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**SCHEFFERVILLE PERMAFROST RESEARCH
VOLUME I: PARTS 1a AND 1b
SUMMARY, REVIEW AND RECOMMENDATIONS
AND
CATALOGUE OF AVAILABLE MATERIALS**

**H.B. Granberg, J.E. Lewis, T.R. Moore
P. Steer and R.K. Wright
Department of Geography
McGill University
Montreal, Quebec
H3A 2K6**

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Abstract

The report forms a part of an attempt to collect, collate and synthesize the information on permafrost in the Schefferville area deriving from 25 years of open-pit mining by the Iron Ore Company of Canada and from research projects conducted by the McGill Sub-Arctic Research Laboratory. The Open-File here contains Volume I, the summary, review and catalogue of materials available currently in the total collection comprising 25 volumes. The remaining material will be made available in microfiche form to potential research users.

Résumé

Une tentative de recueillir, d'examiner et de synthétiser les données sur le pergélisol dans la région de Schefferville est en cours. Ces données proviennent de 25 années d'exploitation à ciel ouvert par la compagnie Iron Ore du Canada et des projets de recherche effectuée par le Laboratoire de recherche subarctique de McGill. Ce dossier-public, Volume I, contient le résumé, la révision et la liste des documents et données maintenant disponibles dans le recueil qui, à date, comprend 25 volumes. Le reste du matériel sera disponible, sur microfiche, aux usagers potentiels.

EXECUTIVE SUMMARY

The past quarter century has seen a wide variety of permafrost related research projects in the Schefferville area. Open pit mining of iron ore and problems encountered in the extraction process has provided the general stimulus for most of the research which has been performed by researchers from both the Iron Ore Company of Canada and from the McGill Subarctic Research Station at Schefferville. In addition to papers and other publications a large number of notes and unpublished reports have been produced and a considerable body of knowledge has been created.

The purpose of the project reported here is to collate and synthesize permafrost information from the Schefferville area, to produce in computer compatible form thermocable data and other permafrost data, to evaluate the state of the art of permafrost research at Schefferville and to suggest possible avenues for future research.

This report delivers the assembled information, largely as outlined in the contract. However, recommendations are made for annotation of permafrost prediction maps, error checking and assembly of complementary geological and terrain information in order to maximize the usefulness of the permafrost data file.

The conclusion drawn is that, although the Iron Ore Company of Canada have closed their Schefferville operations, the Schefferville area remains quite viable for permafrost research. A shift in emphasis is needed to accommodate the change in available logistics support. Modelling of ground thermal regime, both temporally and spatially, detailed studies of the influence of snow, vegetation, microclimate and near surface groundwater movement on the upper boundary condition and studies of palsa dynamics and other permafrost-related surface phenomena are still feasible. A sufficient number of thermocables still exist to warrant a regular observation program in the Schefferville area. Iron Ore Company operations at Labrador City and Strange Lake may also offer opportunities for programs involving deep thermocable observations.

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PART 1a

SUMMARY, REVIEW AND RECOMMENDATIONS

1. INTRODUCTION

1.1 BACKGROUND

Permafrost poses a wide variety of problems to mining operations. Research on different aspects of permafrost has therefore been encouraged by the Iron Ore Company of Canada (IOCC) since the start of its Schefferville operations in 1954. At that same time, McGill University established the McGill Sub-Arctic Research Laboratory at Schefferville. The rather unique research opportunity presented by the IOCC mining operations in an area of discontinuous permafrost, coupled with the presence of the McGill Research Station has over the years led to a large number of permafrost related investigations which have been reported in the literature. It has also led to the gradual accumulation of permafrost related information in the files of both the IOCC and McGill and in the files of individual researchers.

In 1982 the present group started a project, the aim of which was to gather and collate as much of the existing permafrost information as possible and to put thermocable data and active layer depth information from trenching operations into computer retrievable form. The purpose of the project was to facilitate access to the data for scientific research and to ensure that valuable information was not accidentally lost through fire or neglect. The second purpose was to assess the current status of permafrost research at Schefferville as a necessary first step towards a revival of such research.

The project was quite timely as the old files from the McGill Station had just been archived, facilitating retrieval. The project was also timely in that the IOCC decided, shortly after the submission of the proposal, to close its Schefferville mining operations. This necessitated moving of some files to other locations, making future retrieval of permafrost data more difficult.

1.2 CONTENTS OF REPORT

In this final report of the project, the following items are delivered:

1. A catalogue of materials useful in research on permafrost in the Schefferville area.
2. A compilation of thermocable data on Computer Compatible Tape (CCT) and in hardcopy,

transformed to SI units with both UTM and IOCC references. The current status of cables and wells has been assessed and location maps provided.

3. A compilation of ground ice observations from trenching operations, available both on CCT and in hardcopy. The data has been transformed to SI units with IOCC references and location maps. Utility programs are given on the CCT which translate the IOCC reference to UTM reference.
4. A photocopied set of Theses, Reports, Papers, Memoranda and Inter-Departmental Correspondence dealing directly with permafrost in the Schefferville area.
5. A set of maps containing permafrost predictions made by various means by different researchers.
6. An evaluation of the current state-of-the-art of permafrost research at Schefferville.
7. Recommendations for further permafrost research at Schefferville.

A complete compilation of ground temperature observations made in various pits was unfortunately not possible. Some of this information has, however, been included with the IOCC internal reports. Thermistor calibrations for some of the thermocables have not been located. The resistance readings from these cables have not been included in the present report but may be included in the data set at a later date should the calibrations become available.

1.3 ORGANISATION OF THE REPORT

The report is divided into six parts comprising twenty-five separately bound volumes, a slide set and a Computer Compatible Tape (CCT). Parts 1a and 1b are bound together to form Volume I. Part 1a is the written report, entitled Summary, Review and Recommendations. The written report includes a brief review of permafrost research in the Schefferville area, a brief description of methods of collation and presentation of the material and a set of recommendations for future research. Part 1b is a catalogue of available materials, i.e. materials submitted with the final report. This includes a bibliography of Schefferville-related permafrost publications, internal reports, theses and memoranda as well as summaries of the temperature and trenching data files and a listing of the permafrost prediction maps. Also included is a listing of information which is relevant to permafrost research at Schefferville but which has not been included in the report. Volume I, Appendix 1 contains Location Maps for Schefferville area place names and IOCC Base Lines and maps with IOCC and UTM grids and an IOCC map index. Appendix 1 also contains a table of Base Line Coordinates.

Part 2 of the report, which contains reproduced literature, is divided into three sections. Volumes II to VI (Part 2a) is a photocopied set of journal articles, theses and published reports. Some of the theses and major reports form separate volumes. Other literature has been arranged in alphabetical order. Volumes VII to XIII (Part 2b) contain Unpublished Reports and Typescripts. Volume XIV contains Memoranda and Inter-Departmental Correspondance.

Part 3 encompasses three volumes which contain the hardcopy printout of the thermocable data. Volume XV contains data from the Barney, Ferriman, and Fleming 3 deposits. Volume XVI contains data from the Fleming 7, Howse, Knox, and Timmins 1 and 3 deposits. Volume XVII contains the data from the Timmins 4,6, and 7 deposits. The thermocables are listed in Part 1b and in the table of contents at the beginning of each volume.

Part 4 contains all trenching observations bound in seven separate volumes (Volumes XVIII through XXIV). A listing of the deposits included appears in Part 1b and in the table of contents at the beginning of each volume.

Part 5 contains a slide set of the permafrost prediction maps (Volume XXV) and Part 6 is a CCT. The maps are grouped alphabetically according to deposit name or area name and are, as far as has been possible, arranged chronologically. The tape contains all Schefferville thermocable data and a large amount of active layer depth soundings from IOCC trenching and test-pitting operations. The tape also contains a utility program which performs coordinate conversions between the IOCC base line offset coordinate systems and the UTM grid.

1.4 INTRODUCTION TO THE SCHEFFERVILLE AREA

The Schefferville area has been described by several of the papers, theses and reports included in Volumes II to XIV. Further description here is therefore not necessary. Attention is drawn, however, to the location maps for place names and base lines (Appendix 1). Attention is also drawn to three bibliographies (McGill University, 1966; Adams et al, 1974 and Granberg, 1978), which give a full account of research in the Schefferville area until about 1978. Climate summaries for the area have been published by Tout (1964) and Barr and Wright (1981).

2. PERMAFROST RESEARCH AT SCHEFFERVILLE

2.1 INTRODUCTION

During the construction of the railroad from Sept-Iles to Knob Lake (now Schefferville), it became evident that permafrost would be one of the environmental factors influencing mining operations in the Schefferville area (Pryer, 1966). Permafrost research started in 1955 with a joint IOCC and National Research Council of Canada (NRC) program in the Ferriman area and continued as a joint IOCC-McGill project with technical advice from the Division of Building Research of the NRC until the mid-1960's. Reports on results from these studies are given by Bonnlander and Major-Marothy (1957, 1964), Annersten (1961; 1962a; 1963; 1964; 1966) and Ives (1960a; b; c; 1961; 1962).

In 1967, as IOCC operations moved to the Fleming and Timmins deposit areas, a permafrost research site was established at the Timmins 4 deposit (Thom, 1969a; b; 1970a; b; Thom and Granberg, 1970; Granberg and Thom, 1970; Granberg, 1971; 1972a; b; 1973) and studies of permafrost and associated problems in mining operations were initiated in the Timmins 1 pit (Hulan, 1970; Collier, et al., 1970; Garg and Granberg, 1971a; b). A program for application of geophysical techniques in permafrost delineation was launched at this time (Garg, 1971a; b; c; Garg et al, 1971; Seguin, 1967; 1970; 1971a; b; 1974) after some early experiments in the Ferriman area (Annersten, 1962b). A special NRC grant "for the study of environmental factors influencing the distribution of permafrost and for the development of methods to predict the three-dimensional geometry" further spurred research on permafrost into the mid-70's. Results from this project and associated projects have been reported by, for example, Nicholson and Granberg (1973), Nicholson (1975; 1978a; b; c), Jones (1976), Nicholson and Lewis (1976), Lewis (1977), Wright (1980) and Granberg (1981).

Throughout the years, permafrost research at Schefferville has been guided by three main questions:

1. Where is permafrost likely to be encountered?
2. How does/will permafrost affect mining operations?
3. What can be done to alleviate permafrost problems?

However, some research has also been directed towards the effects permafrost and periglacial processes have on landscape evolution (Gardner, 1964; Williams, 1962; Petch, 1974), on the evolution of local soils (Nicholson, 1973) and on runoff generation (Wright, 1980). Palsa (Carlson, in progress) and patterned ground features (Thorn, 1970;

Nicholson, 1976b) have also received some attention.

2.2 RESEARCH ON THE SPATIAL DISTRIBUTION OF PERMAFROST

2.2.1 APPROACHES

Different approaches have been taken towards evaluating the spatial distribution of permafrost. First, direct measurements of ground temperatures by thermocables have been used.

A second method has been to project downwards the ground temperature field using a variety of index methods to estimate the spatial variations in surface energy balance that define the upper boundary condition. These projections have then been compared to the actual ground temperatures measured by thermocables and adjusted accordingly.

A third approach has been to obtain a three-dimensional delineation of permafrost by measuring differences between the physical properties of the ground in its frozen and unfrozen states. In particular, differences in electrical resistivity and seismic velocity have been exploited. The different methods, often used in combination, have given useful results.

Predictions have been made on three different scales to satisfy different needs:

- i) Regional scale for long-term planning and for use in the planning of exploration drilling and trenching. Mainly snow, vegetation and topography have been used as predictors.
- ii) Deposit scale for pit planning, using snow, vegetation, topography, seismic and resistivity surveys and thermocables.
- iii) Lift-by-lift predictions for planning of pit operations, particularly blasting, using the aforementioned tools plus detailed observations of permafrost conditions experienced in the previous lift, including temperature measurements in blast drill holes and in the pit floor and rock moisture information from routine ore sampling.

The result of all the different attempts to delineate the distribution of permafrost is a fairly detailed picture of the character of the permafrost distribution in the Schefferville area, which is richly illustrated by the map

collection in Part 5 of this report.

2.2.2 GROUND TEMPERATURE VARIATIONS

A complex ground temperature field results from the spatial and temporal variations in both surface and sub-surface energy fluxes. At the surface the temperature field fluctuates in response to spatial and temporal variations in the surface energy balance. The fluctuations are attenuated with depth, however, such that a few metres below the surface only the annual temperature wave and the thermal pulses due to groundwater movement can be detected. At even greater depths, only the long term surface energy balance, groundwater movement and geothermal heat flow control the thermal field.

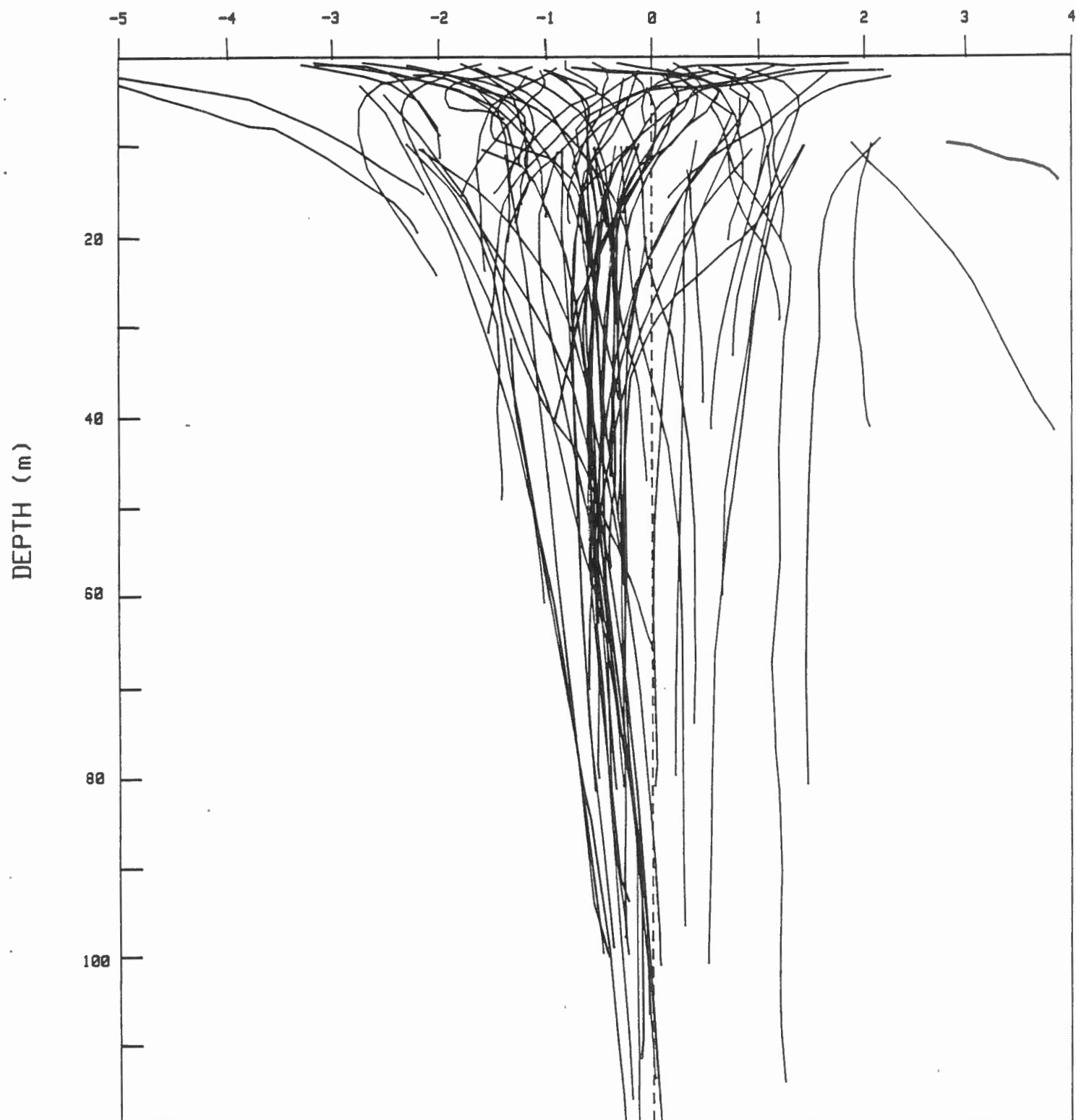
Similarly, the spatial variations in ground temperature decrease with depth, mainly as a result of lateral heat flow. At the surface, the dispersion reflects, though not perfectly, the spatial variations in the surface energy balance. A multi-scale spatial variation in the surface energy balance is demonstrated by observed temperature profiles (Annersten, 1964b; Nicholson and Thom, 1973; Nicholson, 1978c). Anomalies in the surface energy balance project downwards according to their amplitude and surficial extent. Consideration of this multi-scale variation is necessary in the interpretation of thermocable information (Granberg, 1971; 1972b; Nicholson and Granberg, 1973).

