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HEAVY MINERAL ANALYSIS IN LATE WISCONSINAN TILLS OF SOUTHEASTERN MANITOBA

BY

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"HEAVY MINERAL ANALYSIS IN LATE WISCONSINAN

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ABSTRACT

The heavy mineral assemblages in the fine and very fine sand fraction (2-4 Ø) of the four upper late Wisconsinan tills in southeastern Manitoba were catalogued and evaluated. Twenty-six heavy mineral species were identified under the microscope. Typically in the samples of all till units there is 34-49 % hornblende, 8-15 % epidote, 4-14 % pyroxene, 7-14 % magnetite, and 1-9 % garnet; apatite, tourmaline, biotite, pyrite, and hematite normally make up 1-5 % of the heavy mineral suite in all samples. Till units identified previously on the basis of texture and clast lithology could not be distinguished consistantly or reliably using heavy mineral suites, single species, or ratios of selected species.

The Paleozoic bedrock of central Manitoba contributed little to the heavy mineral suites of the tills. In spite of local variations, the Precambrian source rocks display an overall (average) similarity in mineralogy. The result is a striking uniformity in the heavy mineral content of the four upper tills in southeastern Manitoba. Sandy tills of the Labrador lobe, which were deposited by ice moving from northeast to southwest, are weakly distinguished by a higher total heavy mineral content from tills deposited by the northwest to southeast advancing Keewatin lobe. This higher percentage is explained by the relatively close proximity of the Precambrian source area of the Labrador tills.

The correlations of tills in Manitoba with those in North Dakota and Minnesota made by previous workers mainly on the basis of texture, clast lithology, and stratigraphic position, cannot be substantiated by

heavy mineral studies. The tills in Manitoba contain significantly more epidote and less hornblende and garnet than their correlatives to the south, and large differences in other major mineral species occur between the units.

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CHAPTER I

INTRODUCTION

General Statement

The glacial record in North America indicates at least four major glaciations, each of which occupied a period of about 100,000 years (Prest, 1970). The extent of the first three of these in Manitoba is not known, although pre-late Wisconsinan sediments are thick over much of southeastern Manitoba. The ice sheets which covered Manitoba during Wisconsinan time had two major centres of accumulation: (1) in the Northwest Territories west of Hudson Bay, called the Keewatin Centre, from which the ice spread south to southeast, and (2) in northern Quebec and Labrador, called the Labrador Centre[1], from which the ice spread southwest. They are a part of the Laurentide Ice Sheet (Prest, 1970), and will be referred to as the Keewatin lobe and the Labrador lobe. Southeastern Manitoba was covered entirely at the maximum extent of both ice lobes. The ice advanced and retreated many times during Wisconsinan time, reworking older deposits, grinding deeper into bedrock, and depositing new sediments. The areas of bedrock contributing most to these deposits in Manitoba were the Precambrian Shield of Manitoba and northwestern Ontario, and the Paleozoic carbonates and Cretaceous and Jurassic shales of central and southern Manitoba.

1 Some authors, notably Tyrrell (1913) and Zoltai (1961), indicate the presence of a centre of ice accumulation southwest of James Bay, known as the Patrician Centre. Its existence has not been established and is thus not considered in this paper.

Objectives

The glacial stratigraphy of southeastern Manitoba has been described in detail by Fenton (1974) and Keatinge (1975) and has been modified by Teller (1976, pers. comm.). Four late-Wisconsinan tills are recognized, from oldest to youngest, the Senkiw Formation, Roseau Formation, Marchand Formation and an upper till, here called Unit 4. The objectives of this study are to:

1) catalogue the heavy mineral assemblages of each till,

2) determine till provenance using the heavy mineral suites or individual heavy minerals.

3) characterize individual tills using heavy minerals, and

4) correlate the results of this work with the heavy mineral study of Hobbs (1973) in North Dakota.

Location

The area of study (Fig. 1) is located in southeastern Manitoba. It is bounded on the west by the Red River and the southeastern shore of Lake Winnipeg, on the north by the Sandy and Moose Rivers, on the east by the Manitoba-Ontario border, and on the south by the International Boundary. The size of this area is about 10,000 square miles (25,600 sq. km).

