THE UNIVERSITY OF MANITOBA

LATE QUATERNARY TILL STRATIGRAPHY OF SOUTHEASTERN MANITOBA BASED ON CLAST LITHOLOGY.

by

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ABSTRACT

Lithological analyses were made on the 4 to 16 mm and 1 to 2 mm particles in samples of till which were collected from boreholes and surface samples sites in southeastern Manitoba. On the basis of these analyses and on the basis of matrix texture and stratigraphic position, a Quaternary stratigraphy was established in southeastern Manitoba.

Two main groups of till units were found, one containing abundant igneous and metamorphic clasts and few carbonate clasts, the other containing few igneous and metamorphic clasts and abundant carbonate rock fragments. Ten till units were identified in the study area. The main units and their distinguishing characteristics, from oldest to youngest, are as follows:

1) Unnamed till unit; till, very hard, sandy, abundant igneous and metamorphic fragments,
2) Woodmore Formation; till, silty, abundant carbonate rock clasts,
3) Stuartburn Formation; till, silty, abundant carbonate rock clasts but with more dolomite than any other till in the section,
4) Whiteshell Formation, and its less igneous and metamorphic-rich equivalent, the Senkiw Formation;

sandy tills, containing abundant Precambrian igneous and metamorphic clasts,

5) Roseau Formation; and its more crystalline-rich equivalent, the Sprague Formation; silty tills, containing abundant Paleozoic carbonate (limestone and dolomite) clasts,

6) Marchand Formation; till, sandy, abundant carbonate rock fragments,

7) Steinbach Member; till, silty, abundant carbonate rock fragments,

8) Lac du Bonnet Formation; till, silty, abundant carbonate rock fragments: the northern equivalent of the Roseau and Sprague, Marchand, and Steinbach tills.

These units have been correlated with units in northwestern Ontario, southeastern Manitoba, and also with units in North Dakota and Minnesota on the basis of their similar lithologic characteristics and stratigraphic position. In general, the sandier, Precambrian-rich till units were deposited by ice moving across the Precambrian Shield from the east or northeast, while the less sandy, carbonate-rich tills were deposited by ice advancing across the Paleozoic strata from the north or northwest.

The exact ages of the lower three till units are uncertain. The Woodmore Formation and Stuartburn Formation were deposited by an ice advance from the northwest before 39 000 years B.P. and may be early

Wisconsinan or pre-Wisconsinan in age. Deposition of the first late Wisconsinan till, the Senkiw and Whiteshell Formations, took place after 22 260 years B.P. when ice moved into the area from the northeast. Following this, ice advanced from the north or northwest depositing the Roseau and Sprague Formations. Retreat of this ice sheet and subsequent readvance before about 12 800 years B.P. deposited the Marchand Formation. The last advance into the study area deposited the Steinbach till before about 8 000 years B.P.

I INTRODUCTION

Study Area

The area under study is located in southeastern Manitoba from latitude 49° to 51°N and longitude 95°15′ to 96°15′W. It includes townships 1 to 23 and ranges 2 to 17 east of the principal meridian. The area is bounded by the Red River on the west, Ontario on the east, the United States on the south, and the Winnipeg River on the north (Figure 1).

Purpose of Study

1. To test the viability of using 4 to 16 mm clasts and very-coarse-sand (1 to 2 mm) grain lithologies as a means of distinguishing and identifying till units.

2. To establish a Quaternary stratigraphy of the area based on correlations using clast and very-coarse-sand lithologies determined primarily from borehole samples.

3. To correlate this stratigraphy with that of surrounding areas.

4. To interpret the Quaternary history of the area.

Sample Collection and Numbering

The samples of tills used came from surface outcrops and boreholes collected by J. Teller during the past 4 years (1971 to 1974). Boreholes were drilled to a