2.2.2.1 THERMOCABLE MEASUREMENTS

The most important tool for determining ground temperature variations at Schefferville has been the thermocable. Three different types of thermocables have been employed. Until 1971, thermocouple cables were used exclusively. The method of manufacture and installation is described by Bonnländer and Major-Marothy (1957; 1964). To make the temperature measurements a portable Honeywell potentiometer has been used, which under ideal conditions gives an accuracy of 0.1 °C but which under actual field conditions may be considerably less accurate (Granberg, 1972b).

After an unsuccessful attempt in 1969, the first successful installation of thermistor cables at Schefferville was made at the Timmins Dyke, Fleming 3 and Timmins 4 in 1971 (Granberg, 1971). Since then, thermistors have been used almost exclusively. Initially, Yellow Springs Instruments (YSI) epoxy bead thermistors, factory calibrated to an accuracy of 0.1 °C were used. Subsequently, Fenwal glass probe thermistors were employed. Both types

MEAN TEMPERATURE (°C)



were calibrated to an accuracy of better than 0.01°C (using calibration facilities made available by the Heat Flow Group of the Earth Physics Branch of Energy Mines and Resources). In later years Fenwal Uni-Curve thermistors, factory calibrated to an accuracy better than 0.1°C , have been used by the IOCC in their thermocable installations.

Standard 50-conductor telephone cable has been used for most of the thermistor cable installations. The cable is slit at the desired level and a thermistor is soldered onto two free conductors. The slit is filled with silicone caulking compound, with the thermistor embedded in the silicone. Vulcanising rubber tape is tightly wound over the slit and its immediate surroundings. This is followed by several layers of tightly wound vinyl tape.

Initially, a simple Wheatstone bridge was used for the thermistor resistance measurements. A precision Wheatstone bridge (Jessop, 1968) was used from 1972 to about 1975. Since then a less accurate but more convenient Data Precision Digital VOM has been used for most readings, giving an accuracy of about 0.1 or 0.05°C , according to determinations by Nicholson, (pers. comm.) and Wright (1981), respectively.

Following well-logging experiments in the Timmins pit in 1971 (Garg, 1971), a large number of thermal wells (anti-freeze filled plastic pipes of approximately 30 mm inner diameter) were installed at the Timmins 3 and Fleming 7 deposits. Nicholson (1978c, Appendix 2) gives a full description of the well-logging method.

2.2.2.2 THERMOCABLE LOCATION BIAS

There is a recognised bias in the thermocable data from Schefferville, namely that most of the cables have been installed in areas where permafrost was suspected. The cables have also been installed in available exploration or tonnage drill holes, which means that they usually have been installed in the Sokoman (iron) and Ruth formations. Since these formations are fairly competent, they tend to form the convex terrain elements that accumulate less snow in winter. The sample of ground temperatures given by the thermocable data is therefore heavily biased towards the colder part of the regional distribution of ground temperatures. The plot of mean annual ground temperatures (Fig. 1) illustrates this bias. The few cables that are situated in low-lying or concave parts of the terrain exhibit much warmer

temperatures than the rest of the cables.

2.2.3 PREDICTING THE GROUND TEMPERATURE FIELD FROM VEGETATION AND SNOW COVER

Because thermocable measurements are limited by cost factors, a variety of indirect methods have been used to make inferences about the ground temperature field. Vegetation, which in the Schefferville region responds sharply to spatial variations in microclimate, has often been used as an indicator of the upper boundary condition (e.g. Bonnlander and Major-Marothy, 1957; 1964; Garg et al., 1973). Snow cover, indicative of spatial variations in winter insulation has also been used for this purpose. At first, the snowcover was mapped by depth-probing (Roy, 1963; Barnett, 1963), but this method was impractical because the large areas to be mapped required excessive field work. A method was later devised for mapping late winter snowcover using aerial photographs taken sequentially during the melt period in conjunction with snow depth measurements at control sites (Granberg and Thom, 1970; Granberg, 1972a; 1973). This method allows a fairly accurate assessment of snowcover conditions over large areas and has been applied on a large scale for the mine areas (Nicholson, 1975; 1978b; Jones, 1976). A second method using a digital terrain model to predict the snowcover distribution at different times of winter was developed by Granberg (1972a; 1973) and is currently being refined.

Neither snow cover nor vegetation patterns by themselves or in combination provide a very reliable indication of the spatial variations in the surface energy balance. Good correlations have been observed between late-winter snow depth and ground temperature distributions (Nicholson and Granberg, 1973) but despite modelling efforts by, for example, Goodrich (1976) and detailed snow temperature studies by Granberg (1981) the role of the snowcover in the surface energy balance is only partially understood. The same is valid for vegetation. Although a variety of studies at Schefferville indicate that vegetation is important, the detailed nature of the interaction has yet to be demonstrated. A comprehensive study of spatial variations in surface energy balance is needed at Schefferville to provide a better understanding of the upper boundary condition.

2.2.4 INFLUENCE OF MOVING WATER

In the near-surface layers of the ground considerable transfers of heat occur as a result of water movement (Granberg, 1972b; Jones, 1976; Nicholson and Lewis, 1976; Lewis, 1977b; Wright, 1981; 1983). Seasonal variations in the amount and temperature of water flowing in talik

zones cause such zones to be surrounded by a seasonally thawing and refreezing "active layer" as is probably observed at, for example, thermocable number 5 at Timmins 4.

When mine pits are excavated, the changed hydraulic gradient causes streams of water flowing into the pit to incise deeply into the bedrock by melting of ice layers in the bedrock (Garg and Granberg, 1971a). Even relatively minor flows of water through a dyke made of rock chips will prevent permafrost from forming, as demonstrated by thermocable measurements in the Timmins Dyke (Lemelin and Garg, 1972; Jones, 1973). The Howse deposit was believed to be more than half in permafrost according to predictions based on snowcover and vegetation analysis (Garg et al., 1973). However, thermocable information indicates that most of the deposit is unfrozen. The probable reason for the discrepancy is that the overburden on the Howse deposit is highly permeable sands and gravels instead of the relatively impermeable glacial till prevalent elsewhere. This allows a heat gain by warm water infiltration during summer that outweighs the effects of shallow snow accumulation in winter.

An interesting hypothesis has been advanced by Seguin (1973a; 1977), who noted that the water table approximately coincides with the base of permafrost in the Timmins area. He therefore suggested that lateral transfers of heat by water movements at the groundwater table contribute to control the depth of permafrost in the Schefferville area.

For prediction of the spatial distribution of permafrost both Jones (1976) and Nicholson (1978a) found significant improvements in the predictive equations when terms were added to account for the effects of near-surface groundwater flow. The terms added were a distance term accounting for the distance of a point from a "wetline" and a term to account for the upslope drainage area for the particular wetline. However, the complex problems of active layer development and heat transfer by moving water are not well understood and both should be studied further.

2.2.5 THERMAL PROPERTIES

The thermal properties of the bedrock and overburden and their hydraulic permeabilities have, given their importance to permafrost distribution, received remarkably little attention. Only a few laboratory determinations of thermal conductivities of Schefferville rocks exist (Yap, 1972; Judge, pers. comm. to Nicholson, 1974, included in Jones, 1976 and appended to Nicholson, 1978c). Some efforts have been made to determine thermal diffusivities using thermocable information (Annersten, 1964; Granberg, 1972b).

Knowledge of the thermal and hydraulic properties of the bedrock and overburden needs to be substantially improved before highly accurate permafrost predictions can be achieved with thermal methods.

The lower boundary condition is not known for the Schefferville area. Granberg (1972b) adopted a geothermal gradient of $7.2^{\circ}\text{C}/\text{km}$ based on analysis of Timmins 4 thermocable data while Nicholson (1978b) gives an estimate of $7.3^{\circ}\text{C}/\text{km}$. Both estimates are influenced by the aforementioned bias due to selective positioning of thermocables in the area. The local terrestrial heat flow is unknown since no deep-hole temperature and thermal conductivity information is yet available for the Schefferville area.

2.2.6 TEMPORAL VARIATIONS IN THE GROUND TEMPERATURE FIELD

Inherent in the downward projection of the thermal field from a given upper boundary condition is the assumption that the thermal field is in balance with current climatic conditions. This assumption is not necessarily valid at Schefferville. While the permafrost distribution in the near-surface layers relates well to the present climatic conditions (Nicholson and Granberg, 1973), several occurrences of thick, deep-lying ice lenses, observed in both drill cores and mine pits, may be the result of an earlier, more severe climate. Such observations, some of which constitute the deepest known occurrences of permafrost in the area, have been made at the 122 m depth in Rowe Mine and at 91 metres below the surface in Gagnon Mine (Seguin, 1974a). The origin of these thick ice lenses is not currently understood. At Carol Lake, 200 km south of Schefferville, excerpts from drill records indicate the occurrence of ice at depths of 180, 140, 131, 112 and 104 meters in five different locations (Garg, 1972b).

There is also some evidence of recent change in surficial permafrost features in the Schefferville area. A field survey during the summer of 1982 by the McGill Terrain Analysis Group showed that recently there has been a substantial decay of palsa in the area. Palsa fields evident in air photos taken in 1949 have in some cases been reduced to 15-20% of their former extent. Many smaller palsa fields have disappeared completely since 1949. These changes may or may not be the result of the cyclic nature of palsa development (Seppala, 1982).

Local changes in the surface energy balance occur as a result of forest fires and changes in surface drainage by trenching operations. Granberg (1972b) in an analysis of Timmins 4 thermocable data found indications of a recent warming that may have been caused by increased snow

accumulation around the schacks that were installed at each thermocable head to facilitate measurements during adverse winter conditions.

A special case of temporal variations in the ground temperature field is the development of permafrost in treat-rock dumps where low-grade ore has been stockpiled for future use. In 1970 it was discovered that permafrost had developed in several dumps near Schefferville (Petch, 1970). Further investigations revealed that in the Wishart Dump and the Retty Stockpile a cap of permafrost 10 to 15 metres deep had formed (Garg, 1972a; Collins, 1972; Lewis, 1977a). The cap at Wishart had a high moisture content near the top, with a decline in moisture content downwards (Nicholson, 1976b). This would indicate that the permafrost is climatically induced and not caused by winter dumping. The top surface of a dump is kept relatively snow-free throughout the winter and experiences considerable heat loss. Instead of, as planned, simply loading the stockpiled treat-rock into ore cars for shipment, the ore had to be retrieved by a bulldozer intermittently scraping off the thawed surface layer (Lewis, 1977a; Nicholson, 1974).

Similar, though less severe problems with the freezing of stockpiles have been encountered at Sept Iles. Some use has been made of snow fences to reduce winter heat loss (Garg, 1974). The geometry of the stockpiles, however, makes it difficult to efficiently catch the snow.

2.2.7 GEOPHYSICAL METHODS

A variety of geophysical techniques have been used for the delineation of permafrost in the Schefferville area. Since comprehensive summaries of the state of the art in this field are given by Seguin (1974a; b; c; 1977a; b;), Seguin and Garg (1973) and Garg (1970; 1973; 1974; 1976a; b; 1978b) in Volumes II to XIV of this report, the present discussion will only briefly touch upon some of the factors influencing the applicability of the geophysical methods in the Schefferville area.

2.2.7.1 VARIABILITY IN ROCK PROPERTIES

Other conditions being equal, both dielectric properties and seismic velocities differ between frozen and unfrozen materials. The magnitude of the difference shows correlation with rock type (Seguin, 1974a). These differences can be used to make inferences about the presence or absence of permafrost. However, there is a great variability in both seismic velocities and electrical properties both within and between rock types at Schefferville which makes the delineation of the permafrost

boundary difficult, particularly if the detailed stratigraphy is not known.

An early laboratory study by Bacon (1957) showed that the shift in electrical resistivity does not necessarily coincide with the freezing point. In one sample, the increase in resistivity started at $+6^{\circ}\text{C}$ and in other samples at $+3^{\circ}\text{C}$ or less. These findings, if correct, are important to the application of resistivity techniques to permafrost delineation. The anomalous results are presumed to have been caused by experimental error but no follow-up study has been made to check if this is indeed the case.

2.2.7.2 FREEZING POINT DEPRESSIONS

The question of freezing point depression is an important one to permafrost delineation by geophysical techniques. A variety of estimates exist for the area, usually without documentation of the rock type for which the estimate was made. Nicholson and Thom (1973) found no significant freezing point depression while Nicholson (1978a) reports a freezing point depression to -0.02 to -0.03°C , as shown by the zero curtain effect during the autumnal freeze-back of the active layer. In a frequency analysis of weekly temperature readings at cable number 7 on Timmins 4 Granberg (1972b) found that the temperature class recorded with the greatest frequency at the uppermost sensing levels was -0.11°C to -0.06°C . This agrees quite well with more recent thermistor cable measurements by Wright (1981), who found zero curtain temperatures ranging from -0.03 to -0.08°C with an estimated accuracy of $\pm 0.03^{\circ}\text{C}$.

The sparse information available on freezing-point depressions in Schefferville rocks indicates that freezing-point depressions are relatively small. However, all of these determinations have been made within the active layer, where conditions may differ considerably from the conditions in the deeper layers of permafrost. Analysis of resistivity survey data by Seguin (1973) suggests that there may be layers of unfrozen rock sandwiched between layers of frozen rock in the lower strata of the permafrost. It is possible that freezing-point depressions may exist which are considerably greater than those found in the active layer.

During studies of blast response in the Timmins pit in 1971 and 1972 one of the authors (Granberg) repeatedly observed "cracking rocks". Fine-grained rocks would begin to break up into smaller chunks immediately after a blast as a result of ice needles growing in hairline cracks in the rock. Since the ambient air temperature was well above freezing, this observed ice growth implies the presence of supercooled water in the rock. The phenomenon, while

familiar to local miners, is not well understood. The ice growth could be caused either by pressure release or change in capillary tension or both. The degree of supercooling is, unfortunately, unknown.