Previous Work

The glacial stratigraphy of the southern part of the study area is described in detail by Fenton (1974) and Keatinge (1975). The Pleistocene stratigraphy of the northern portion of the study area is described by McPherson (1968, 1970) and McPherson et al (1971). Tills along the

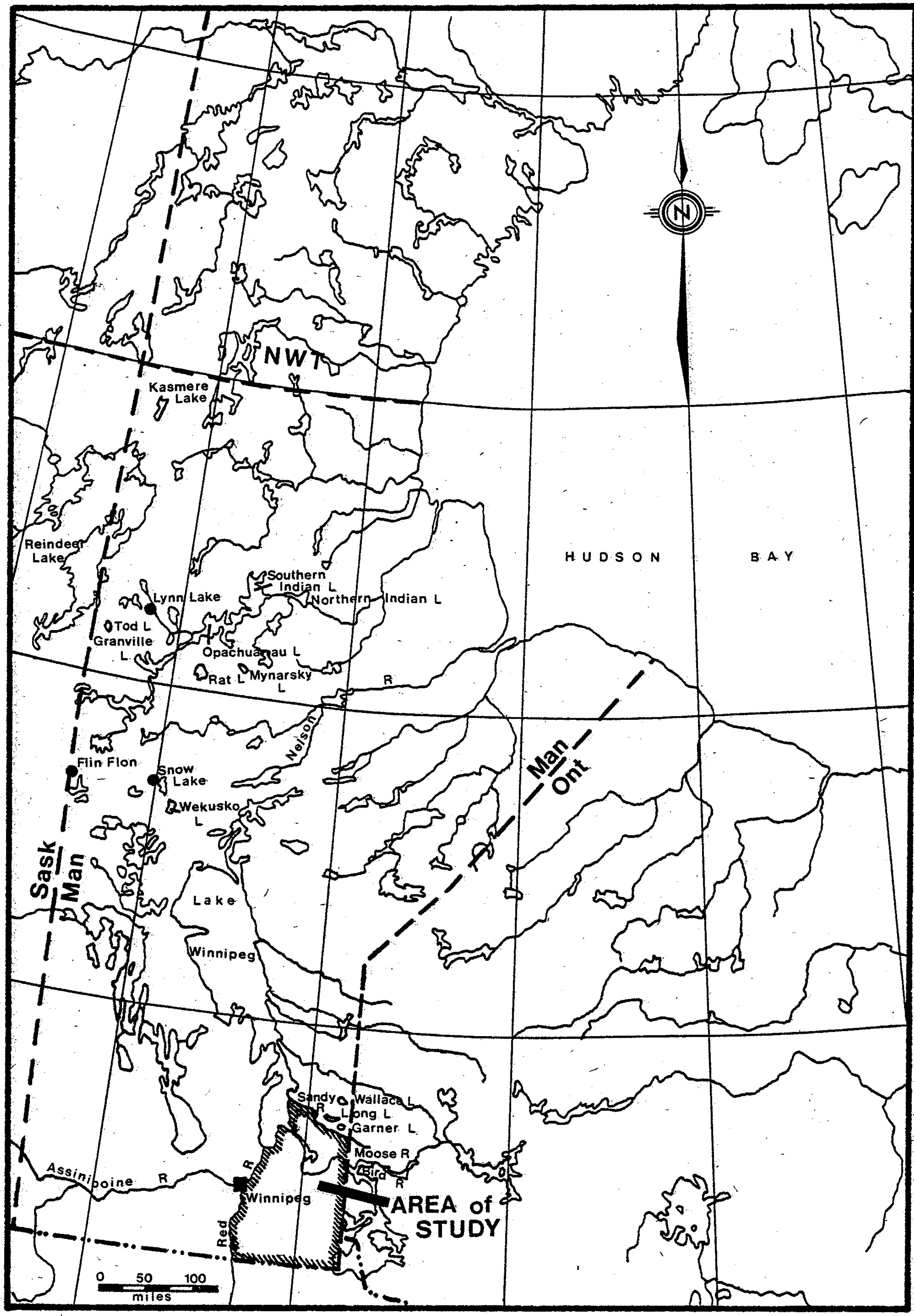

Figure 1. Area of study and place names mentioned in text.