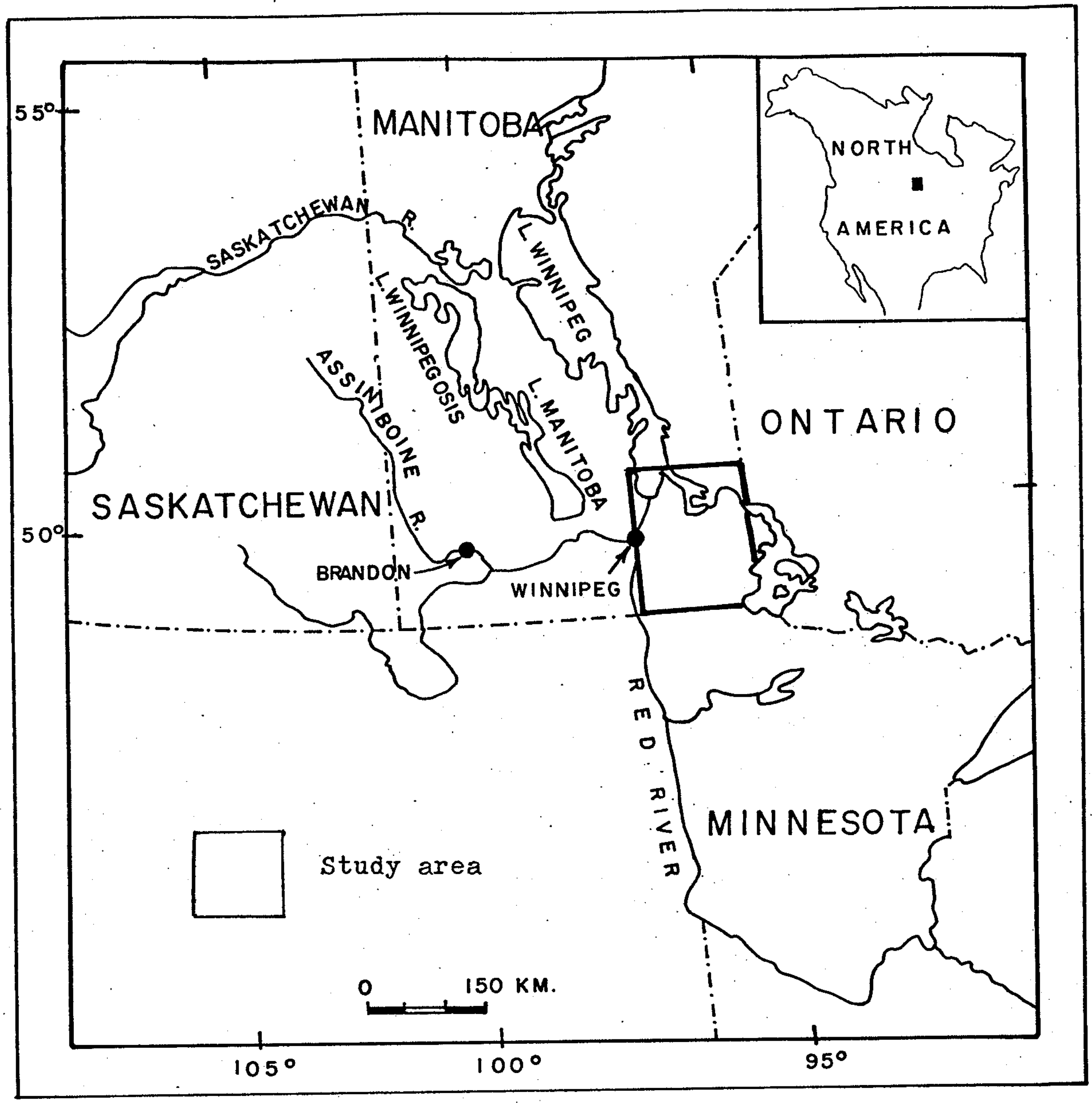

Figure 1. Location of the study area.

maximum depth of 50 m using a truckmounted power auger. Each surface sample is identified by a number-letter combination referring to the standard number and letter of the 1:250 000 topographic map, (Canadian topographic map system): for example 62H is the Winnipeg 1:250 000 topographic map sheet. Following this letter-number combination is another number (and sometimes letter) to locate the sample locality on that map.

Borehole sample locations are identified by a letter which is also taken from the 1:250 000 topographic map and that is followed by another letter to distinguish it from other boreholes on the same map sheet: for example borehole HW is located in map area 62H. Each surface occurrence and borehole is located, where possible, to the nearest legal subdivision (LSD).