2.3 PERMAFROST INVESTIGATIONS IN OPERATING MINES

2.3.1 INTRODUCTION

A considerable effort has been made to document, analyse and alleviate the problems caused by permafrost during the different stages of mining operations. Detailed accounts of research on mining problems are given by Ives (1962), Lang (1966), Garg and Stacey (1972), Garg (1974; 1979a; b; 1982) and Nicholson (1978b) and many of the IOCC Internal Reports and Memoranda and Inter-Departmental Correspondence give details of these problems. A complete survey of the research by the IOCC on mining problems caused by permafrost was, unfortunately, not possible. The following therefore deals only briefly with some aspects of the research that has been conducted.

2.3.2 PIT TEMPERATURE OBSERVATIONS

In the summers of 1970 and 1971 a program was developed for routine, lift-by-lift monitoring of permafrost-related factors likely to influence mining on subsequent lifts (Collier et al, 1970; Garg and Granberg, 1971a; b). Among the factors monitored were temperatures at the bottom of blast drill holes and pit floor temperatures. Blast performance was monitored both by photographs of the blast sequence and by photographs of the blast debris. The spatial distribution of Rock moisture content was obtained from routine ore-grade sampling of blasthole drill chippings.

Special probes were developed both for the blast hole temperature monitoring and for the pit floor temperature measurements. For the blast holes, a thermistor, shielded by a polystyrene foam disc was used. Generally, thermal disturbance by the drill was too great to make it possible to obtain accurate estimates of the undisturbed temperatures. A set of readings was obtained at fixed time intervals and the changes in temperature were used to obtain an estimate of whether or not permafrost was present.

For the pit floor measurements, a thermistor probe with a short time constant was developed. The probe was usually inserted to a depth of about 0.7 meters or more using a drill rod and a sledge hammer. While the measurements were subject to errors of a variety of kinds, they could usually

detect the presence of permafrost with good accuracy, mainly because of the thermal buffering which occurs at 0°C in the usually moisture-rich bedrock. Samples of permafrost delineations using pit floor temperature measurements are given by Garg and Granberg (1971a) and by maps in Part 5.

2.3.3 PERMAFROST HYDROLOGY STUDIES

During excavation of the Timmins 1 pit considerable hydrologic problems were encountered, partly as a result of melting of permafrost but also as a result of the greatly reduced permeability of permafrost (Garg and Granberg, 1971a;b;). The runoff from three small drainage basins, together smaller than the pit itself, was entering the pit at its south end. The associated flows of water would, in a pit free of permafrost, be of no consequence. However, because of the frozen state of the ground, the water added by the streams kept the active layer on the impermeable pit floor water saturated, making vehicle traffic difficult. Attempts to alleviate the problem by periodically scraping the pit floor had several adverse effects. First, it maintained a shallow active layer, thus narrowing the conduit for the water which was slowly making its way along a gentle slope towards the north. Secondly, the shallow active layer increased the rate of thawing of the ice-rich permafrost below, releasing more water and maintaining a saturated condition. Thirdly, the scraping caused topographic depressions to form in which water collected.

Unsuccessful attempts were made to intercept the small streams before they entered the pit. The streams had melted their way down through ice along bedding planes and at this stage, two years after the pit was opened, flowed through narrow conduits several tens of metres below the original ground surface and were not easily found by drilling. Nor was it at this stage possible to trap them by re-freezing the near-surface layers of the ground.

An interesting attempt was made to create a "permafrost dam" by constructing a low dyke using waste rock materials (Lemelin and Garg, 1972). The idea was to encourage permafrost development by creating a snow-free area with high winter heat loss. Unfortunately, the waste rock materials used in the construction formed a dyke of very high permeability, which allowed considerable heat transfer by moving water penetrating parts of the dyke at its base during summer. This prevented permafrost from forming beneath the crucial portions of the dyke. However, on the south side of the pit, where no appreciable amounts of water flowed, the dyke, according to temperature measurements at specially installed thermocables (Jones, 1973), did have the desired effect.

Caving of blast holes occurs when a water-saturated active layer overlies the permafrost. When a hole is drilled, a hydraulic gradient is created which allows water to drain into the hole. This causes undercutting and, in some cases, melting at the base of the active layer and causes gradual slumping of materials into the hole. Ultimately, the hole is filled with mud and water and a characteristic conical depression is formed at the surface.

The hydrologic studies led to the recommendations that before a pit in permafrost is opened the pit hydrology should be very carefully planned and pumped wells and sumps should be installed prior to the start of excavation (Jones, 1975b). The pit floor on each lift should be gradually sloping towards a sump or natural outlet. Shallow drainage ditches should be constructed in the pit to minimize water retention by the pit floor. A summary of IOCC's mine de-watering experience is given by Garg (1979a).

2.4 PERMAFROST AMELIORATION

Permafrost, with the high rock moisture contents prevailing at Schefferville, renders mining more expensive (at least four times more expensive according to unofficial estimates) than mining of unfrozen rock. It is therefore natural that ideas about how to remove existing permafrost are generated.

Thom (1970b) suggested a variety of amelioration methods based on literature on earlier experiments in the Soviet Union. The suggestions included the use of snow fences, artificial reduction of surface albedo, modification of surface drainage and inhibition of the latent heat flux using bitumen or plastic film. Later experiments by Nicholson (1976a) showed some of the methods to be impractical or ineffective.

Nicholson's experimental results showed that a substantial thermal amelioration can be achieved, at least initially, by using snow fences to retain a deep accumulation of snow on areas normally swept free of snow by the wind. One of the problems with this method, however, is that the returns diminish as time progresses. It can be shown theoretically that it would take decades to remove permafrost from just one lift (about 12m) by this method. Unfortunately, the Permafrost Amelioration Site at Timmins 4 was destroyed by stripping in 1982.

3. METHODS OF COMPILATION OF MATERIALS

3.1 CATALOGUE OF AVAILABLE MATERIALS

The catalogue of available materials is divided into five sections. Section one is a bibliography of relevant publications, reports, and related documents pertaining to permafrost in the Schefferville area. This is split into three sub-sections consisting of:

- i) Journal articles, conference proceedings, theses and published reports,
- ii) Unpublished reports and typescripts and
- iii) Memoranda, Inter-Departmental Notes and Correspondance both within and between the IOCC and the McGill Sub-Arctic Research Laboratory.

Section two comprises a listing of available thermocable data which appears on CCT and in hardcopy. The listing includes the assigned file name, the IOCC cable number, the first and last dates that the cable was read, the number of observations, the maximum depth and the present status of the cable.

Section three is a listing of all trenching data which appears on CCT and in hardcopy. The listing includes the IOCC deposit code (usually the file name), the deposit name and the years in which trenching observations were carried out.

Section four is a listing of all permafrost prediction maps included with the final report. These are catalogued according to deposit name or mine area and include a brief descriptive title and the date of the prediction (if known).

The final section of the catalogue is a list of other available information. This includes related information which is not included in the final report but which may be made available by IOCC or McGill University.

3.2. LOCATION MAPS

The location maps appended to this Volume (Appendix I) show place names and the location of base lines. Map overlays giving the IOCC Grid Reference System and the UTM system and a map of the IOCC Map Sheet system are also included. Equations for conversion of the IOCC Grid

Reference system to the UTM reference grid are given in Section 3.3.1. below. Conversion of IOCC Base Line Reference to UTM is performed by the computer program given in Part 6.

A table of relevant data for the location and direction of the base lines is also included in Appendix 1.

3.3 GROUND TEMPERATURE DATA

3.3.1 DATA PRESENTATION FORMAT

All available ground temperature observations from the IOCC and the McGill University Subarctic Research Laboratory were compiled as follows (See sample next page):

- A. The first line of the file consists of the file name (up to 17 characters), used both to identify the file and as a title for the index. The file name typically consists of:
 - i) A number of alphameric characters representing the name of the ore body or mine.
 - ii) One or two digits representing the number of the ore body or mine.
 - iii) a period.
 - iv) A set of digits identifying the site within the ore body or mine.

For example: TIM4.23 indicates Timmins No. 4 ore body/mine area and cable number 23. Where cables were not conveniently numbered, the IOCC drill hole designation was generally used, for example: BAR1.B1048DG indicates the Barney No. 1 area and IOCC drill hole number B1048DG.

Following the file name, but still on the first line of the file, is the place name. This is a descriptive, local name for the site. The name may be up to 30 characters long.

The last item to appear on the first line of the file is the IOCC designation for the observation site, which may be up to 10 characters long. From the second example above, this would be B1048DG.

- B. The second line of the file consists of both the IOCC Grid Reference and UTM coordinates, the number of

observations and the number of sensor levels. The first two items, the IOCC eastings and northings are given to the nearest foot. The easting and northing each occupy seven columns. Following the IOCC easting and northing is the IOCC elevation in feet (five columns). Note that the IOCC grid uses an assumed datum of 1900 feet for Knob Lake (actual elevation 1645 feet).

The fourth item on the second line of the file is the map sheet grid zone designation which is 19UFL for all temperature data. Following this is the UTM easting and northing (7 columns each) and the site elevation in metres (4 columns).

The final two items on the second line of the file are the number of observations (3 columns) and the number of depths at the site (2 columns).

- C. The third line of the file consists of the depths of the observation points recorded in centimetres (5 columns each).

NOTE: Generally only the IOCC Grid References were known (i.e. surveyed). To convert IOCC grid references to standard UTM coordinates, a series of geodetic points within the Schefferville mining area were chosen whose coordinates were known in both systems. Linear regression yielded the following two equations for obtaining UTM coordinates from IOCC eastings (eq. (1); $r = .999$) and northings (eq. (2); $r = 1.000$):

$$(1) \text{ UTM(E)} = 611078.812 + 0.30828 * \text{IOCC(E)}$$

$$(2) \text{ UTM(N)} = 6066335.000 + 0.30178 * \text{IOCC(N)}$$

The IOCC grid uses Knob Lake as datum with an assumed elevation of 1900 ft (actual elevation 1645 ft). Thus, UTM elevation in metres above mean sea level is obtained as:

$$(3) \text{ UTM(HT)} = (\text{IOCC(HT)} - 255) * 0.3048$$

However, analysis of seven geodetic points with elevations known both in metres and feet gave the following relationship:

$$(4) \text{ UTM(HT)} = (\text{IOCC(HT)} - 241.64) * 0.3048$$

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
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T I M M I N S N O . 4 C A B L E N O . 1 E L 1 0 0 2 M																																																																															
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3 2 8 9 1 1 6 4 6 0 0 2 4 6 0 1 9 U F L 6 2 1 2 1 8 6 0 8 5 8 3 0 1 6 7 6 0 7 6 1 2																																																																															
e a s t i n g n o r t h i n g e l e v z o n e e a s t i n g n o r t h i n g e l e v # # o b s d e p t h s																																																																															
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3.3.2 PRESENT STATUS OF THERMOCABLES AND WELLS

The same ore extraction process which opened the drill holes and provided unique opportunities for permafrost study also led to the destruction of almost all the cables and well installations. Of over 250 cables and wells installed at Schefferville, only a few dozen still exist, and only a few of those have remained relatively undisturbed by mining activities.

Only cables not located on ore-bodies or located on ore-bodies which were explored and drilled but not subsequently stripped and/or mined remain intact. This includes Ferriman 7, Howse 1, and Barney 1 and 2. All other major installations of cables such as Ferriman 1, Timmins 1, 3, and 4, Fleming 3 and 7, and the installations at Wishart Lake and Ruth Lake, have been destroyed. In most cases, the original site no longer exists. In a few areas (e.g. north of Fleming 7), certain cables and wells are still intact, but in place of the original rolling scrub tundra is a pit 500 m long, a large area of stripped ground, and many newly-formed ponds. Interpretation of data from such a cable or well would be difficult.

Three main thermocable sites still exist in relatively undisturbed states: Ferriman 7, Howse 1, and Barney 1 and 2. The installations at Howse and Barney were made by IOCC and reach depths of up to 130 m. The thermistors are factory calibrated to an accuracy of 0.1 °C. The cables at Ferriman are those installed in IOCC exploration holes from 1957 to 1961. They are of the copper-constantan thermocouple type. Most of them are equipped with oil-bath thermocouple switches, but some are not.

In addition to the cables at Howse, Barney, and Ferriman, there are a few shallow thermistor cables located at McGill research sites, notably near Hematite Lake (Wright, 1981) and at the Boundary Ridge palsa (Carlson, in progress). No shallow thermocable data has been included in this report.

In the information for each cable and well-logging site (see section 2.0) is a status field indicating the present status of the measurement site. The three classifications used are:

Destroyed (X) is applied to those sites which no longer exist or could not be located. In addition, it is applied to those cables and wells that have been irreparably damaged.

Disturbed (D) is applied to sites at which the cable or well is intact, but where the site has been disturbed by trenching, stripping or mining.

Intact (I) is applied to cables and wells which are operational and located at sites that have not been disturbed.

In summary, there are only a few sites which still have intact thermocables. Ferriman Ridge has, by far, the longest run of data (over 20 years). Observations at Ferriman have been infrequent in the past few years, but the cables are intact. The Ferriman 1 pit is situated only 500 m from the research area, but its effect on ground temperatures is probably small. Some of the cables at Ferriman extend to depths of 30 m.

The Howse deposit has a grid of thermistor cables, most of them intact, extending from a broad hilltop of scrub tundra down a gentle slope into open lichen woodland. It presents a rather unusual situation for Schefferville in that it has a deep overburden, approaching 30 m in spots, which consists mainly of sands and gravel. This facilitates groundwater flow and has a marked influence on the ground temperature field.

The Barney deposit has several cables which are intact and sited in relatively undisturbed terrain. They are mainly shallow, reaching less than 50 m in most cases. The Barney deposit is located 30 km NW of Schefferville, requiring over one hour of travel in summer and over two hours in winter.

Finally, there are some shallow thermistor cables located near Hematite Lake, and near Boundary Ridge (SW of Ferriman 7). The cables were installed for studies of the active layer and therefore do not extend below 3 m. The cables at Boundary Ridge have some defects, but are in working order. The cables at Hematite Lake are still intact and operational.

3.4. GROUND ICE OBSERVATIONS (TRENCHING DATA)

The data in this file come from the IOCC trenching operations in the Schefferville mining area. Essentially, this process consists of a backhoe excavating a trench through the overburden to the bedrock below. A geologist then records such variables as overburden depth, type of bedrock, presence of frost (if any occurs) and whether or not there is water in the trench. This information, along with the trench coordinates, is then plotted on graph paper at a scale of 1:1200.