Trans-Canada Highway east of Winnipeg were studied by Muhammad (1972). In Minnesota and North Dakota, the glacial stratigraphy has been summarized by Harris (1973), Harris et al (1974), Moran et al (1975), and Salomon (1975).

A stratigraphy based on the studies of Fenton (1974), Keatinge (1975), and McPherson (1970) which has been subsequently modified by Teller (1976, pers. comm.) is used in this study.

The study of heavy minerals of glacial deposits near the thesis area is limited. Di Labio (1973) attempted a preliminary heavy mineral study in southern Manitoba by analyzing till samples collected by Fenton (1970). Wallace and McCartney (1928) and Organ (1952) discuss briefly the heavy minerals in Pleistocene deposits of western Manitoba and Birds Hill respectively. Hobbs (1973) presents a detailed analysis of the heavy minerals occurring in the glacial deposits of North Dakota and northwestern Minnesota.

In Canada, the study of heavy minerals in glacial deposits has been concentrated in the southern Ontario region; the works of Cook (1952), Knox (1952), Moretti (1954), Dreimanis et al (1957), Vagners (1969) and Gwyn (1971) are good examples. Their research presents guidelines for the differentiation of tills through the use of heavy mineral identification and correlation in southern Ontario.

CHAPTER II

SAMPLE PREPARATION

Introduction

Samples of the tills used in this study came from several sources: (1) borehole and surface samples collected by Dr. J. T. Teller, University of Manitoba, Department of Earth Sciences, during the summers of 1971, 1972 and 1973,
(2) borehole samples collected by R. A. McPherson (1970), and
(3) borehole samples collected by Bill Last and myself during the Manitoba Water Resources (Department of Mines, Resources and Environmental Management) drilling program of 1973.

A total of 44 sample sites from the above sources were chosen for the study (Fig. 2); this includes 93 samples, with at least one from each till at every site. Usually the borehole samples were chosen from wells which contained more than one till. Wherever possible, samples were chosen from holes that reached bedrock. I attempted to obtain a uniform sample density throughout the area to aid in correlation and in the identification of trends.

A flow chart indicating the handling of all samples is reproduced in Figure 3.