Analyses Performed

The laboratory analysis consisted of identifying the lithology of all rock fragments between 4 and 16 mm (-2 to -4ø) and very-coarse-sand grains between 1 and 2 mm (0 to -1ø). Appendices A to D outline more fully the methods employed and results obtained in the analysis. 244 4 to 16 mm samples and 75 1 to 2 mm samples were analyzed. Borehole and surface outcrop descriptions and grain size data were made available by J. Teller.

II BEDROCK GEOLOGY

As this study is concerned primarily with the rock fragments and very-coarse-sand lithologies present in tills of southeastern Manitoba, a brief review of the bedrock from which the glaciers acquired their load is pertinent. The rocks in the surrounding region range in age from Precambrian to Tertiary. Detailed descriptions can be found in Davies et al.(1962) and McCabe(1971). A brief description of the main lithological units is given here.

The Precambrian Shield may be divided into the Superior Geologic Province in the southeast of Manitoba and the Churchill Geologic Province in the north and northwest. The boundary between the Provinces lies to the north of Lake Winnipeg and trends northeast-southwest.

Both Provinces are characterised by seven main groups of rocks (Davies et al., 1962):

1) Intermediate to basic volcanic rock.

2) Greywacke.

3) Arkose and quartzite, which often rest unconformably on 1) and 2).

4) Paragneiss derived from 2) and 3).

5) Granitized equivalents of 4).

6) Mafic and ultramafic intrusions.

7) Granitic rocks.

Only the gneissic, granitic and dark coloured basic-igneous material has been found in the 4 to 16 mm size range in the samples under study, but all of the above Precambrian rock types must have contributed in some way to the glacial drift.

The Paleozoic and Mesozoic strata occurring in southwestern Manitoba form a wedge of sedimentary rock which thickens from 0 m at the edge of the Precambrian Shield to over 1500 m in the southwestern corner of the Province. The Paleozoic strata consist predominantly of limestone, dolomite, and some shale, while the Mesozoic lithologies are in general shale and sandstone. Table 1 provides a summary of the formations in the area together with their basic lithology.

The bedrock immediately below the study area (Figure 2) consists of four units:

1) Granite, schist, metasediment and volcanic rock in the east.

2) The Ordovician Winnipeg Formation dips gently southwestward and consists of a mudstone-sandstone unit, which outcrops in a linear belt trending roughly north-south in the central part of the study area (McCabe, 1971, Vigrass, 1971).

3) The Ordovician Red River Formation is composed largely of mottled dolomitic limestone and dolomite, which occurs in the western part of the study area (McCabe, 1971).

4) The Jurassic Amaranth Formation consists of red sandy argillaceous siltstone and interbedded anhydrite and shale and outcrops in the southwestern part of the study area (McCabe, 1971).