The trenching information in the file has been derived from the information in the trenching data plots. In the computer file, each screen line contains (See sample sheet):

- (1) A file name consisting of up to six characters, the first of which is a "T" to designate trenching data. The following characters are numbers corresponding to the IOCC deposit code for the area. Areas trenched, for which no deposit code exists, were assigned a unique number. Where trenching operations span two deposits, the deposit code for each is included in the file name separated by a period: e.g. trenching in Timmins No. 7 and No. 8 would have the file name T92.94. A listing of the deposit codes appears at the beginning of each hardcopy volume of trenching data.
- (2) a descriptive name of up to 23 characters. The deposit code is used and this indicates the base line for the particular coordinate system in which the trenching operations were carried out.
- (3) the trench location in IOCC coordinates. This consists of a total of twelve characters. The first six indicate the section line along the base line and the second six indicate the distance (in feet) from the base line. Negative numbers indicate positions SW of the base line and positive numbers positions located NE of the base line.
- (4) the date trenching occurred. This is standard six digit DDMMYY format. Where the day, month or entire date is unknown the field is blank.
- (5) the depth (in tenths of feet) at which permafrost was found. Three digits are used and three cases are possible:
 - i) permafrost exists at, for example, 10.5 feet; then the number entered is 105.
 - ii) if no permafrost was encountered, three zeroes are entered.
 - iii) if permafrost was present but the depth was not specified, the number entered is 999.
- (6) the depth of the overburden in feet. Again tenths of feet are given so that an overburden depth of 14.0 feet appears as 140. If the overburden depth was not given the field is left blank.
- (7) the depth of the trench in tenths of feet. Similar in format to the overburden depth, this measurement is rarely given and so the field is usually blank.

Note that the coordinates of each sampling point are in IOCC base line offset coordinates. A utility program, TRENCHUTM.PLI, provided on the CCT will convert the base

[illegible]

line offset coordinates to UTM coordinates. Location maps are provided at the beginning of each hardcopy volume of trenching data showing the base line locations with end points in both IOCC grid and UTM coordinates. The IOCC base line coordinates are given by Table 1.

Note also from the location maps that one base line may extend through several deposits; for example Barney No. 1 leads into Fleming No. 9 which leads into Fleming No. 6 which leads into Star Creek No. 3 which leads into Ferriman No. 4. This may lead to a descriptive name such as "Fleming No. 9 - Barney No. 1" which still indicates the base line but suggests that trenching occurred near where the two deposits meet.

3.5 PERMAFROST PREDICTION MAPS

The permafrost prediction maps are reproduced as prints from 70mm negatives of the original maps in IOCC files. Initially, each map was going to be re-drafted at a common scale, but this was not feasible. All maps are grouped according to the ore body/mine area for which they were produced. No attempt has been made to annotate the individual maps or to provide cross-reference to the reports in which some of the maps are illustrations.

3.6 PERMAFROST DATA ON COMPUTER COMPATIBLE TAPE

All of the thermocable data files and trenching data files are provided in computer compatible form on a 9 track, 1/2 inch tape at 1600 bpi. The files have been transferred to the tape in ASCII format using a utility program (UTIL) available at McGill University and running under the IBM VMS operating system. The logical record length of all the records on the tape is 80 bytes, although only the first 72 bytes are actually used (in order to facilitate editing and viewing on 72 character-wide terminals). In addition to the data files, one utility program, TRENCHUTM.PLI is provided. This program transforms IOCC base line offset coordinates to UTM grid reference. The program is written in PL/I source code and will compile under either the IBM PL/I Checkout or Optimizing compilers running under IBM VMS.

4. RECOMMENDATIONS FOR FUTURE RESEARCH

4.1 FACTORS INFLUENCING THE POTENTIAL FOR FUTURE PERMAFROST RESEARCH AT SCHEFFERVILLE

Future permafrost research at Schefferville must take into consideration that the IOCC mining operations have closed and probably will not be re-started in the foreseeable future. The immediate need for permafrost information that previous research programs were designed to fill has therefore ceased to exist. The tremendous logistical support that IOCC has provided for permafrost research programs is also no longer available. Deep drill holes and other "free commodities" are no longer available without major expense. The opportunity to study permafrost in open pits is also gone.

A change in emphasis will therefore be required for future permafrost research at Schefferville. The primary, local factors justifying further permafrost research at Schefferville are the large amount of background data available (both on permafrost and other factors), the availability of researchers with experience in permafrost research at Schefferville, and the presence of discontinuous permafrost and a variety of permafrost-related terrain features. Although there are presently no mining operations at Schefferville, the IOCC operations at Labrador City and Strange Lake are located in terrain where discontinuous permafrost is present and offer some research opportunity, particularly for research requiring deep thermocables, rock samples or easy inspection of ground ice in open pit mines.

A number of the thermocables at Schefferville are still intact. They include the Ferriman 7 cables for which a data record spanning some 20 years is available. This is a unique series which should be continued. It offers an opportunity to study effects of annual variations in climatic factors on ground temperatures. The Howse cables offer the opportunity to study the effects of heat transfer by interflow through the highly permeable overburden at the Howse deposit.

The assembled data base could serve to test and develop further models for prediction of temporal and spatial variations in the ground temperature field, developed at Schefferville and elsewhere.

The Schefferville area with its wide range of environments and background information is an excellent field area, very well suited for research on effects of

temporal and spatial variations in the surface energy balance, effects of the seasonal snow cover and effects of near-surface groundwater flow on the ground thermal regime.

The presence of palsa and patterned ground opens the opportunity to study their dynamics. Recent, substantial changes in the extent of palsa has been documented and should be further investigated

4.2 RECOMMENDATIONS FOR FURTHER WORK ON THE DATA FILE

The next step, following the completion of this report should be the evaluation and upgrading of the data-base compiled in the first year's work. Some further upgrading of the data base is possible if thermistor calibrations can be located. A thorough checking of the cable data should be made and analyses performed to assess the reliability of the data.

To further enhance the usefulness of the permafrost data file, geological information for the thermocable sites should be assembled and appended to the data set. The permafrost prediction maps, assembled in this report, should be annotated. It is also recommended that annotated aerial stereophoto models be prepared for the thermocable sites using aerial photographs taken prior to disturbance of the ground by mining. This would enable analysis of topography, vegetation, surficial drainage and other factors important to the ground temperature field.

4.3 MODELLING OF THE GROUND THERMAL REGIME

Several modelling efforts that would yield further insight into the factors controlling permafrost distribution at Schefferville are feasible using the present data set.

Numerical modelling of surface and sub-surface thermal regimes can be used to effectively simulate temporal variations in permafrost, describing changes in active layer depth, ice lens growth and the role of surface modifications on sub-surface regimes. These models (e.g. Guymon and Luthin, 1974; Outcalt and Carlson, 1975; Goodrich, 1976 and Outcalt and Goodwin, 1980) usually express time-varying energy and moisture fluxes using time-invariant model parameters. A one-dimensional energy-balance model is driven by a 'small' number of standard micrometeorological measurements. Varying degrees of mathematical and physical sophistication has been incorporated into the structure of these models, but an extensive search of the literature has shown that very little verification of the models has been done.

With the data base now available, possibly augmented by additional field data from shallow thermocables, the opportunity exists to extensively test models based on both seasonal frequencies (attempt to predict active layer changes) and low frequency types that describe thermal variations over decades.

4.4 SPATIAL MODELLING OF THE GROUND TEMPERATURE FIELD

Spatial modelling of the ground temperature field has been an essential component of research on permafrost at Schefferville. The simple models that have been developed have aided considerably in the extrapolation of ground temperature information. The models have generally been based on snow cover and some qualitative interpretation of surface vegetation and near-surface hydrology.

A terrain analysis project, to produce a digital terrain model (DTM) of an area including several of the Timmins, Barney and Howse deposits is currently in progress. The product of the terrain analysis is a detailed DTM of surface vegetation, topography, soils and other terrain factors. Snow cover distribution, solar radiation and other microclimate factors are modelled spatially.

The DTM is produced for the purpose of vehicle mobility modelling and presently covers part of the area used by Nicholson (1975, 1978c) for permafrost predictions using sequence melt photography. It offers the opportunity both to test predicted snow cover (Granberg, 1973), as opposed to snow cover mapped from sequence melt photographs, as alternate predictor of the spatial distribution of permafrost and to further develop, in quantitative form, spatial prediction models based on snow, terrain factors and microclimate.

The DTM can be extended to other areas of interest. Large scale topographic maps (Scale 1:1200) and large scale aerial photographs taken prior to ground disturbance by mining operations make it possible to reconstruct in the DTM the original state of the ground and the original snow distribution patterns that prevailed prior to ground disturbance by mining. This makes it possible to use all of the thermocable and active layer information in the model development.

4.5 RE-ESTABLISHMENT OF THERMOCABLE OBSERVATIONS

The existence of intact, relatively undisturbed thermocables at Schefferville, some of them with long records, makes it desirable that the series of observations

be continued. The cables with the longest temporal sequence (Ferriman 7) are thermocouples, while the rest are thermistor cables.

Re-establishment of thermocable observations would require maintenance and repair (where necessary) of the cables and instrument shelters (most of the cables are in shacks for winter-time observations). In addition, there is, at present, no instrument available that is capable of accurately reading the thermocouples, so such an instrument would have to be procured. Finally, some funds would have to be obtained to hire personnel to make the required observations.

For the (relatively) readily-accessible cables at Ferriman 7, bi-weekly observations during the thaw season and monthly visits during the winter would be both sufficient and feasible. At the more distant locations, such as Howse and Barney, monthly and bi-monthly observations, respectively, would have to suffice. Observations of the thermocables at Hematite and the Boundary Ridge palsa could also be easily accommodated within this scheme.

4.6 MODELLING OF THE ROLE OF THE SNOW COVER

Research at Schefferville has shown that snow cover indices are quite good predictors of the permafrost distribution (Nicholson and Granberg, 1973). It would be highly desirable, however, to develop a better model of the mechanisms by which the unevenly distributed seasonal snow cover affects the ground thermal regime. A large amount of snow data from studies of the spatial and temporal distribution of snow cover in relation to permafrost exists and could be used, with some additional field observations for the initial modelling of the snow cover influence.

Field observations of snow cover properties and ground/snow interface temperatures could be used for development and preliminary testing of the model. Equipment for such measurements exists and can over a few days of field work provide detailed information about the spatial variations in ground/snow interface temperatures over a large area.

Later aspects of this research program would include detailed monitoring of near-surface ground heat fluxes, heat fluxes through the snow cover and energy exchanges at the

snow surface.

5. CONCLUSIONS

The objective of this project has been fulfilled. Most of the ground temperature data and active layer depth soundings from the Schefferville area have been made available. Reports, theses, papers and other relevant, written communication on permafrost and its distribution in the Schefferville area have been collected and reproduced. The present status of all existing cables has been verified. The current status of permafrost research in the area has been assessed and recommendations made for continued research on permafrost at Schefferville.

This report has made no assessment of the quality of the data, nor has any analysis been made. This should be done, however, together with some upgrading of the data set. The present data set is unique and should be made generally available.

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PART II

CATALOGUE OF AVAILABLE MATERIALS

1. BIBLIOGRAPHY OF PERMAFROST RESEARCH AT SCHEFFERVILLE

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- * Nicholson, F.H. and H.B. Granberg, 1971. Notes on the map of permafrost distribution deduced from snow distribution maps. McGill Subarctic Research Laboratory, April 19, 1971. Typescript in I.O.C.C. files, 4p.

- * Petch, J.R., 1974. Some periglacial mass movements in fine grained unconsolidated material in subarctic Canada. Working Paper No. 63, Department of Geography, University of Leeds, 23p. Typescript, McGill files.
- Seguin, M.K., 1967. Resistivity models for the localization of the water table and permafrost in the Knob Lake area. Private report to I.O.C.C., 14 p.
- Seguin, M.K., 1970. Interpretation of seismic and resistivity survey data from summer of 1970. Technical Services Report No. 6908-1, Geotechnical Engineering Section, I.O.C.C.
- * Seguin, M.K., 1971. Quantitative interpretation of the refraction seismic survey conducted for permafrost and overburden depth determination in the Fleming #3 area. August 16, 1971. Typescript in I.O.C.C. files, 6p.
- Seguin, M.K., 1971. Summary report on aeroelectromagnetic (Helicopterborne) survey for permafrost prediction. Internal Report to I.O.C.C., December 13, 1971, 2p.
- * Seguin, M.K., 1971. Interpretation of the seismic refraction survey conducted on the Timmins #4 (Elross #1) deposit for outlining permafrost zones. Typescript in I.O.C.C. files, Aug. 12, 1971, 5p.
- * Seguin, M.K., 1973. Schefferville area discontinuous permafrost study. I.O.C.C. translation from: Etude du pergélisol discontinu dans la région de Schefferville. Technical Report, National Defence Council Research Grant No. 9511-130-73, October 1973, 29p.
- Seguin, M.K., 1973. Etude du pergélisol discontinu dans la région de Schefferville. Rapport Technique, Conseil National de Recherche (Canada), Octroi No. 9511-130-73. 27p.
- Seguin, M.K., 1974. Conception et construction de sondes électriques et thermiques pour l'étude du pergélisol continu ou discontinu, vérification de leur fonctionnement dans les trous de forages effectués à Schefferville et en Abitibi. Rapport Technique, Conseil National de Recherche (Canada) Octroi No. 9511-130-74. 35p.
- * Seguin, M.K., 1979. Permafrost delineation on Knox Mine (Schefferville). Geotechnical Engineering Section I.O.C.C., July 8, 1979, 21p.

- * Seguin, M.K., 1979. Permafrost distribution on the Timmins #7 deposit (Schefferville). Geotechnical Engineering Section I.O.C.C., Knob Lake Division, 18p.

- Thom, B.G., 1970. Comprehensive report on Timmins 4 permafrost experimental site. Technical Services Report No. 6907-4, Geotechnical Engineering Section I.O.C.C., October 21, 1970, 40p.

- * Thom, B.G., 1970. Principles and recommendations for moisture-thermal amelioration of the ground oversites to be mined in the future. Technical Services Report No. 6907-3, Geotechnical Engineering Section, October 1970.

1.3. MEMORANDA AND INTERDEPARTMENTAL CORRESPONDENCE

- * Indicates memoranda that have been included in Part 2
- M.S.A.R.L. is McGill Subarctic Research Laboratory.
- I.O.C.C. is Iron Ore Company of Canada.

Collins, F., (I.O.C.C.), to O. Garg, I.O.C.C.,
 * June 14, 1972.
 ref: Wishart dump. 4p.

Collins, F., (I.O.C.C.), to O. Garg, I.O.C.C.,
 Aug. 10, 1972.
 ref: Wishart dump.

Crawford, C.B., N.R.C. Div. Bldg. Res., to I.O.C.C., Sept. 14, 1956.
 * ref: Ground temperatures in Labrador. 7p.

Garg, O., I.O.C.C., to D. Lemelin, I.O.C.C., June 11, 1971.
 * ref: Temperature readings in Timmins #1 holes. 3p.

Garg, O., I.O.C.C., to P.F. Stacey, I.O.C.C., July 14, 1971.
 * ref: Sub-surface permafrost distribution in Timmins 4. 2p.

Garg, O., I.O.C.C., to P.F. Stacey, I.O.C.C., Sept. 9, 1971.
 * ref: Water study in Timmins 1 pit (Addendum to
 Report #6908-2). 5p.

Garg, O., I.O.C.C., to P.F. Stacey, I.O.C.C., Aug. 10, 1972.
 * ref: Permafrost investigation on Wishart #1 TRX dump.

Garg, O., I.O.C.C., to J. Lancaster, I.O.C.C., Dec. 31, 1974.
 * ref: Regional permafrost appraisal Part II - Triangle
 Lake to Greenbush Lake areas. 5p.

Hetu, G., I.O.C.C., to J. Devon, I.O.C.C., Dec. 2, 1976.
 * ref: Snow fences for Wishart mine treat rock stockpile. 2p.

Hulan, G.C., I.O.C.C., to P. Collins, I.O.C.C., December 4, 1969.
 * ref: Permafrost report. 1p.