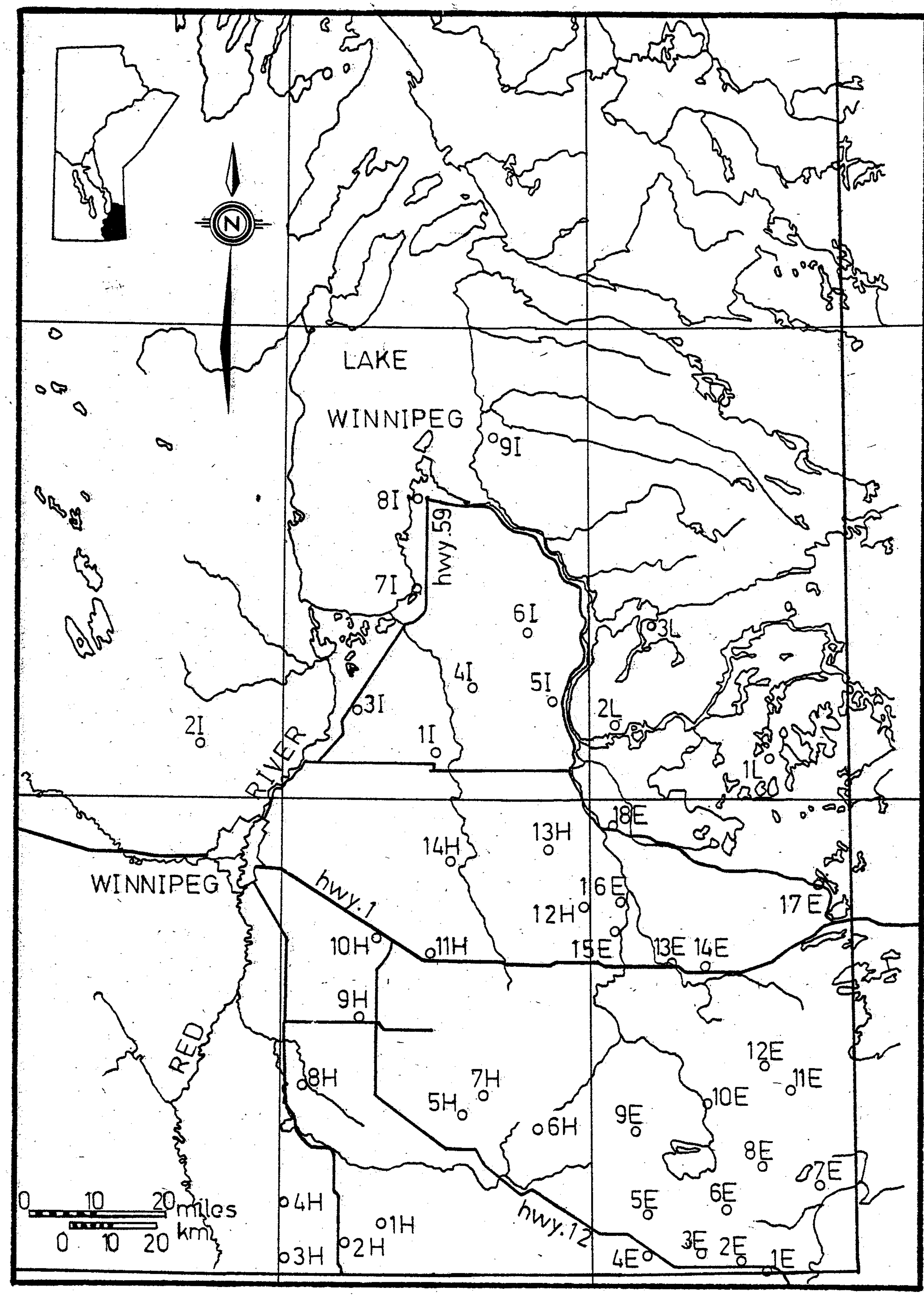

Figure 2. Location of sample sites.

DRIED FIELD SAMPLE

gentle crushing (rubber mallet)

splitting (50 g.)

dissaggragation (soaking in water)

wet sieving to remove 2 - 4 Ø fraction

drying and weighing of 2 - 4 Ø fraction

heavy mineral separation using bromoform

splitting h.m. fraction for slide mount

SLIDE MOUNT

FIGURE 3. Flow Chart Showing Sample Preparation

Heavy minerals, those minerals which have a specific gravity greater than about 2.89, are commonly a very minor constituent of a detrital mineral assemblage, usually making up less than 1% and rarely exceeding 5% of the total sample (Mueller, 1967). Why then is this fraction of the geologic record studied in detail by many authors? There are several reasons:

(1) heavy minerals are relatively easy to isolate and identify,

(2) heavy minerals have been shown to be indicators of provenance of the sedimentary unit in which they are found, and

(3) heavy minerals can be used, like other lithologic parameters, to correlate sedimentary units over relatively large areas.

Choice of Grain Size

Table 1 indicates the size fractions used by various authors in their investigations of heavy minerals. All fall within the sand size fraction (-1.0 ø to 4.0 ø or 2.0 mm to 0.0625 mm), with most authors studying the fine sands. I have chosen the 2 ø to 4 ø interval, fine and very fine grained size, for heavy mineral analysis for several reasons:

(1) the coarse limit was chosen so that the cover slides could still be easily placed over samples without causing air bubbles under the slide.

(2) Kruger (1937) noted that coarser fractions (larger than 2 ø) tend to include rock fragments more often than the finer sands. As only pure mineral species were sought, the coarser fragments were avoided.

(3) the 2-4 ø size range incorporates a majority of the heavy minerals in the heavy mineral assemblage of a sediment. Mueller (1967) noted that heavy minerals are enriched in the fine sands.

(4) the lower limit (4 ø) was set because identification of minerals smaller than this size becomes increasingly difficult.