TABLE 1
GEOLOGIC FORMATIONS OF MANITOBA

Era	Period*	Formation	Member	Max. Thickness	Basic Lithology
CENOZOIC	Recent				Soil, alluvial deposits, sand dunes, bogs.
	Pleistocene			450	Glacial deposits
	Eocene to Pliocene (0 to 60)	Not present in Manitoba			
		Turtle Mountain		400	Shale, sandstone, lignite
	Palaeocene	Boissevain		100	Sand and sandstone, greenish grey
MESOZOIC	Cretaceous 60 to 130	Riding Mountain	Odanah	1100	Hard grey siliceous shale
			Millwood		Greenish bentonitic shale
		Vermilion River	Pembina	80	Non-calc. shale, bentonite beds
			Boyne	150	Calcareous speckled shale
			Morden	200	Carbonaceous shale; septarian concretions
		Favel		125	Calc. speckled shale, limestone bands
		Ashville / Ashville Sand		375	Non-calc. silty shale; 0-90′ sand
		Swan River		300	Sand, sandstone, shale, clay
	Jurassic 130 to 155	Waskada		175	Varicoloured shale
		Melita		475	Varicoloured shale, calc. shale, limestone
		Reston		150	Argillaceous limestone and shale
		Amaranth	Upper: evaporite	175	Anhydrite, gypsum; shale, dolomite
			Lower: red beds	160	Dolomitic shale to siltstone, anhydritic
	Triassic	Not present in Manitoba			
PALAEOZOIC	Permian Pennsylvanian 155 to 240				
	Mississippian 240 to 265	Charles		115	Dolomite and anhydrite
		Mission Canyon		300	Limestone, dolomite, anhydrite; oil production
		Lodgepole	Whitewater Lake Virden Scallion Routledge	580	Limestone, argillaceous and cherty; shale; oil production
		Bakken		55	Black shale and siltstone
	Devonian 265 to 320	Group: Qu'Appelle	Lyleton	115	Red dolomitic shale
		Saskatchewan	Nisku	130	Fossiliferous limestone and dolomite
			Duperow	560	Shaly limestone, dolomite, anhydrite; cyclical
		Manitoba	Souris River 1st Red	300	Limestone, evaporite, shale; cyclical
			Dawson Bay 2nd Red	220	Limestone, anhydrite, basal red shale
		Elk Point	Prairie Evaporite	430	Halite, with potash, anhydrite, dolomite
			Winnipegosis	335	Dolomite, reef and inter-reef
			Elm Point	50	High calcium limestone
			Ashern	50	Dolomite and Shale, brick red
	Silurian 320 to 360	Interlake		400	Dolomite
	Ordovician 360 to 440	Stonewall		60	Dolomite
		Stony Mountain	Gunton Penitentiary Stony Mtn. Shale	180	Dolomite, upper part shaly Argillaceous dolomite Fossiliferous calc. shale; red, grey, green
		Red River	Upper dolomite Selkirk Cat Head Dog Head	550	Dolomite, minor limestone Dolomitic limestone, mottled Dolomite, cherty Dolomitic limestone, mottled
		Winnipeg		225	Quartzose sand, sandstone; shale
	Cambrian 440 to 520	Deadwood		35	Glauconitic sandstone
		Major unconformity			

*Numerals refer to age in millions of years.

from Davies <u>et</u> <u>al</u>., (1962).