Hulan, G.C., I.O.C.C., to P. Collins, I.O.C.C., March 23, 1970.

- * ref: Mapping permafrost. 2p.

- Jones I., I.O.C.C., to O. Garg, I.O.C.C., Aug. 21, 1973.
- * ref: Fleming 3 thermocables. 2p.

- Jones I., I.O.C.C., to O. Garg, I.O.C.C., Aug. 22, 1973.
- * ref: Permafrost investigations - Timmins dyke. 2p.

- Jones, I., I.O.C.C., to O. Garg, I.O.C.C., Mar. 26, 1974.
- * ref: Timmins pit temperature measurements (Lift 2433). 9p.

- Jones, I., I.O.C.C., to O. Garg, I.O.C.C., June 10, 1975.
- * ref: Permafrost predictions for lifts 2442 and 2404, Timmins No. 2 mine. 4p.

- Jones, I., I.O.C.C., to O. Garg, I.O.C.C., Aug. 1, 1975.
- * ref: Permafrost sections, Fleming #3 mine. 4p.

- Jones, I., I.O.C.C., to O. Garg, I.O.C.C., Sept, 12, 1975.
- * ref: Permafrost distribution withing future mine sites in the Timmins-Barney area. 7p.

- Jones, I., I.O.C.C., to O. Garg, I.O.C.C., Sept. 12, 1975.
- * ref: Preliminary permafrost delineation; Barney 1. 6p.

- Jones, I., I.O.C.C., to O. Garg, I.O.C.C., Oct. 8, 1975. 6p.
- * ref: Preliminary permafrost delineation Timmins No. 4.

- Jones, I., I.O.C.C., to O. Garg, I.O.C.C., Oct. 24, 1975.
- * ref: Ground temperature measurements Timmins No. 1 dyke. 4p.

- Lemelin, D. and O. Garg, I.O.C.C., to P.F. Stacey, I.O.C.C., Apr. 28, 1972.
- * ref: Temperature measurements in Timmins dyke area. 7p.

- Lewis, J., M.S.A.R.L., to F. Lambert, I.O.C.C., Undated.
- * ref: Snow fences on Wishart and Retty Stockpiles. 2p.

- Mihalovic, G., I.O.C.C., to R. Ethier, I.O.C.C., Mar. 14, 1980.
- * ref: Timmins 7: Permafrost and water table. 1p.

- Mihalovic, G., I.O.C.C., to R. Ethier, I.O.C.C., Mar. 14, 1980.
- * ref: Barney 1 & 2: permafrost. 6p.

Mihalovic, G., I.O.C.C., to J.F. Boudreau, I.O.C.C., Mar. 26, 1980.
 * ref: Howse permafrost March 20/80. 4p.
 (includes a subsequent memo; same people; same ref.
 April 11, 1980)

Mihalovic, G., I.O.C.C., to J.F. Boudreau, I.O.C.C., Apr. 8, 1980.
 * ref: Timmins #4 permafrost. 1p.

Mihalovic, G., I.O.C.C., to O. Garg, I.O.C.C., May 12, 1980.
 * ref: Howse permafrost update. 2p.

Mihalovic, G. and R. Ethier, I.O.C.C., to J. Boudreau, I.O.C.C.,
 * Nov. 6, 1979.
 ref: Permafrost - Howse deposit. 2p.

Nicholson, F.H., M.S.A.R.L., to L. Nichols and P.F. Stacey, I.O.C.C.,
 * July 24, 1973.
 ref: Knox mine site - possible presence of permafrost. 6p.
 (includes comments by I. Jones (I.O.C.C.) Oct. 30,
 1975. 1p.)

Nicholson, F. H., M.S.A.R.L., to O. Garg, I.O.C.C., Aug. 12, 1975.
 * ref: Thermistor cable and antifreeze pipe in drill hole
 FL 7004cc. 3p.

Nicholson, F.H., M.S.A.R.L., to R. Arndt, I.O.C.C., Nov. 5, 1976.
 * ref: Wishart mine treat rock stockpile. 4p.

Stacey, P.F., I.O.C.C., to P. Collins, I.O.C.C., Aug. 10, 1972.
 * ref: Permafrost investigation on Wishart #1 TRX dump. 8p.

Thom B.G., M.S.A.R.L., to J. Dagenais, I.O.C.C., Apr. 29, 1968.
 * ref: Ground temperatures at Timmins 1. 3p.

Thom, B.G., M.S.A.R.L., to R. Martin, I.O.C.C., June 17, 1968.
 ref: Permafrost investigations at Timmins 1.

Thom, B.G., M.S.A.R.L., to P.F. Stacey, I.O.C.C., Oct. 7, 1970.
 * ref: Potential deposits with permafrost. 1p.

Thom, B.G., M.S.A.R.L. and T. Carmichael, I.O.C.C., to J. Dagenais,
 * ref: Timmins service garage site - permafrost study. 17p.

2. AVAILABLE THERMOCABLE DATA

CABLE STATUS

I = Intact
D = Disturbed
X = Destroyed

CABLE TYPE

TMR = Thermistor
TCP = Thermocouple
LOG = Logging pipe

File name	I.O.C.C. Cable #	Start Date	End Date	No. Obs	Max d (m)	Cable Status	Cable Type
BAR1.Z2223CCT	Z2223CC	220779	300980	6	14.63	X	TMR
BAR1.Z2237CCT	Z2237CC	220779	300980	6	30.48	X	TMR
BAR1.B1048DGT	B1048DG	150877	300980	8	29.41	X	TMR
BAR1.B1051DGT	B1051DG	011077	300880	9	71.63	I	TMR
BAR1.B1053DGT	B1053DG	011077	300880	8	14.33	X	TMR
BAR1.B1054DGT	B1054DG	011077	300980	8	7.32	D	TMR
BAR1.B1055CCT	B1055CC	011077	260280	4	30.48	I	TMR
BAR1.B1056CCT	B1056CC	011077	300880	9	33.83	X	TMR
BAR2.B1046DGT	B1046DG	200777	310879	5	53.34	D	TMR
BAR2.B1047DGT	B1047DG	200777	260280	6	35.05	I	TMR
BAR2.B2001CCT	B2001CC	220779	300980	6	25.91	I	TMR
BAR2.B2006CCT	B2006CC	220779	300980	6	42.67	X	TMR
FER1.RL707T	RL707	060857	240857	3	30.50	X	TMR
FER1.1T						X	TCP
FER1.2T	F1172RD	240858			60.60	X	TCP
FER1.3T	X641C	220859			15.20	X	TCP
FER1.4T	X642C	220859			29.20	X	TCP
FER1.5T	F1102C	240859			15.20	X	TCP
FER1.7T	F197	211157	151062	15	38.10	X	TCP
FER1.9T		170160			18.20	X	TCP
FER1.10T						X	TCP
FER1.11T						X	TCP
FER1.1104T	F1104	091057	121159	3	60.95	X	TCP
FER1.1105T	F1105R	280959	150560	9	27.45	X	TCP
FER1.1114T	F1114	091057	091057	1	45.70	X	TCP
FER1.1115T	F1115RD	021157	021157	1	53.30	X	TCP
FER1.122T	F122	060857	240857	3	24.10	X	TCP
FER1.128T	F128	010857	240857	3	60.95	X	TCP
FER1.1283CCT	F1283CC	070678	070678	1	17.07	X	TMR
FER1.1285CCT	F1285CC	070678	240878	2	13.40	X	TMR
FER1.1288CCT	F1288CC	070678	070678	1	17.10	X	TMR
FER1.147T	F147	010857	170558	6	30.50	X	TCP
FER1.149T	F149	030857	240859	8	30.50	X	TCP
FER1.171T	F171	310757	310757	2	30.50	X	TCP
FER1.173T	F173	310757	240857	3	30.50	X	TCP
FER1.175T	F175	070857	310859	10	30.50	X	TCP
FER1.177T	F177	060857	310859	9	30.50	X	TCP
FER1.178T	F178	140857	220857	3	30.50	X	TCP
FER1.187T	F187	020857	240857	3	30.50	X	TCP

FER7.12T	FE7001	171161			30.50	I	TCP
FER7.13T	FE7002	201161			30.50	I	TCP
FER7.14T	FE7004	161161			58.00	I	TCP
FER7.15T	FE7003	161161			30.50	I	TCP
FER7.16T	FE7005	161161			15.20	I	TCP
FER7.17T	FE7006	171161			15.20	I	TCP
FLEM3.3084CCT	FL3084CC	220774	280676	14	70.71	X	LOG
FLEM3.3089CCT	FL3089CC	220774	150376	12	73.15	X	LOG
FLEM3.3090CCT	FL3090CC	220774	280676	14	42.06	X	LOG
FLEM3.3092CCT	FL3092CC	220774	280676	19	76.20	X	LOG
FLEM3.3093CCT	FL3093CC	220774	150376	12	35.05	X	LOG
FLEM3.3101T	FL3101CC	121174	280676	12	56.69	X	LOG
FLEM3.3103T	FL3103CC	121174	071075	6	55.47	X	LOG
FLEM7.1638T	X1638C	070574	070678	23	12.19	X	LOG
FLEM7.1639T	X1639C	070574	070678	23	10.67	X	LOG
FLEM7.1640T	X1640C	190274	070678	23	14.63	D	LOG
FLEM7.1641T	X1641C	251074	070678	26	8.84	X	LOG
FLEM7.1643CT	X1643C	190274	201077	21	22.55	X	LOG
FLEM7.1644CT	X1644C	190274	070678	21	7.32	D	LOG
FLEM7.1645T	X1645C	190274	070678	16	5.79	X	LOG
FLEM7.1646T	X1646C	190274	201077	17	7.32	X	LOG
FLEM7.1647CT	X1647C	190274	140377	16	8.53	X	LOG
FLEM7.1649T	X1649C	070574	011177	22	11.58	X	LOG
FLEM7.1650T	X1650C	070574	181077	31	18.90	X	LOG
FLEM7.1651CT	X1651C	070374	120678	25	18.29	D	LOG
FLEM7.1652T	X1652C	070574	120678	32	8.23	X	LOG
FLEM7.1653T	X1653C	070574	120678	22	5.33	X	LOG
FLEM7.1654T	X1654C	070374	011177	20	14.32	X	LOG
FLEM7.1655T	X1655C	070574	120678	24	14.02	D	LOG
FLEM7.1656T	X1656C	190374	120678	30	25.30	D	LOG
FLEM7.1657T	X1657C	190574	120678	18	10.67	D	LOG
FLEM7.1658T	X1658C	190374	120678	19	18.29	X	LOG
FLEM7.1659T	X1659C	190374	120678	21	10.67	X	LOG
FLEM7.1660T	X1660C	190374	181077	30	27.43	X	LOG
FLEM7.1661T	X1661C	021274	011177	7	5.97	X	LOG
FLEM7.1664T	X1664C	190374	120678	18	7.62	X	LOG
FLEM7.1665T	X1665C	190374	120678	16	7.62	X	LOG
FLEM7.1666T	X1666C	190374	070676	14	9.75	D	LOG
FLEM7.2124T	Z2124C	210574	210377	18	11.58	X	LOG
FLEM7.2127T	Z2127C	190374	210377	30	9.14	X	LOG
FLEM7.7004CCT	FX7004CC	140675	210377	42	137.16	X	LOG
FLEM7.7007CCT	FX7007CC	110679	010880	5	32.00	X	TMR
FLEM7.7008CCT	FX7008CC	110679	010880	6	42.67	X	TMR
FLEM7.7009CCT	FX7009CC	110679	010880	5	30.48	X	TMR
FLEM7.7020T	FL7020CC	170678	170678	1	85.34	D	TMR
FLEM7.7021T	FL7021CC	170678	170678	1	50.90	X	TMR
FLEM7.7025CCT	FL7025CC	110679	010880	6	27.43	D	TMR
FLEM7.7031CCT	FL7031CC	110679	010880	5	28.65	D	TMR
FLEM7.7032CCT	FL7032CC	110679	010880	6		D	TMR
FLEM9.9010CCT	FL9010CC	180679	010880	4	56.08	X	TMR
HOW.X1869CCT	X1869CC	031179	071080	9	114.91	I	TMR
HOW.1004CCT	HW1004CC	190680	180781	7	115.21	I	TMR
HOW.1007CCT	HW1007CC	030780	180881	6	78.64	I	TMR
HOW.1008CCT	HW1008CC	030780	180881	6	59.44	I	TMR
HOW.1013CCT	HW1013CC	030780	180881	6	60.96	I	TMR
HOW.1016CCT	HW1016CC	290780	080781	4	73.76	I	TMR
HOW.1018CCT	HW1018CC	110780	180881	5	112.78	I	TMR
HOW.1019CCT	HW1019CC	110780	080881	5	60.96	I	TMR

HOW.1024CCT	HW1024CC	290780	080881	4	47.85	I	TMR
HOW.1027CCT	HW1027CC	290780	101080	3	62.48	I	TMR
HOW.1030CCT	HW1030CC	250880	101080	2	38.10	I	TMR
HOW.1038CCT	HW1038CC	071080	071080	1	42.06	I	TMR
HOW.1046CCT	HW1046CC	071080	071080	1	23.77	I	TMR
HOW.1047CCT	HW1047CC	071080	071080	1	35.81	I	TMR
HOW.1049CCT	HW1049CC	101080	101080	1	52.12	I	TMR
KNOX.8070CCT	FL8070C	230774	150277	16	60.96	X	LOG
KNOX.8071CCT	FL8071C	240774	250276	12	121.92	X	LOG
KNOX.8073CCT	FL8073C	240774	150277	18	76.20	X	LOG
KNOX.8082CCT	FL8082CC	030874	300676	14	76.20	X	LOG
KNOX.8083CCT	FL8083CC	030874	300676	14	40.47	X	LOG
KNOX.8084CCT	FL8084CC	030874	300676	12	76.20	X	LOG
LANCE.1017CCT	LR1017CC	180975	300676	8	39.32	X	LOG
LANCE.1023T	LR1023CC	071075	071075	2	15.24	X	LOG
PINX.1717T	X1717CC	170975	240776	6	106.68	I	TMR
PINX.1718T	X1718CC	021274	190676	6	64.92	I	LOG
RED5.5001CCT	RE5001CC	090782	090782	1	48.77	X	TMR
RED5.5012CCT	RE5012CC	090782	090782	1	22.86	X	TMR
STAR1.321CE	Z321C	021157	021157	1	21.35	X	TCP
STAR3.3075CCT	SC3075CC	190779	190779	2	30.48	X	TMR
TIM1.1T	FL1092M	240468	170768	2	54.70	X	TCP
TIM1.2T	FL1049M	240468	170768		54.70	X	TCP
TIM1.3T	FL1055M	240468	170768	2	70.10	X	TCP
TIM1.4T	FL1062M	240468	030868		73.20	X	TCP
TIM1.5T	FL1085M	240468	170768	2	67.10	X	TCP
TIM1.6T	FL1029M	240468	030868	2	94.50	X	LOG
TIM1.7T	FL1072M	240468	030868	2	67.10	X	TCP
TIM1.8T	FL1066M	240468	030868	2	48.60	X	TCP
TIM3.FL2027T	FL2027CC	291074	110877	22	97.38	X	LOG
TIM3.FL2028T	FL2028CC	291074	030877	20	96.93	X	LOG
TIM3.FL2029T	FL2029CC	291074	110877	21	79.25	X	LOG
TIM3.FL2031T	FL2031CC	290575	110877	17	76.20	X	LOG
TIM3.FL2033T	FL2033CC	090775	140777	12	106.68	X	TMR
TIM3.FL2035CCT	FL2035CC	170975	030877	14	57.91	X	LOG
TIM3.FL2036CCT	FL2036CC	170975	110877	19	74.37	X	LOG
TIM3.FL2038CCT	FL2038CC	200975	110877	14	45.72	X	LOG
TIM3.FL2040CCT	FL2040CC	160875	110877	14	11.89	X	LOG
TIM3.FL2041CCT	FL2041CC	180975	110877	16	35.05	X	LOG
TIM3.FL2042CCT	FL2042CC	280875	110877	14	25.60	X	LOG
TIM3.FL2043CCT	FL2043CC	160875	110877	15	78.94	X	LOG
TIM3.FL2044CCT	FL2044CC	060875	110877	13	85.95	X	LOG
TIM3.FL2045CCT	FL2045CC	280676	110877	10	4.88	X	LOG
TIM3.FL2047CCT	FL2047CC	060875	020276	3	90.52	X	LOG
TIM3.FL2052CCT	FL2052CC	060875	110877	15	91.44	X	LOG
TIM3.FL2053CCT	FL2053CC	160875	110877	13	76.50	X	LOG
TIM3.FL2054CCT	FL2054CC	160875	110377	16	78.64	X	LOG
TIM3.FL2055CCT	FL2055CC	170975	110877	13	76.80	X	LOG
TIM3.2058T	FL2058CC	150975	110877	8	72.24	X	LOG
TIM3.2064T	FL2064CC	150976	110877	8	134.11	X	LOG
TIM3.2070T	FL2070CC	150976	030877	8	3.96	X	LOG
TIM3.2075T	FL2075CC	130976	110877	8	76.20	X	LOG
TIM3.2078T	FL2078CC	150976	150976	2	19.81	X	LOG
TIM4.1T	EL1002M	221068	220976	76	71.60	X	TCP
TIM4.2T	EL1010M	221068	010174		60.40	X	TCP
TIM4.3T	EL1009M	221068	280877		10.70	X	TCP
TIM4.4T	EL1003M	221068	280877		60.80	X	TCP
TIM4.5T	EL1004M	221068	280877		52.70	X	TCP