Bromoform Analysis

The 2-4 ø sand samples were not pretreated with hydrochloric acid as many workers have done. Acidizing will remove iron oxide stains and cements, carbonates, pyrite, and apatite. In a preliminary study, iron oxide staining on grains was not found to be an impediment to identification, so this step was eliminated.

TABLE 1 SIZE FRACTIONS USED BY VARIOUS AUTHORS IN THE INVESTIGATION OF HEAVY MINERALS

	PHI (ø)	MM
ARNEMAN & WRIGHT (1959)	2 - 4	0.25 - 0.0625
BAYROCK (1962)	2.75 - 3.75	0.15 - 0.075
CONNALLY (1964)	1.5 - 4	0.35 - 0.0625
COOK (1952)	0.25 - 2.75	0.833 - 0.147
DiLABIO (1973)	2 - 3	0.25 - 0.125
GWYN (1971)	2 - 4.75	0.25 - 0.037
HOBBS (1973)	2 - 3	0.25 - 0.125
KNOX (1952)	1.3 - 2.75	0.39 - 0.149
KRUGER (1937)	2 - 4	0.25 - 0.0625
LINDBERG (1944)	-1 - 4	2.00 - 0.0625
MORETTI (1954)	0.25 - 2.75	0.833 - 0.147
MUELLER (1967)	2.25 - 4	0.20 - 0.0625
MURREY (1953)	2 - 4	0.25 - 0.0625
TELLER (1972)	2 - 4	0.25 - 0.0625
VAGNERS (1969)	2 - 5	0.25 - 0.031

The fine and very fine sands were handled in the standard bromoform-gravity apparatus as outlined by Gwyn (1971). Tribromonethane, $CHBr_3$ (bromoform), with a specific gravity of 2.89, was the heavy liquid used. The density of the bromoform was frequently checked by the pyknometer method and remained constant throughout the study.

Mounting of Grains

The bromoform-gravity apparatus invariably yielded more heavy minerals from a 50 g sample than were necessary for grain mounts. In order to reduce the size of the sample, the method of coning and quartering was employed (Otto, 1933). By this method the sample is poured onto a glass slide until a cone is formed. A small piece of plastic is used to quarter this cone. The subsequent sample fraction is again coned and quartered. This process is repeated, usually about two or three times, finally resulting in a representative sample size of 1000 - 5000 grains.

Each slide of heavy minerals was prepared in the following way:

(1) A glass petrographic slide (size 27 x 46 mm) was heated on a hotplate.

(2) A small amount of Aroclor #4465 (Monsanto Canada Ltd., n = 1.664 to 1.667) was placed on the slide until it melted.

(3) The representative heavy mineral fraction was sprinkled over the molten medium and spread evenly over the slide with a thin metal rod. It was found best to remove the slide from the hotplate at this point to allow the Aroclor to harden somewhat.

(4) A cover slip was then placed over the centre of the slide and the slide was once again put on the hotplate, allowing the Aroclor to remelt. The cover slip was pressed gently downward from the centre towards its edges with a small wooden rod. In this way, few bubbles occur in the resulting petrographic slide.

(5) The slide was removed once again from the hotplate, and the cover slip was pressed gently and evenly with a soft cloth or wooden rod until the medium hardened. The slide was subsequently cleaned with a drop of acetone and a soft cloth. It was then ready for observation under the microscope.

Identification of Grains

A Wild petrographic binocular microscope was used for the identification of the minerals. Identification was based on the standard optical properties: color, pleochroism, birefringence, optic sign, elongation, direction of maximum absorption, and extinction angle. Mineral form, including the presence and type of cleavage, fracture, and surface features, as well as inclusions and alterations were also criteria used in the identification of the minerals.

Description of Minerals

All mineral species encountered under the microscope are dessribed in Appendix A. Only those properties which are diagnostic of the particular species are mentioned. Fine works dealing with complete detrital mineral descriptions are those of Krumbein and Pettijohn (1939), Milner (1940), and Tickell (1947). Kerr (1959) and Heinrich (1965) present useful identification tables, and each contains a chart of interference colors (in color).