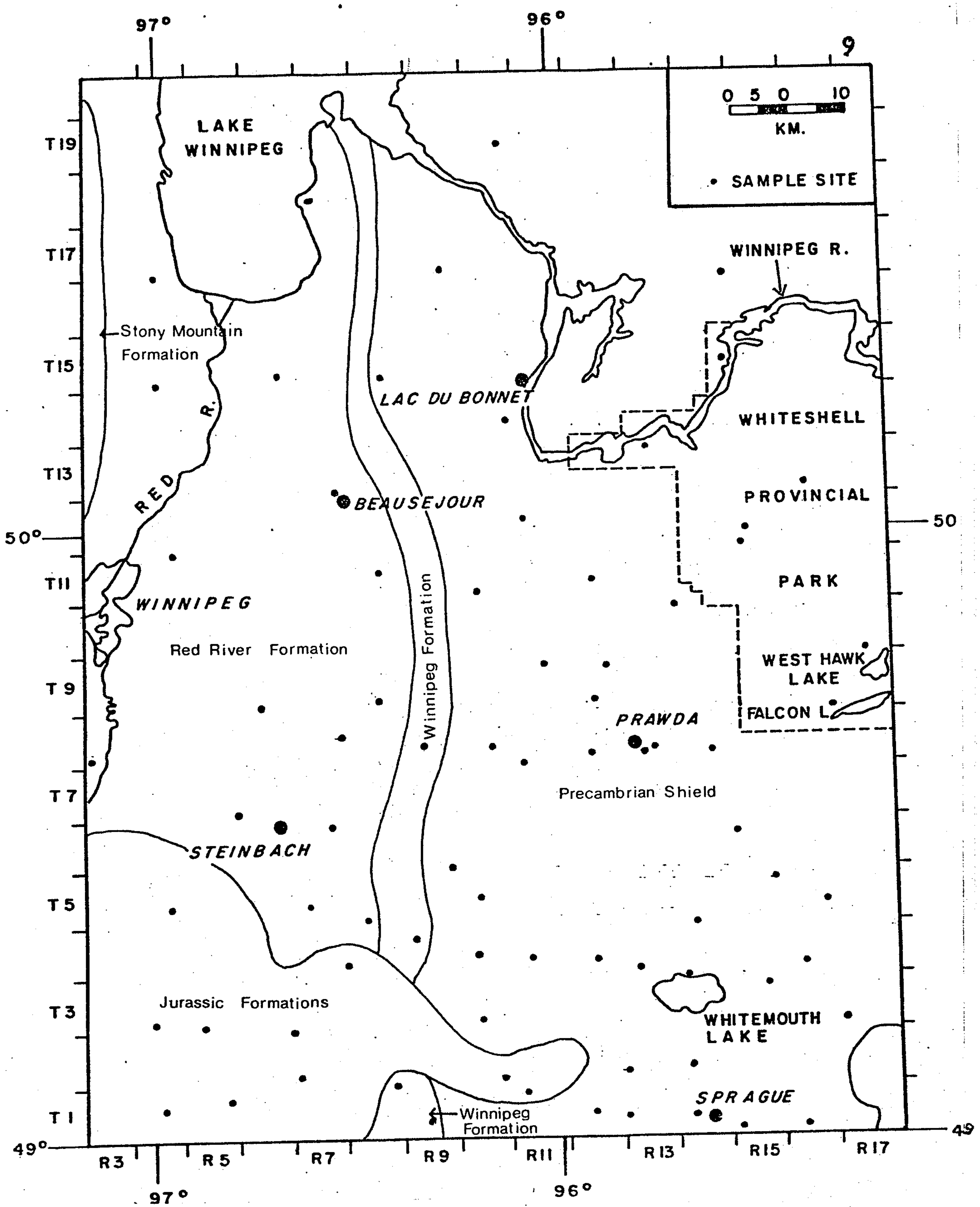

Figure 2. Bedrock geology underlying the study area.

III CLAST AND VERY-COARSE-SAND ANALYSES

Introduction

The main purpose of this study is to construct a Quaternary stratigraphy based on the lithology of rock fragments (4 to 16 mm) found in till samples. Analysis of the very-coarse-sand fraction (1 to 2 mm) of till from selected boreholes was also undertaken in order to support the correlations and conclusions reached with 4 to 16 mm rock-fragment analyses.

Clast Analysis

Introduction

Clast lithology has been studied widely as a supplement to the textural analysis of tills (Fenton, 1974) and as an indicator of ice-flow direction. However it has rarely been used as the main parameter on which to base correlations. Two examples of studies where clast lithology has been used are those of Norris et al. (1950) in Ohio and Teller (1972) in southeastern Indiana.

Choice of clast size range

Dreimanis and Vagners (1969) have shown that every lithology contributing to a till has a bimodal distribution. One mode consists of larger-than-sand-sized rock fragments and occurs near the source area. With increasing distance from the bedrock source, due to abrasion and crushing during transportation, the matrix mode of a given rock type increases at the expense of the clast mode and eventually the clast mode may disappear altogether. The matrix mode generally stays within the same grain-size range, with each mineral being reduced to a minimum size called its terminal grade. For granitic rocks, which are primarily composed of quartz and feldspar, this is approximately 0.25 to 0.03 mm, for dolostone (dolomite) 0.06 to 0.016 mm, and for limestone (calcite) 0.0016 to 0.002 mm.

The result of counting clasts of the greater-than-4 mm size, reflects the local bedrock contributing to the till rather than far-travelled material. Anderson (1957) used a 12 to 24 mm grain size as he felt this contained greatest variety of rock types and therefore afforded the best possibility of differentiating the till sheets. Jarnefors (1952) used two size fractions, 16 to 128 mm and 4 to 16 mm. He concluded that both fractions gave a reliable although somewhat different conception of the petrographic composition of the till. Arneman and Wright (1959) used both 4 to 64 mm and 2 to 4 mm size ranges for their stone counts in Minnesota. In Ohio, workers have standardly used 1 to 3 inch stones (J. Teller, pers. comm., 1975). Fenton (1974) used a 4 to 8 mm size range to avoid transporting large and bulky samples.