TIM4.6T	EL1008M	221068	160877		8.30	X	TCP
TIM4.7T	EL1007M	071168	280877		15.10	X	TCP
TIM4.8T	EL1005M	221068	280877		43.43	X	TCP
TIM4.9T	EL1006M	221068	220976		46.33	X	TCP
TIM4.10T	EL1011M	071070	010174	33	15.20	X	TCP
TIM4.11T	EL1012M	071070	010174	33	30.50	X	TCP
TIM4.12T	EL1013M	071070	010174	33	43.60	X	TCP
TIM4.13T	EL1014M	071070	010174	33	61.00	X	TCP
TIM4.14T	EL1015M	081070	070274	37	105.80	X	TCP
TIM4.15T	EL1016M	081070	070274	40	29.60	X	TCP
TIM4.16T	EL1017M	081070	070274		14.32	X	TCP
TIM4.17T	EL1018M	091070	070274		15.85	X	TCP
TIM4.18T	EL1021CC	200274	230877	60	27.43	X	TMR
TIM4.19T	EL1023CC	210274	230877	65	27.43	X	TMR
TIM4.20T	X1616C	230573	230877	81	17.50	X	TMR
TIM4.21T	X1611C1	070372	100778	268	11.70	X	TMR
TIM4.22T	X1612C1	270672	260877	250	8.50	X	TMR
TIM4.23T	X1613C1	040772	260877	254	4.90	X	TMR
TIM4.24T	X1614C	270672	260877	252	5.00	X	TMR
TIM4.25T	X1615C	040272	100778		18.00	X	TMR
TIM4.26T	X1020C	210672	100778	248	24.50	X	TMR
TIM4.29T	X1598C	210172	081173	11	15.24	X	TCP
TIM4.30T	X1605C	310772			15.24	X	TMR
TIM4.1024T	EL1024CC	120975	140677	6	35.35	X	LOG
TIM4.1025T	EL1025CC	160975	230976	7	80.75	X	LOG
TIM4.1026T	EL1026CC	271075	230976	3	9.15	X	LOG
TIM6.1042T	FX1042M	140976	140976	1	76.20	X	LOG
TIM6.1044T	FX1044CC	140976	140976	1	97.50	X	LOG
TIM6.1046T	FX1046CC	140976	310577	3	58.85	X	LOG
TIM6.1047T	FX1047CC	140976	140976	1	69.30	X	LOG
TIM6.1048T	FX1048CC	140476	140476	1	64.80	X	LOG
TIM6.1049T	FX1049CC	140976	140976	1	69.90	X	LOG
TIM6.1051T	FX1051CC	140976	140976	1	19.30	X	LOG
TIM6.1056T	FX1056CC	140976	140976	1	56.05	X	LOG
TIM7.TM7009CCT	TM7009CC	150679	100880	6	38.40	I	TMR
TIM7.TM7010CCT	TM7010CC	150679	100880	6	36.58	I	TMR
TIM7.TM7012CCT	TM7012CC	150679	100880	6	33.53	I	TMR

3. AVAILABLE TRENCHING DATA

File name	Ore Body/Mine Area	Observation Years
T10	Gagnon A (Ferriman 3)	1974
T12	Barney No. 2	1979
T14	Ferriman No. 4	1974, 1975, 1977
T17	Malcolm No. 2	1962, 1977, 1978, 1979
T22	Burnt Creek No. 5	1956, 1968, 1970
T25	Malcolm No. 1	1962, 1963, 1979
T27.86	Fleming No. 3	1957, 1967, 1968, 1970 1971, 1973
T28	Retty (Fleming No. 5)	1956
T29.79	Fleming No. 7	1968, 1973, 1980, 1981
T30	Knox Mine	1956, 1957, 1966, 1973 1974, 1976, 1977, 1979
T31	Fleming No. 9	1971, 1972, 1978, 1979 1980
T32.A	Denault No. 2	1951
T33	Sawmill No. 1	1972, 1978, 1979, 1980
T35	Barney No. 1	1977
T36	Fleming No. 6	1950, 1956, 1957, 1975
T39	Goodwood No. 1	1970
T41	Leroy Lake	1956
T44	Star Creek No. 1	Date Unknown
T45	Star Creek No. 2	1957, 1974, 1975, 1976, 1977
T47	Sunny Lake No. 3	1950
T47.A	Sunny Lake No. 4	1950
T49	Lance Ridge No. 1	1968, 1972, 1975, 1977 1978, 1979, 1980
T49.A	Lance Ridge No. 2	1979
T50	Star Creek No. 3	1957, 1974, 1977, 1979
T63.15	Rowe (Ruth Lake No. 7) and (Ferriman No. 1)	1950, 1955, 1956, 1958 1971, 1973, 1974
T64	Ruth Lake No. 8	1958, 1959, 1973, 1975 1976
T65	James (Ruth Lake Ext.)	1959, 1971, 1976, 1979
T66	Ruth Lake No. 9	1976, 1977, 1978
T67	Ferriman No. 7	1970, 1971, 1973, 1974 1977
T68	Green Lake No. 1	1976
T74	Kivivic No. 4	1950
T76	Houston No. 3	1961, 1976, 1977, 1978 1979
T77	Howse No. 1	1978, 1980
T80	Knob Lake No. 1	1955
T81	Redmond No. 5	1976, 1978
T82.38	Houston No. 2	1962, 1976, 1977, 1978 1979
T83	Wishart No. 1	1957, 1958, 1970, 1972 1980

T84	Wishart No. 2 ✓	1958
T87	Timmins No. 1	1957, 1966, 1967, 1968 1971, 1973
T88.26	Timmins No. 3 South	1957, 1974, 1976, 1977 1978, 1980
T89	Timmins No. 2	1966, 1968, 1973
T90	Timmins No. 6	1968, 1973, 1976, 1977 1979
T91	Timmins No. 4	1973, 1975, 1976, 1977
T92	Timmins No. 7	1973, 1974, 1975, 1979
T92.94	Timmins Anomalies 16 and 16S and Dump Clearance	1970, 1975, 1976
T93	Houston No. 1	1961, 1976, 1977, 1978 1979
T94	Timmins No. 8	1973, 1975, 1979, 1980
T96	Redmond No. 1	1957, 1970, 1976
T97	Redmond No. 2	1957, 1962, 1973, 1976 1978
T100	Carol Lake	1973
T101	Christine Lake	1975, 1977
T103	"Pitting North Camp"	1956

4. PERMAFROST PREDICTION MAPS

Deposit	Map Title	Date
BARNEY 1	PERMAFROST DELINEATION	AUG. 1975
BARNEY 1	PERMAFROST PREDICTION	NOV. 1977
CAROL LAKE	PRELIMINARY PMF PREDICTION	NOV. 1972
FLEMING 3	VELOCITIES OF FROZEN ROCKS	JAN. 1971
FLEMING 3	DELINEATION OF PMF UPPER SURFACE	JAN. 1971
FLEMING 3	PMF PREDICTIVE MAP	MAR. 1971
FLEMING 3	PMF BASE DELINEATION BY RESISTIVITY	SEP. 1971
FLEMING 3	PMF PREDICTION FOR LIFT 2580	JUL. 1973
FLEMING 3	PMF PREDICTION FOR LIFT 2542	JUL. 1973
FLEMING 3	PMF DISTRIBUTION ALONG SECTION 440	MAR. 1974
FLEMING 3	PMF PREDICTION FOR LIFT 2504	JUN. 1975
FLEMING 3	PMF PREDICTION FOR LIFT 2466	JUN. 1975
FLEMING 3	PMF PREDICTION FOR LIFT 2504	OCT. 1975
FLEMING 3	PMF PREDICTION FOR LIFT 2466	OCT. 1975
KNOX MINE	PMF STUDY VLF IMPEDANCE	JUL. 1979
KNOX MINE	UNCORRECTED PHASE SHIFT	JUL. 1979
KNOX MINE	TOPO CORRECTED PHASE SHIFT	JUL. 1979
KNOX MINE	RESISTIVITY DEPTH SOUNDING	JUL. 1979
KNOX MINE	VLF, JULY 1979.	
ROWE MINE	PERMAFROST PREDICTION	
ROWE MINE	PMF PREDICTION FOR LIFT 2350	APR. 1973
ROWE MINE	PMF PREDICTION FOR LIFT 2350	JUL. 1973
ROWE MINE	PMF PREDICTION FOR LIFT 2312	JUL. 1973
ROWE MINE	PMF PREDICTION	AUG. 1973
TIMMINS 1	PMF PREDICTION	1968
TIMMINS 1	LONGITUDINAL SECTION A-A'	1968
TIMMINS 1	CROSS SECTION B-B'	1968
TIMMINS 1	CROSS SECTION C-C'	1968
TIMMINS 1	CROSS SECTION D-D'	1968
TIMMINS 1	TEMPERATURE-MOISTURE LIFT 2585	1970
TIMMINS 1	RESISTIVITY SURVEYS, LIFT 2585	1970
TIMMINS 1	RESISTIVITY, LIFT 2585	1970
TIMMINS 1	TEMPERATURE-MOISTURE, LIFT 2547	1970
TIMMINS 1	PERMAFROST PREDICTION FOR LIFT 2471	
TIMMINS 1	TEMPERATURE MEASUREMENTS, LIFT 2471	
TIMMINS 1	TEMPERATURE MEASUREMENTS, LIFT 2471	
TIMMINS 1	RESISTIVITY SURVEYS, LIFT 2433	
TIMMINS 1	RESISTIVITY, LIFT 2433	
TIMMINS 1	PMF PREDICTION, LIFT 2433	MAR. 1972
TIMMINS 1	PMF PREDICTION, LIFT 2433	SEP. 1972
TIMMINS 1	PMF PREDICTION, LIFT 2433	JUN. 1973
TIMMINS 1	PMF PREDICTION, LIFT 2319	JUL. 1975
TIMMINS 2	TOPOGRAPHIC SECTIONS OF TIMMINS 2 AND 6 DEPOSITS	
TIMMINS 2	VEGETATION	
TIMMINS 2	PMF DELINEATION	
TIMMINS 2	PMF DELINEATION	AUG. 1972
TIMMINS 2	PMF PREDICTION LIFT 2442	JUN. 1975
TIMMINS 2	PMF PREDICTION, LIFT 2404	JUN. 1975

TIMMINS	2	PMF PREDICTION, LIFT 2366	JUL. 1975
TIMMINS	2	LONGITUDINAL PMF SECTION	JUL. 1975
TIMMINS	3	PERMAFROST	
TIMMINS	3	VLF IMPEDANCE	AUG. 1979
TIMMINS	3	VLF PHASE ANGLE PHASE-SHIFT	
TIMMINS	3	ELECTERICAL DEPTH SOUNDING	AUG. 1979
TIMMINS	3	PMF DELINEATION	
TIMMINS	4	VEGETATION	
TIMMINS	4	PMF PREDICTION LEVEL 2540	
TIMMINS	4	PMF PREDICTION LEVEL 2490	
TIMMINS	4	PMF PREDICTION LEVEL 2440	
TIMMINS	4	PMF PREDICTION LEVEL 2400	
TIMMINS	4	PMF PREDICTION SECTION A-A'	
TIMMINS	4	PMF PREDICTION SECTION B-B'	
TIMMINS	4	PMF PREDICTION SECTION C-C'	
TIMMINS	4	PMF PREDICTION BASED ON RESISTIVITY	JUN. 1971
TIMMINS	4	EXPERIMENTAL SITE	
TIMMINS	4	PMF DELINEATION	SEP. 1975
TIMMINS	4	WATER TABLE	SEP. 1979
TIMMINS	4 AND 6	PMF PREDICTION	AUG. 1975
TIMMINS	6	PMF DELINEATION	AUG. 1972
TIMMINS	6	PMF DELINEATION	MAR. 1972
TIMMINS	6	PMF PREDICTION	NOV. 1977
TIMMINS	6	PMF, UNDATED (PROBABLY 1977).	
TIMMINS	6	SURFACE FEATURES	JUL. 1977
TIMMINS	6	VLF IMPEDANCE CONTOUR MAP	JUL. 1979
TIMMINS	6	VLF, PHASE ANGLE, UNCORRECTED PHASE SHIFT	JUL. 1979
TIMMINS	6	RESISTIVITY DEPTH SOUNDING	JUL. 1979
TIMMINS	6	PMF DELINEATION	JUL. 1979
TIMMINS	7	VLF IMPEDANCE	AUG. 1979
TIMMINS	7	VLF PHASE ANGLE, PHASE SHIFT ANGLE	1979
TIMMINS	7	RESISTIVITY DEPTH SOUNDING	AUG. 1979
TIMMINS	7	PMF DELINEATION	AUG. 1979
TIMMINS	7	PERMAFROST	AUG. 1979
		PMF PREDICTION, FLEMING 7 - TIMMINS 8	AUG. 1975
		REGIONAL PMF APPRAISAL, RETTY-BARNEY	MAR. 1973
		REGIONAL PMF APPRAISAL, TRIANGLE LAKE - GREENBUSH	MAR. 1974
		REGIONAL PMF APPRAISAL, GREENBUSH - GOODWOOD	SEP. 1978

5. OTHER AVAILABLE INFORMATION

5.1. ARCHIVES AT MCGILL UNIVERSITY

1. Box # 25, file 13 - a topographic map of Timmins 4.
2. Box # 26, file 14 - radiation, wind and air temperature data from 1972 at the Timmins 4 ground thermal amelioration plots.
3. Box # 26, file 16 - Timmins 4 global radiation charts, Sept. and May 1973.
4. Box # 26, file 27 - C.C.R.S. flight. Temperatures etc. during flight over Timmins 4.
5. Box # 27, file 8 - snow accumulation graphs from Timmins 4, 1968-1969. Compiled by H.B. Granberg.
6. Box # 27, file 10 - thermal conductivity of Schefferville rocks, data, reports 1972-1973.
7. Box # 27, file 19 - hygrothermograph chart, Timmins 4, August 17, 1976.
8. Box # 27, file 22 - vegetation survey and active layer data, Fleming 7.
9. Box # 27, file 25 - computer printout of Timmins 2 snow and elevation (base data) 1974.
10. Box # 27, file 35 - diffusivity graphs and notes.
11. Box # 27, file 36 - organic terrain, graphs and notes.
12. Box # 28, file 2 - Timmins 4, section 125, snow and elevation data.
13. Box # 28, file 18 - Timmins 4, geological sections.
14. Box # 28, file 22 - snowmelt photography (1972) and associated notes.
15. Box # 28, file 24 - Timmins 4 weekly radiation charts, April 1971 to June 1971.
16. Box # 28, file 26 - Timmins 4 snow temperatures from Sept. and Oct. 1974. Also 1975 hygrothermograph sheets.
17. Box # 29, - entire box is computer printouts.
 - i) digest of linear regressions, Timmins 4, Fleming 7, Timmins 3.
 - ii) Ferriman Ridge snow map - snow depth averages for 50 ft. rings.
 - iii) first prediction Timmins 4, July 1974 using snow R72.
 - iv) Timmins 3, Fleming 7 1974 snow maps, mean snow depth over 50 ft. rings, Aug. 1976.
 - v) Timmins 4 1974 corrected data, snow depth average for 50 ft. rings
18. Box # 30, file 21 - thermograph charts from Colin Thorn's Timmins 4 site, Sept. 25, 1970 to Nov. 7, 1971.