The minerals encountered during the study, listed in general order of abundance are: hornblende, epidote, orthopyrozene, clinopyrozene, garnet, apatite, tourmaline, biotite, magnetite, pyrite, hematite, leucozene, altered minerals (alterands), rutile, zircon, staurolite, titanite (sphene), monazite, kyanite, actionolite, brookite, fluorite, glaucophane, corundum, chlorite, zoisite, and dolomite.

Point Counting

The "line method" of counting minerals, as described by Galehouse (1971), was used in this study. A mechanical point counting stage was used to set up equidistant linear traverses across each slide. An individual mineral was counted as it was encountered by the intersection of the crosshairs. The traverses were planned such that the entire area of the slide was sampled in the count. This eliminated inconsistancies derived from bias that may have occurred in the assemblages when they were spread out over the slide during production.

There are potential dangers in using the results statistically. Galehouse (1971) points out that the resultant values are a "number frequency" and not a percent frequency, simply showing how often a species is encountered during the count. "The sample is biased because a larger grain is more likely to be encountered during the analysis than a smaller one. The number frequency underestimates the area of larger grains and overestimates the area of smaller grains." (Galehouse, 1971, p. 392-394). The percentage is also larger than the number percent for larger grains and smaller than the number frequency. Number frequency only equals the number percent in the line method of counting when all the grains have the same cross-sectional area. The errors can be minimized by counting only a limited particle size range. The results of this report are treated as frequency percent because of the relatively narrow range of particle sizes studied (2-4 ø).

There is some differences of opinion in regard to how many heavy mineral grains per sample should be counted. Gwyn (1971) found that point counts for minerals making up 10% or less of the total heavy mineral fraction stabilized after 400 counts and that for minerals making up 10% or more of the total sample, the count stabalized after 300 counts. Galehouse (1971) indicates that 300 counts result in accurate readings. Two counts of the same slide produces no significant difference at the 95% confidence level of statistical T and F tests according to Gwyn (1971). Below 300 counts, reliability decreases slowly. On the basis of these results, I decided to count 350 to 450 grains per slide, averaging about 400 grains.

CHAPTER 111

SOURCE AREAS OF HEAVY MINERALS

Glacial Movement

Part of the Wisconsinan glacier moved south from the Keewatin Ice Centre located northwest of the present-day Hudson Bay (Fig. 4). As indicated by striae, eskers and other glacial landforms (Prest, 1970), the Keewatin lobe advanced southward and southeastward across the Precambrian rocks of northern Manitoba (Churchill Province), and continued 300 to 350 miles (480 to 560 km) across the Paleozoic strata of central Manitoba to the study area. Instrumental in directing the path of this Wisconsinan glacial lobe were the regional northwest trend of the Palezoic bedrock, the regional bedrock slope toward the northeast, and topographic features such as the Manitoba Escarpment.

Another part of the Wisconsinan ice sheet, the Labrador lobe, moved west and southwest from the Labrador Ice Centre located south of Ungava Bay, Quebec. This advance moved across much of the Precambrian rock of the Superior Province in the Canadian Shield into the area of study. Glacial striae, groovings and land forms in western Ontario and southeastern Manitoba (Prest, 1970) indicate a westerly to southwesterly advance of the Wisconsinan ice which affected the main portion of the Superior Province (Fig. 4).