The size fraction chosen for this study was 4 to

16 mm (-2 to -4ø), which corresponds to the lower part of the pebble category of the Wentworth size scale.

Larger clasts were not included because there would be too few in the sample to produce accurate results. Because it was hoped that clast identification may eventually be useful for field identification in south-eastern Manitoba, smaller than 4 mm clasts were also rejected as being too small.

Lithology of the rock fragments

The lithologic categories chosen were based on easily recognizable features such as mineralogy and colour. Initially over twenty five categories were chosen. After about twenty samples had been counted a comparison between these categories and a combination of some of the more similar ones (for example fossiliferous limestone, creamy white limestone) was made. Trends of the combined and individual categories was often parallel and it was decided to reduce the total number of categories accordingly. The result was to establish fifteen categories which were even more readily distinguishable. These are as follows:

Limestone; pink-purple, buff, and others.

Dolomite; pink-purple, buff, and others.

Coarse siliceous igneous; pink, green, and black and white.

Fine siliceous igneous.

Basic and metamorphic material.

Others: chert, shale, lignite, and pyrite.

For gross correlation purposes it was found that total carbonate-rock content and total igneous-rock content provided the most useful information and were the easiest to work with. It was hoped that more detailed correlations could be made using the individual categories described.

Provenance

In a study of this kind it is always hoped that the rock-fragment lithologies may be linked to specific bedrock outcrops. Such indicators would establish the direction of glacier movement.

Harrison (1960) assumed the approximate flow paths taken by Wisconsinan and Illinoian ice streams reaching Central Indiana. He related the pebble and sand lithologies found in tills to bedrock formations over which the ice had flowed. He was able to convert the mineral and rock fragments of a till back into the bedrock from which they were derived. Enough mineral and rock fragments were present in the tills of Harrison's study to "make bedrock" in amounts equal to the proportion of the area of each of the bedrock types traversed by the ice.

Arneman and Wright (1959) found they could assign different Wisconsinan tills to different ice lobes due to the distinctive types of bedrock lithology in Minnesota and adjacent areas. They indicated that "stone counts" were the most useful analyses that could be made on Minnesota tills, as they revealed both the source region of the till, and the gross direction of ice movement.

It was not possible to assign the individual clasts of the tills in the study area to specific bedrock formations. This is because individual Paleozoic and Mesozoic formations in southwestern Manitoba generally exhibit similar lithologies, and even the colour of the rock, for example buff limestone, is not restricted to one formation. The Precambrian Shield also has similar lithologies in different areas, which does not allow the source of a particular rock fragment to be pinpointed.

An exception is shale clasts. Figure 3 illustrates the distribution of shale clasts within the area. Shale was only found in nine samples and even then was less than 8% of the total clast content. As shale is quickly reduced to silt and clay sizes, the source of the 4 to 16 mm shale clasts must be very close to the sample location. Shale obtained from till samples in the southeastern part of the area has been identified as belonging to the Ordovician Winnipeg Formation.