19. Box # 30, file 22 - thermograph charts from Timmins 4 thaw plot, Nov. 14, 1971 to June 14, 1972.
20. Box # 30, file 23 - thermograph charts from Timmins Shack 5, Dec. 27, 1970 to June 6, 1971.
21. Box # 30, file 24 - thermograph charts from Colin Thorn's Timmins Ridge site, snow depth sensor Nov. 13, 1970 to May 9, 1971.
22. Box # 30, file 25 - Timmins frost heave measurement site, June 1970 to Oct. 1971.
23. Box # 30, file 26 - thermograph charts from Timmins screen, Nov. 1969 to Sept. 1970.
24. Box # 30, file 27 - thermograph charts from Timmins Shack 5, Nov. 30, 1969 to June 19, 1970.
25. Box # 30, file 28 - thermograph charts from Colin Thorn's Timmins Ridge site, Nov. 30, 1969 to June 12, 1970.
26. Box # 30, file 29 - same as above but from Aug. 8, 1970 to Sept. 21, 1970.
27. Box # 30, file 30 - thermograph charts from Timmins 4 control plot, Sept. 13, 1972 to Sept. 12, 1973.
28. Box # 30, file 31 - thermograph charts from Timmins 4 thaw plot, Sept. 13, 1972 to Sept. 12, 1973.
29. Box # 30, file 32 - thermograph charts from Timmins 4 thaw plot, snow temperatures, Nov. 1, 1972 to May 21, 1973.
30. Box # 30, file 33 - thermograph charts from Timmins 4 control plot, snow temperatures Nov. 6, 1972 to April 18, 1973.
31. Box # 30, file 34 - actinograph records, Timmins 4 global, Sept. 13, 1972 to Sept. 12, 1973.
32. Box # 30, file 35 - hygrothermograph charts, Timmins 4, Sept. 15, 1972 to Nov. 11, 1972.
33. Box # 31, file 1 - hygrothermograph charts, Timmins 4, May 13, 1974 to Jan. 9, 1975.
34. Box # 31, file 2 - screen and ground (very shallow) temperatures for Timmins 4 control plot (chart form), Sept. 12, 1973 to May 16, 1974.
35. Box # 31, file 3 - shallow ground temperatures (chart form), Timmins 4 thaw plot, Sept. 12, 1973 to Sept. 12, 1974.
36. Box # 31, file 4 - snow temperatures, Timmins 4 thaw plot, Oct. 24, 1973 to Jan. 3, 1974.
37. Box # 31, file 5 - global pyrliometer, Timmins 4, Sept. 12, 1973 to Feb. 20, 1974 and May 7, 1974 to Nov. 7, 1974.
38. Box # 31, file 6 - snow temperatures, Timmins 4 control plot, winter '73/'74, Nov. 28, 1973 to May 1974.
39. Box # 31, file 7 - thermograph charts from Timmins 4 control plot, Nov. 7, 1971.
40. Box # 31, file 8 - thermograph charts from Timmins 4 thaw plot, Nov. 14, 1971 to Sept. 13, 1972.
41. Box # 31, file 9 - Timmins 4 radiometer charts, Oct. 3, 1971 to Sept. 13, 1972.

- 42. Box # 31, file 10 - hygrothermograph charts from Timmins 4 screen on control plot, June 1972 to Sept. 13, 1972.
- 43. Box # 31, file 15 - miscellaneous charts from Timmins 4, 1973 (e.g. global radiation, surface temperatures).
- 44. Box # 31, file 17 - miscellaneous charts from Timmins 4, 1973-74 (e.g. global radiation, surface temperature, heat flux).
- 45. Box # 31, file 18 - global radiation at Timmins 4 1972-74.
- 46. Box # 32, file 8 - global solar radiation data, Schefferville, May 1974 to Mar. 1977.
- 47. Box # 32, file 10 - Knob Lake thermograph charts, May 1963 to July 1966.
- 48. Box # 32, file 11 - Knob Lake hygrograph charts, May 1963 to Nov. 1966.
- 49. Box # 32, file 12 - Dolly Ridge thermograph charts, June 1961 to Aug. 1965.
- 50. Box # 32, file 13 - hygrothermograph charts, Knob Lake, July to Nov. 1966.
- 51. Box # 32, file 14 - meteorological data, 1961-1963, Dolly Ridge, Woods site, Mine Dry, Ferriman Ridge.
- 52. Box # 32, file 16 - Ferriman Ridge thermograph charts, June 1959 to Aug. 1965 (discontinuous).
- 53. Box # 33, file 1 - thermograph charts from Woods site, 1961-66 (discontinuous).
- 54. Box # 33, file 2 - RCAF (Marconi, Lakesite) thermograph, Oct. 1962 to July 1963.
- 55. Box # 33, file 4 - Ferriman and West Ridge stations, climate data, June 1959.
- 56. Box # 33, file 5 - recording anemograph charts, Ferriman Mine Dry, July 1959 to May 1962 (discontinuous).
- 57. Box # 33, file 6 - Ferriman Mine Dry thermograph charts, June, 1959 to Aug. 1965.
- 58. Box # 33, files 8 - Knob Lake hygrograph and thermograph
13 - charts,
16 - 1968-1972.
- 59. Box # 40, 41, 42 - various hydrologic data from the Schefferville area.

5.2. ATMOSPHERIC ENVIRONMENT SERVICE DATA

In addition to the archived material at the McGill University Library there exists a great deal of standard climatological data from the weather station at Schefferville. This information is published by the Atmospheric Environment Service. Climate summaries for the area have also been published by Tout (1964) and Barr and Wright (1981).

5.3. I.O.C.C. FILES

Although only the I.O.C.C. permafrost prediction maps are presented here, there exists a complete set of topographic maps at scales of 1:4800 and 1:1200 covering parts of the mining area. Also included in I.O.C.C. files are a variety of geologic maps and sets of aerial photographs in the visible and near-infrared bands.

5.4. MISCELLANEOUS INFORMATION AT MCGILL

On file at the Department of Geography, McGill University there are several data sets for which information is incomplete. These consist of:

- 1) Data from sites, the locations of which are not precisely known. Data from these sites is predominantly near-surface (<0.40m) ground temperatures and may be appended to the data file as an update if they are accurately located at a later date.
- 2) Data files in which the temperatures are presented as a resistance reading. For these cables, calibration equations have not been found, however, should conversion to temperature become possible at a later date these files will be appended as an update to the main data file.

APPENDIX I

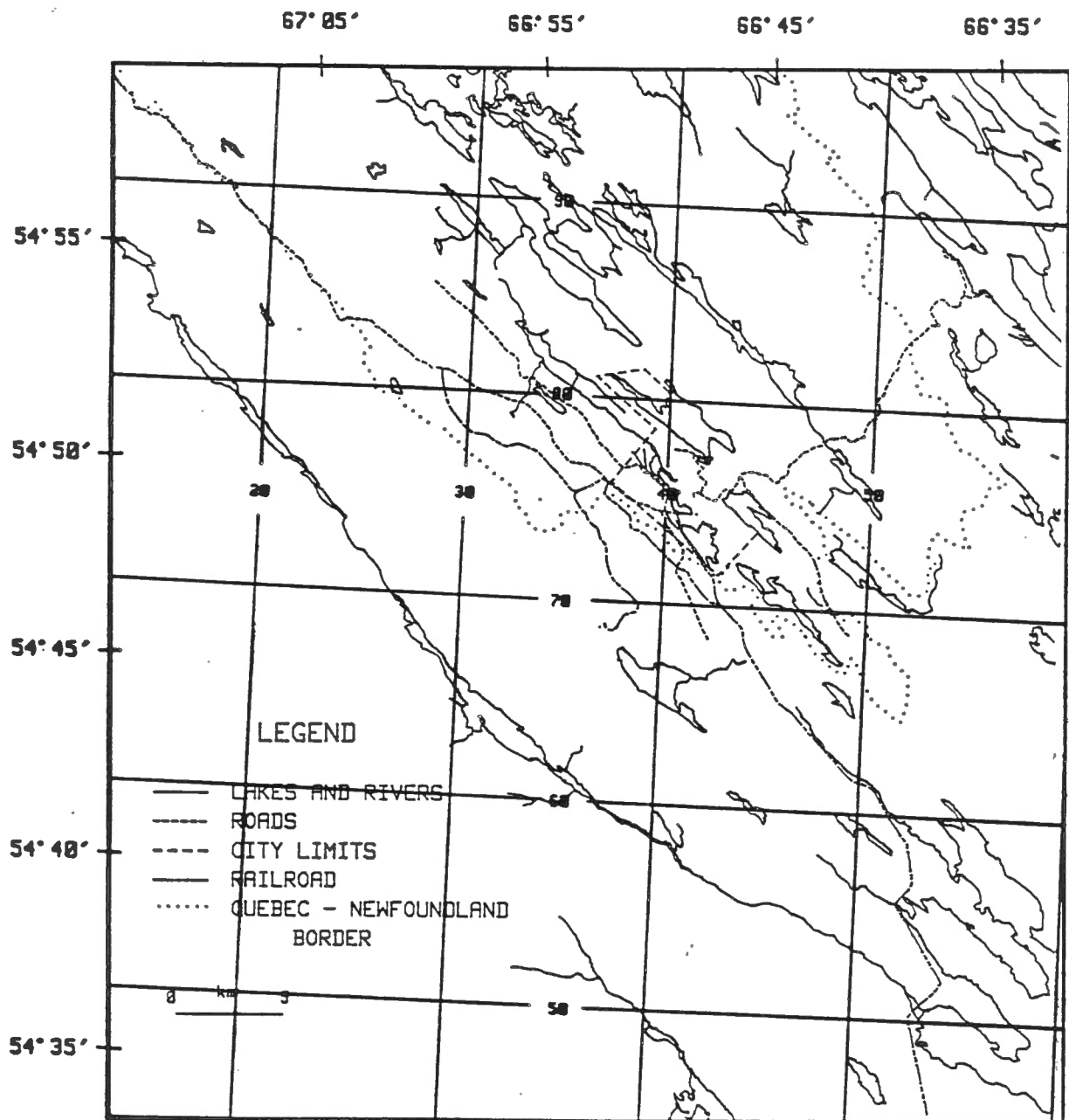
TABLE OF BASE LINE INFORMATION

BASE LINE	SECTIONS		STARTING		ENDING	
	STARTING	ENDING	NORTHING	EASTING	NORTHING	EASTING
Sundown						
1. Barney 1	580-790		63602.97	40392.33	78452.21	25542.46
Barney EXT	678-763		73997.44	36927.40	80007.85	30916.99
2. Bean Lake TRX	734-749		78664.34	33674.70	79725.01	32614.05
3. Burnt Creek 1, 2, 3	145-205		16840.26	96159.74	12597.62	100402.38
4. Burnt Creek 5	55-82		31483.10	82517.00	33392.29	80607.81
5. Crouse Lake	67-90		30331.60	79668.40	31957.95	78042.05
6. Denault 1	425-455		59289.62	57999.18	61410.94	55877.86
7. Denault 2	123-160		40541.40	81958.60	43157.70	79342.30
8. Denault 3	87-107		37494.93	84005.08	38909.14	82590.87
9. Elross 2	122-129		40081.80	81640.40	40576.77	81145.43
10. Elross 3	600-651		58426.01	32347.38	60688.75	30084.64
11. Elvis	591-639		56292.03	31522.31	59686.14	28128.20
12. Ferriman-Fleming	(-206)-(-340)		-14285.37	101920.10	-23760.60	111395.33
13. Ferriman-Fleming	175-215		37369.32	71434.21	40197.74	68605.78
14. Ferriman-Fleming	386-425		52289.27	56514.25	55046.98	53756.54
15. Ferriman-Fleming O/S	478-596		58794.65	50008.87	67138.51	41665.01
16. Ferriman 1	350-502		56814.75	66130.91	67562.77	55382.89
17. Ferriman O/S	122-173		31219.79	72780.20	34826.04	69173.95
18. Ferriman 3	90-130		27542.84	73628.73	30371.27	70800.30
19. Ferriman 4	143-179		37260.16	74673.40	39805.83	72129.50
20. Ferriman 7	215-270		40197.74	68605.78	44086.83	64716.69
21. Fleming 3	125-185		29181.94	70318.07	33424.58	66075.43
22. Fleming 5	380-457		47060.68	52134.08	52505.40	46689.36
23. Fleming 6	341-386		47692.72	58283.76	50874.70	55101.78
24. Fleming 7	308-386		46773.83	62029.69	52289.26	56514.26
	445-508		53351.14	49232.83	57805.91	44778.06