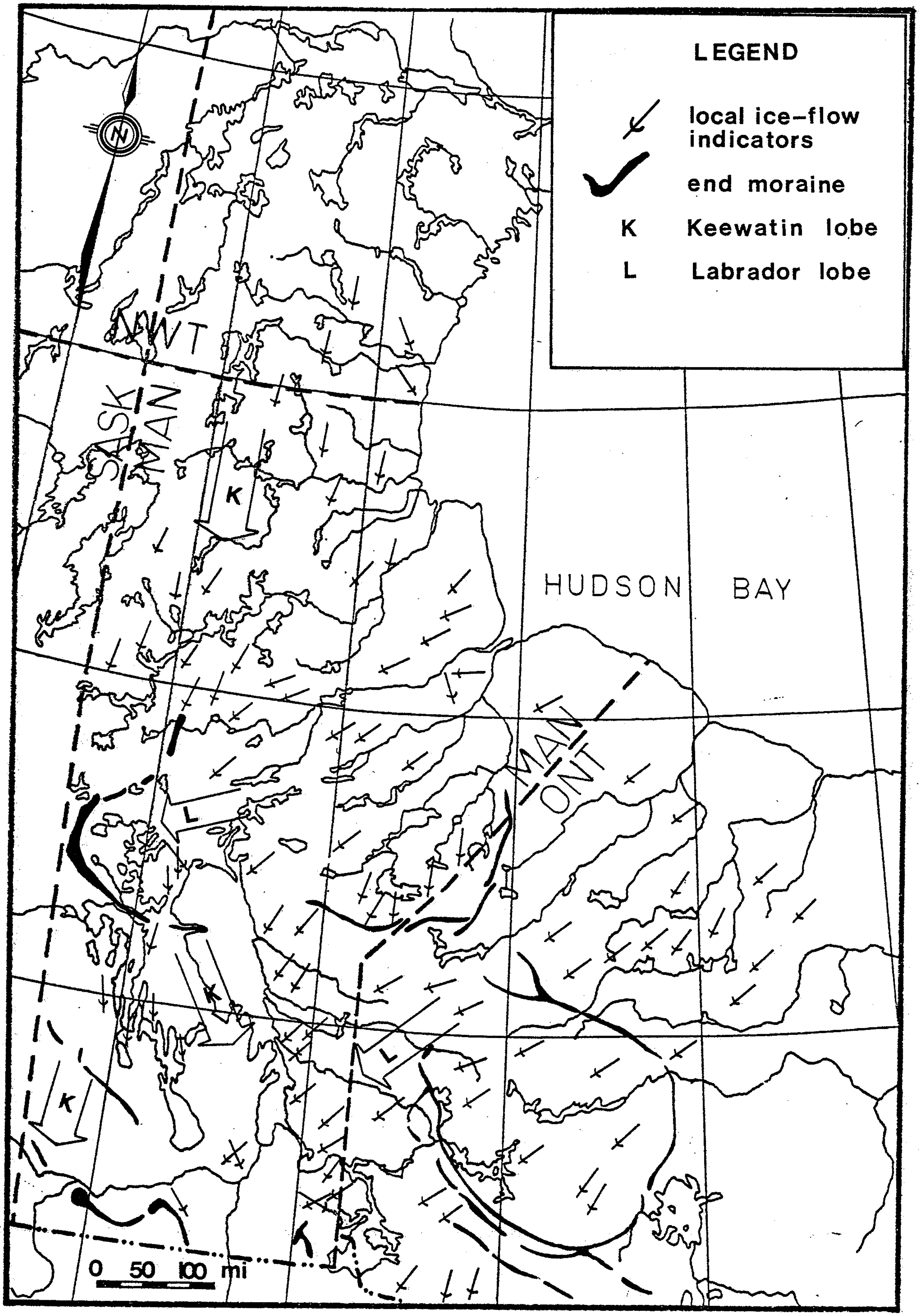

Figure 4. Glacial movements.

Paleozoic Bedrock

General Geology

The study area is underlain by Paleozoic and Mesozoic bedrock west of a line roughly coincident with R8E (Fig. 5). These rocks consist of the Winnipeg and Red River Formations, both of Ordovician age, and the Amaranth, Reston, Melita and Waskada Formations, of Jurassic age. In the area of study, these formations trend roughly north-south;300 miles (480 km) north of the study area the trend gradually changes to almost east-west, just south of Flin Flon, Manitoba.

Exposures of Paleozoic bedrock are not abundant, although they occur under a shallow drift cover in the Interlake region. Except for the basal part of the Ordovician which is composed of sandstone and shale, Paleozoic strata are overwhelmingly limestones, dolomitic limestones, and argillaceous limestones.

Heavy Mineral Sources

The heavy mineral species studied in Paleozoic sedimentary rocks have generally been found to be limited in number and type. Bayrock (1962) in Alberta, Willman el al (1963) in Illinois, and Dreimanis et al (1957) in Ontario determined that the Paleozoic shales and limestones over which the glaciers of those areas passed had little or no effect on the heavy mineral assemblages of the tills investigated.