the base. Because there is no data for the sections above or below the massive ice zones, the significance of these 2 $^{0}/oo$ shifts cannot be determined.

The remaining samples are representative of only small intervals within various boreholes. However, collectively they can still be useful in describing the lack of climatic shifts throughout the region. Even the 1981 massive ice samples, which were collected from as deep as 14 metres, do not display any isotopic variations which could be attributed to climatic changes. Therefore, it would appear that all of the permafrost sections examined to date are relatively young in age.

In an attempt to determine the maximum age of the permafrost, a sample of wood contained within the massive ice of core 81-01-060 was radiocarbon dated. The sample, taken from a depth of 9.8 to 10.0 metres, is bounded above and below by silt. Above a depth of eight metres the section is dominated by fibrous peat and organic-rich silts according to the borehole logs provided by Foothills. The radiocarbon age of the wood (Table 1) was determined to be 7510 ± 260 years. Therefore, the upper ten metres of sediment has been deposited since the area was deglaciated, and the maximum age of the permafrost can only be 7,500 years. Since the isotope contents do not indicate the preservation of any change in climate, the age of the permafrost in most likely post-Hypsithermal.

Table 1 Radiocarbon data for core 81-01-060 of the Alaska Highway pipeline route.

SAMPLE #	DEPTH (M)	$\delta^{13}C$ ($^0/oo$ PDB)	% MODERN (PMC)	^{14}C AGE (YRS. B.P.)	WAT #
81-01-060	9.8-10.0	-25.1	39.3	7510±260	904

IV

SUMMARY AND CONCLUSIONS

Radiocarbon dating has shown that sediment accumulation can be relatively rapid along the base of the St. Elias Mountains west of Whitehorse, and that the permafrost conditions existing in these sediments have formed since deglaciation of the area. Permafrost waters sampled during the current contract period are isotopically similar to groundwaters in active shallow and deep flow systems within the region. Since the preservation of climatic changes has not been detected, it is concluded that all of the permafrost waters examined are probably post-Hypsithermal in age. Any future studies of the isotope contents of permafrost waters undertaken along the Alaska Highway should concentrate on sections which are most likely to contain old permafrost. Investigations of other sections would require deep boreholes (15 metres plus) in order to encounter older permafrost.

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Appendix A

STABLE ISOTOPE DATA FOR CORES AND GROUNDWATERS FROM THE PROPOSED ALASKA HIGHWAY PIPELINE ROUTE

GROUNDWATER SAMPLES

SAMPLE NO.	LOCATION	TYPE	$\delta^{18}O$ (‰ SMOW)
12	BIG RIVER CAMPGROUND	HANDPUMP	-22.4
13	MARSH LAKE CAMPGROUND	HANDPUMP	-22.7
33	WALKER FORK CAMPGROUND	HANDPUMP	-20.0
37	KLUANE LAKE CAMPGROUND	HANDPUMP	-23.1
39	TAGISH LAKE CAMPGROUND (50 M. FROM LAKE)	HANDPUMP	-18.4
40	MORLEY RIVER CAMPGROUND	HANDPUMP	-21.7
42	GAS STATION AT CASSIAR INTERSECTION	WELL (80 FT)	-20.5

PIPELINE CORES

CORE NO.	SAMPLE NO.	DEPTH (M)	$\delta^{18}C$ ($^{0}/_{oo}$SMOW)
1980-BH-1		2.35-2.5	-20.7
1980-BH-1		3.95-4.1	-21.6
1980-BH-19		2.6 -2.75	-21.9
1980-BH-19		3.5 -3.6	-22.2
1980-BH-19		7.25-7.3	-21.4
1980-BH-19		7.3 -7.4	-21.9/-21.4
1980-BH-28		5.35-5.5	-22.0
1980-BH-43		3.15-3.35	-21.9
PC-1		1.0 -1.15	-22.6
PC-3-14	A	3.0 -3.1	-22.8
	B	3.1 -3.2	-23.6
	C	3.2 -3.25	-23.3
	D	3.25-3.3	-23.9
	E	3.3 -3.35	-23.3/-23.3
	0	3.35-3.4	-23.0
	1	3.4 -3.45	-23.0
	2	3.45-3.5	-23.0/-22.9
	3	3.5 -3.55	-23.2
	4	3.55-3.6	-22.8
	5	3.6 -3.65	-22.5
	6	3.65-3.7	-22.0
	7	3.7 -3.75	-21.9
	8	3.75-3.8	-21.7

CORE NO.	SAMPLE NO.	DEPTH (M)	$\delta^{18}O$ (‰/SMOW)
80-01-113	SOIL	2.1 -2.25	-21.1
80-01-113	ICE	2.25-2.35	-21.0
80-01-126		4.65-4.85	-20.4
80-01-126		4.85-5.05	-19.6
81-01-060	A	9.8 -10.0	-21.1
	B	"	-21.4
	C	"	-21.2
	D	"	-20.8
	E	"	-21.1
	F	"	-20.8
	G	"	-21.1/-21.3
81-01-201	A	13.9 -14.1	-20.8
	B	"	-22.1
	C	"	-22.1
	D	"	-22.2
81-02-348(2)	A	6.0 -6.2	-23.5/-23.6
	B	"	-23.3
	C	"	-22.8
	D	"	-22.7
	F	"	-21.2
81-02-348(3)	A	2.4 -2.5	-21.8
	B	"	-20.9
	C	"	-21.5
	D	"	-20.8
81-02-350(4)	A	2.7	-19.3
	B	"	-20.1