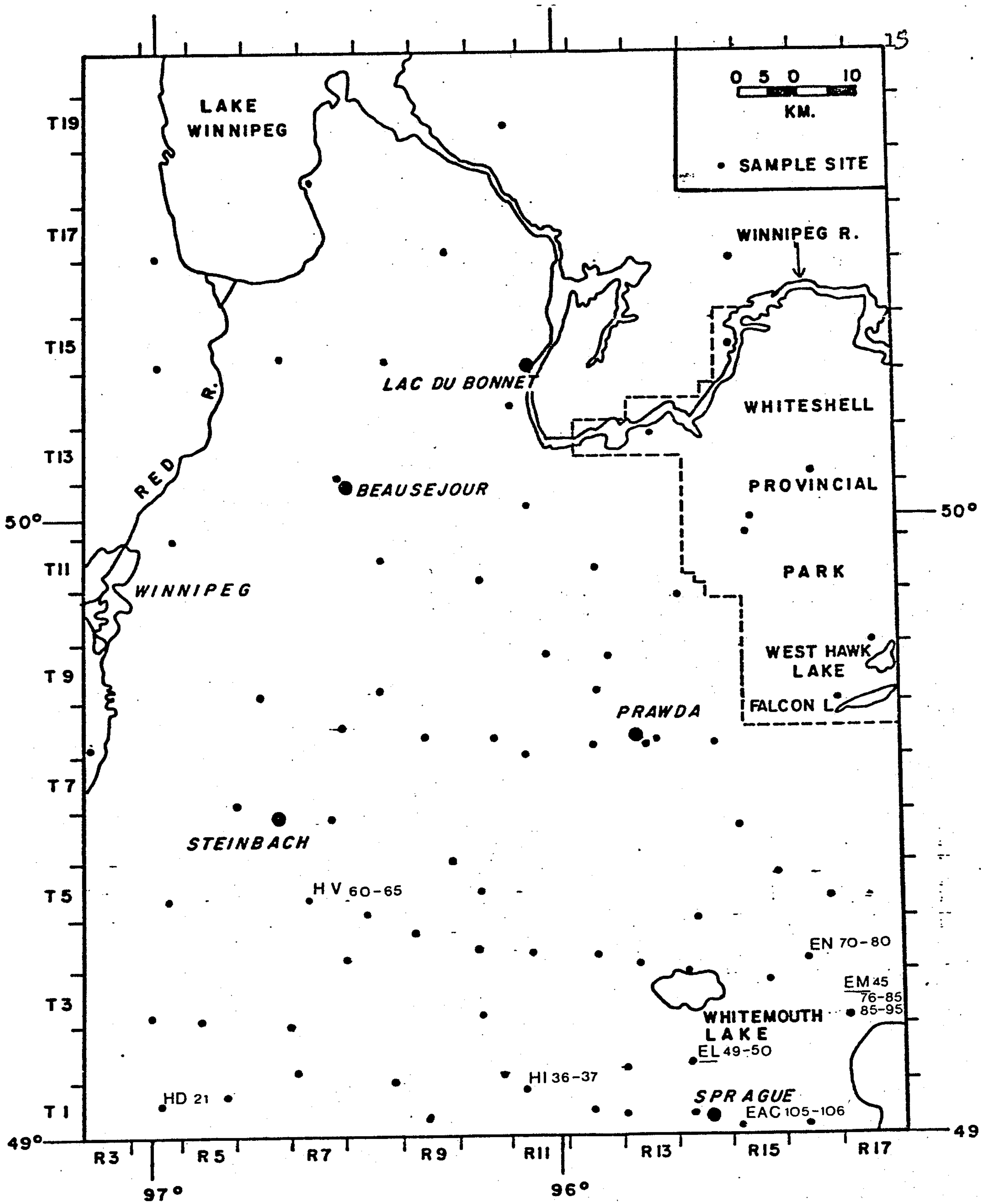

Figure 3. Occurence of shale in the 4 to 16 mm size range. All samples with shale belong to the Roseau and Sprague Formations and, with the exception of HV 60-65 and HD 21, all the shale came from the Ordivician Winnipeg Formation. Those locations underlined indicate that shale was also found in the 1 to 2 mm size range.

Summary and results of clast analysis

Appendix A gives the details of the laboratory procedure. Appendix B presents the results of the 4 to 16 mm clast analysis. All the clasts obtained from each till sample were counted and identified. In most cases the number of clasts was between 80 and 150, but a few samples contained over 300. Those samples that yielded less than 25 rock fragments were not included as it was felt that this did not give a viable statistical foundation on which to base correlations.

The amount of igneous and metamorphic clasts in a till sample initially provided the best parameter for distinguishing till units. Using this figure, two main groups of till units could be identified. One contains over 60% crystalline clasts, the other generally contains less than 50% crystalline clasts. That group of till units having few igneous and metamorphic clasts, and cosequently a high carbonate clast content in the 4 to 16 mm size fraction, could be further subdivided on the basis of their dolomite content. One set of till samples has over 50% dolomite in contrast to other samples which have less than 30%.

The shale content of the samples is also useful in distinguishing one carbonate-rich till unit from another. All shale found in the 4 to 16 mm size range