25. Fleming 8					
	308-515	46066.27	61322.43	68482.01	54463.65
26. Fleming 9					
	425-478	55046.98	53756.54	58794.65	50008.87
Goodwood 1					
	1470 - 1598	135091.46	-13984.27	144142.43	-23035.24
27. Houston					
	309-364	-4104.23	126669.03	-7992.66	130558.97
Howells River West 1					
	665-864	49237.23	14000.76	66135.10	2761.18
Howells River West					
	865-1093	66205.75	2690.40	85028.31	10731.61
Howells River West 4					
	1093-1277	87008.20	-8751.70	100018.97	-21762.47
28. Howse					
	669-720	64753.97	28957.26	68360.21	25351.02
29. Huntet					
Key Lake					
	355-475	57239.02	65848.06	65724.30	57362.78
Kivivic 4					
	16-84	116225.00	433.00	120962.46	-4445.16
Kivivic 5					
	(-16)-30	124063.60	-4770.30	127825.58	-7417.48
30. Knob Lake Ridge					
	0-125	24585.79	93414.21	33424.62	84575.37
31. Knob Lake 1					
	15-44	18057.16	98442.84	20107.77	96392.23
Knox Mine see Fleming 6					
32. Lance Ridge 1					
	245-315	45167.68	69333.26	50117.43	64383.51
33. Lance Ridge 2					
	270-306	48703.22	69333.26	51248.80	66787.68
34. Lance Ridge 3					
	306-325	51637.71	67176.69	52981.21	65833.19
Leroy 1					
	18-32	141474.20	-5942.40	142522.69	-6870.23
35. Malcolm 1					
	(-309)-(-70)			14216.54	111213.92
36. Redmond 1					
	(-200)-(-300)	-10180.18	105180.18	-17251.25	112251.25
37. Redmond O/S					
	(-314)-(-296)	-19089.72	112392.87	-17816.93	111120.08
Redmond 5					
	(-185)-(-125)	-9695.54	103563.96	-5452.70	99321.33
38. Redmond 2					
	(-185)-(-230)	-9695.34	103563.96	-12877.32	106745.94
39. Redmond 2 O/S					
	(-202)-(-185)	-9483.21	106180.26	-8281.13	104978.18
Retty see Fleming 5					
40. Ruth Lake Extn. (James Mine)					
	50-125	15236.88	95263.71	20540.18	89960.41
41. Ruth Lake 1					
	146-195	22346.40	88795.10	25740.48	85259.57
42. Ruth Lake 7					
	63-80	28037.82	77942.08	29239.90	76740.00
43. Ruth Lake 8					
	146-175	19025.66	85474.34	21076.27	83423.73
42. Ruth Lake 9					

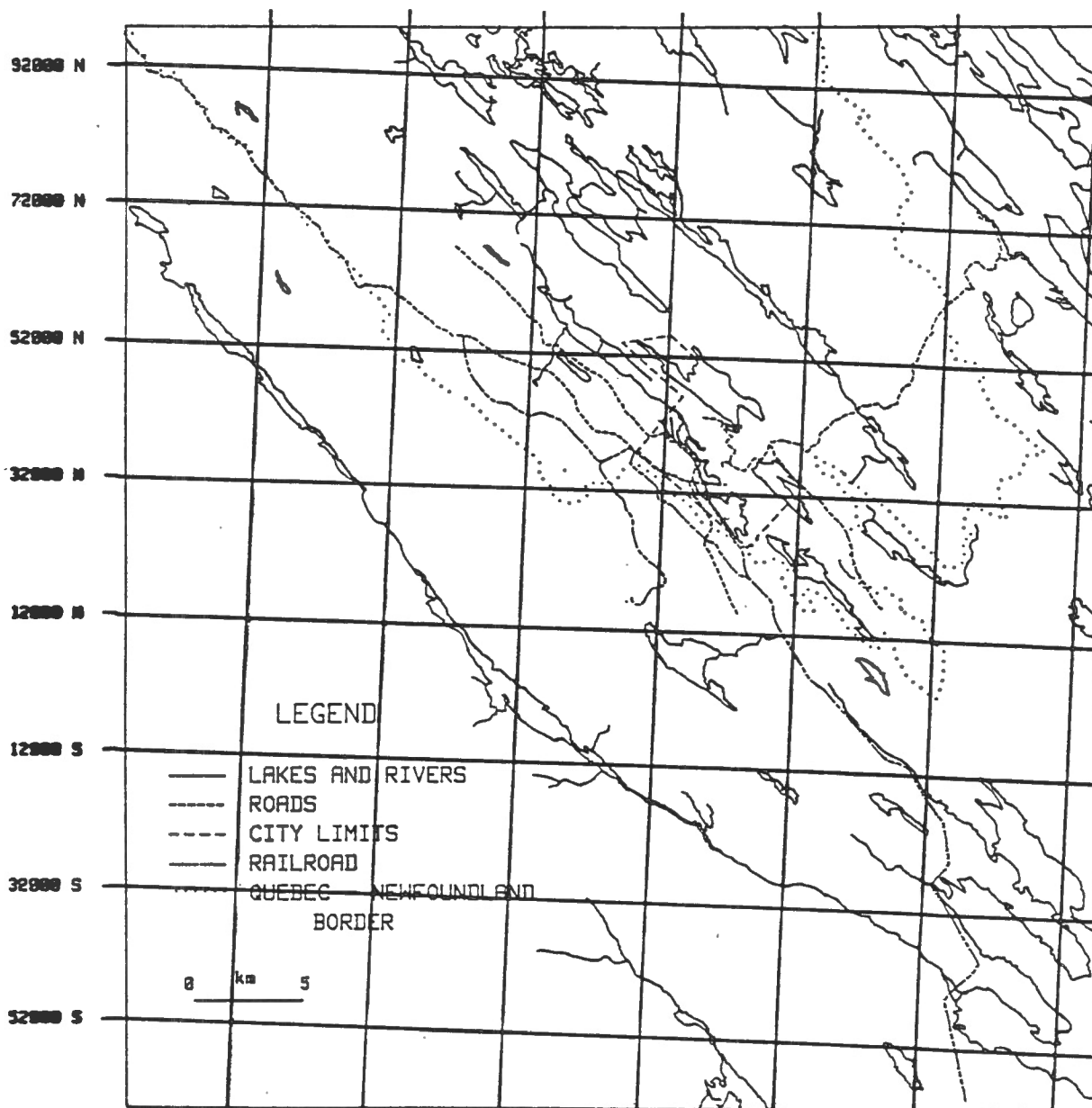
	32-63	25845.79	80134.11	28037.82	77942.08
44. Ruth Lake 9 O/S	12-27	22310.26	79427.00	23370.92	78366.34
45. Sawmill H2	475-496	60279.58	51918.06	61764.50	50433.14
Squaw Lake	38-50	60318.80	84090.10	59470.25	84938.61
46. Star Creek 1	208-245	43300.94	72699.06	45917.23	70082.77
47. Star Creek 2	195-263	39631.66	70868.32	43167.19	67332.79
48. Star Creek 3	270-307	44086.82	64716.70	46703.12	62100.40
Sunny 1	0-56	129604.40	6699.80	132419.72	1858.93
49. Timmins 1	510-585	54622.21	41311.37	59925.51	36008.07
50. Timmins 2	552-606	59167.38	39916.94	62985.76	36098.56
51. Timmins 3	450-550	53278.86	48453.49	60349.93	41382.42
52. Timmins 4	610-710	62278.65	34825.77	69349.72	27754.70
53. Timmins 4 O/S (Pinette Lake)	590-646	59167.38	34542.93	63127.18	30583.13
54. Timmins 6	606-640	62985.76	36098.56	65389.92	33694.40
55. Timmins 7, 8	543-618	59854.09	41876.48	65157.39	36573.18
56. Timmins 7, 8 O/S	572-591	62894.65	40815.82	64238.15	39472.31
57. Wishart 1	70-154	8151.67	85348.33	14091.36	79408.64
58. Wishart 2	87-115	8222.36	83014.90	10202.26	81035.00
	147-191	12465.00	78772.26	15576.27	75660.99
59. Wishart 2 O/S	87-196	7939.52	82732.06	15646.98	75024.60

UTM GRID - LONGITUDE AND LATITUDE



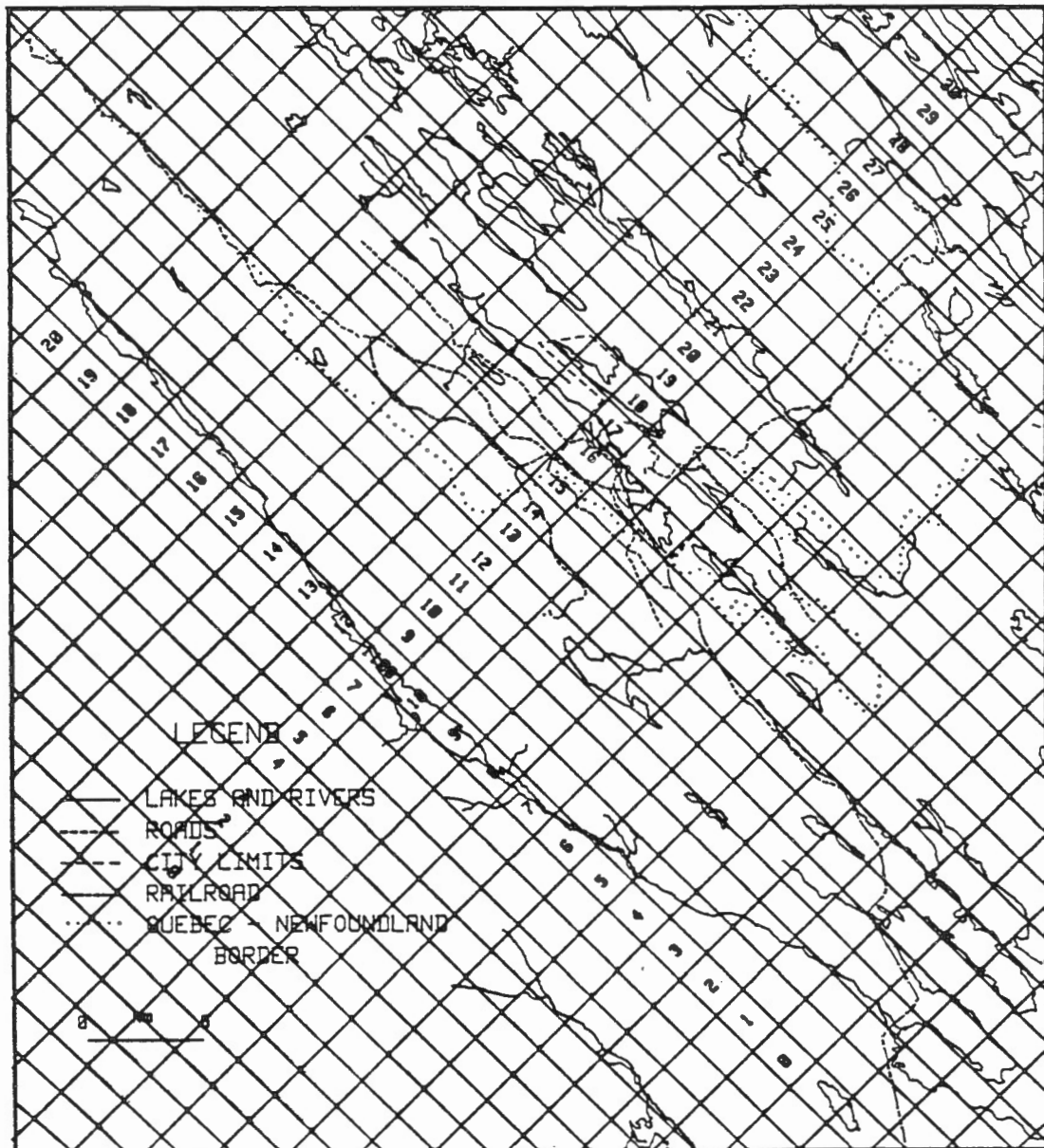
IOCC GRID

29000 E 49000 E 69000 E 89000 E 109000 E 129000 E 149000 E

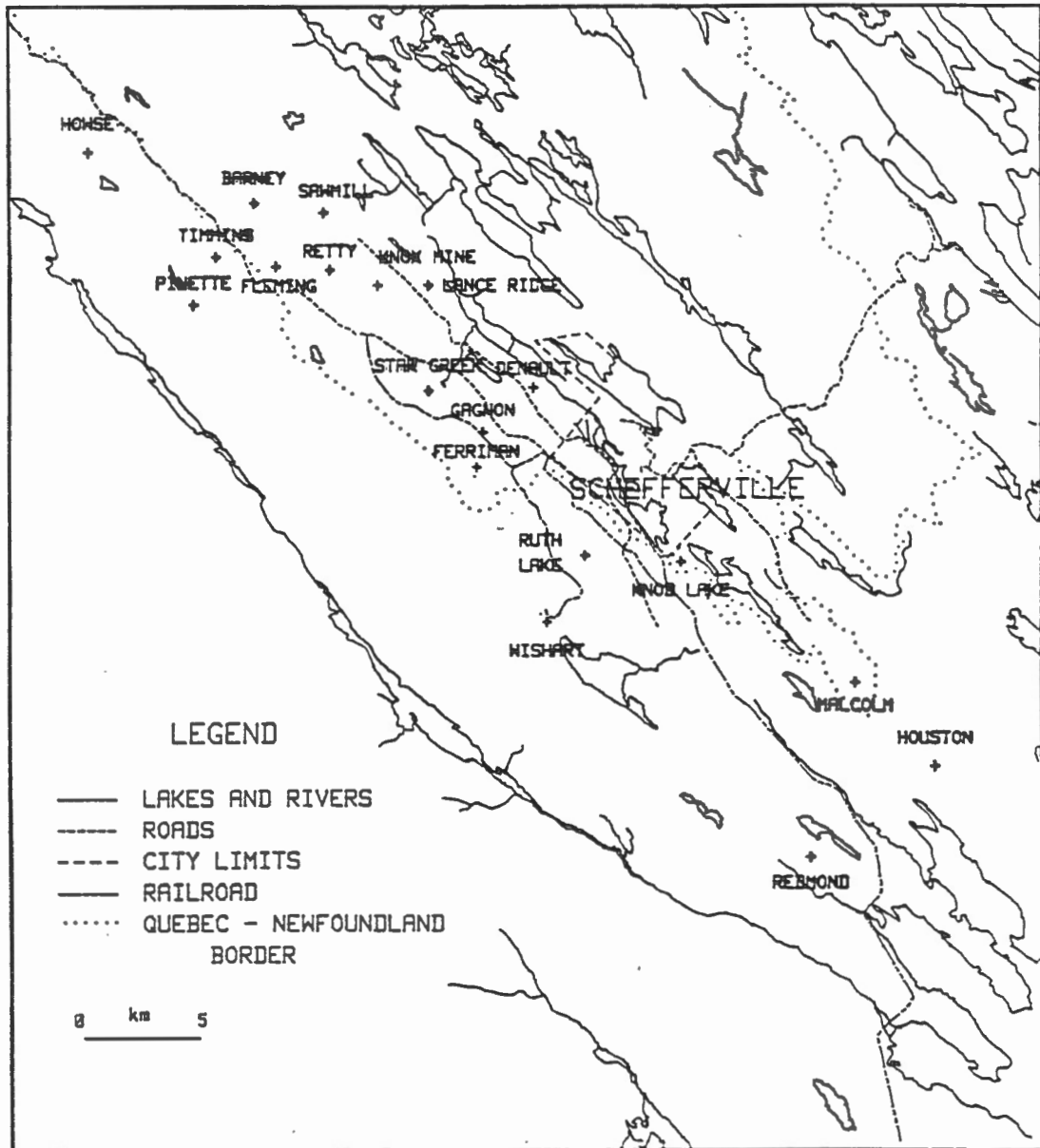




IOCC MAP GRID



LOCATION MAP



IOCC BASE LINES

