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ONTARIO GEOLOGICAL SURVEY

Open File Report 5794

Quaternary Geology, Fort Frances–Rainy River Area

By

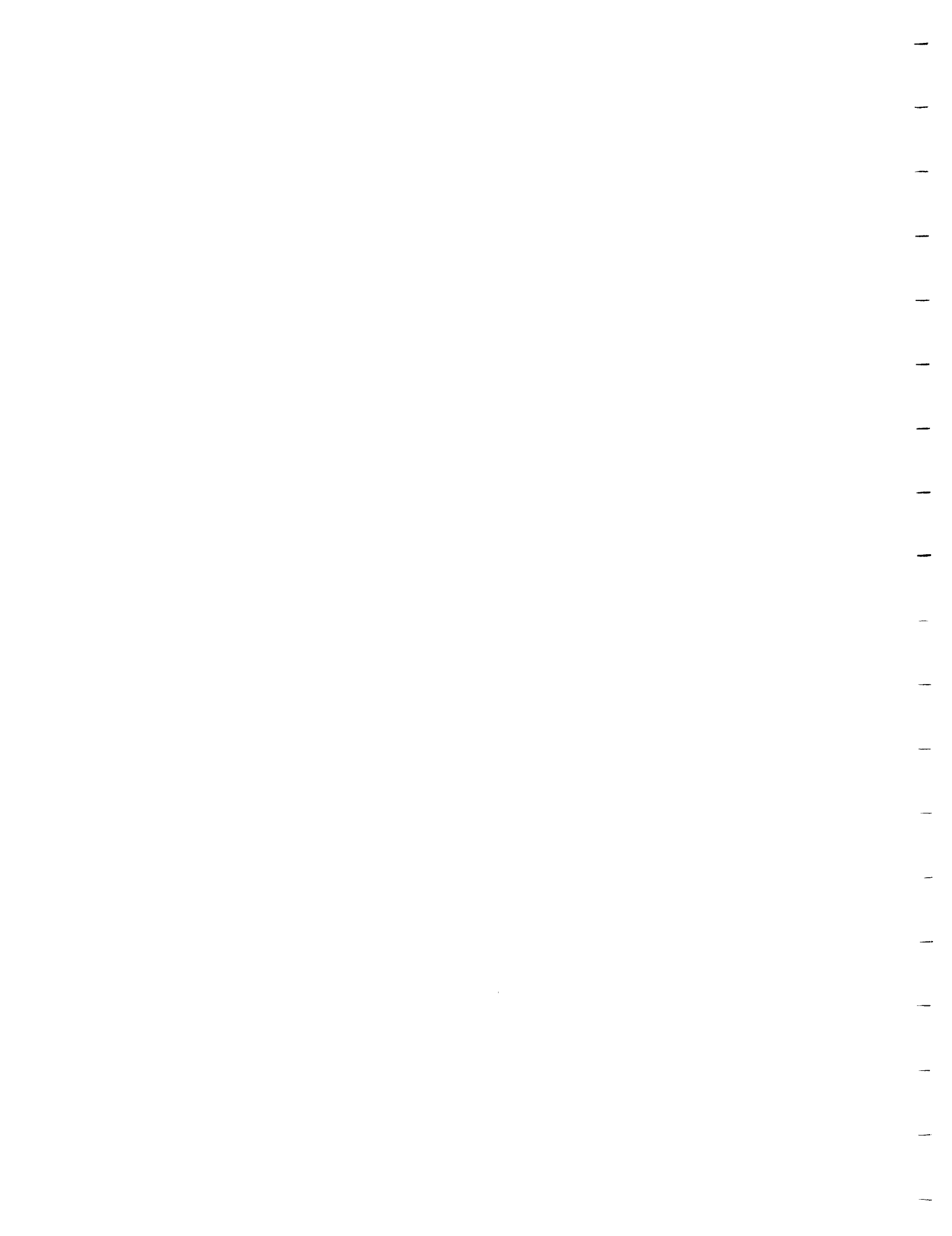
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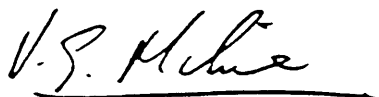
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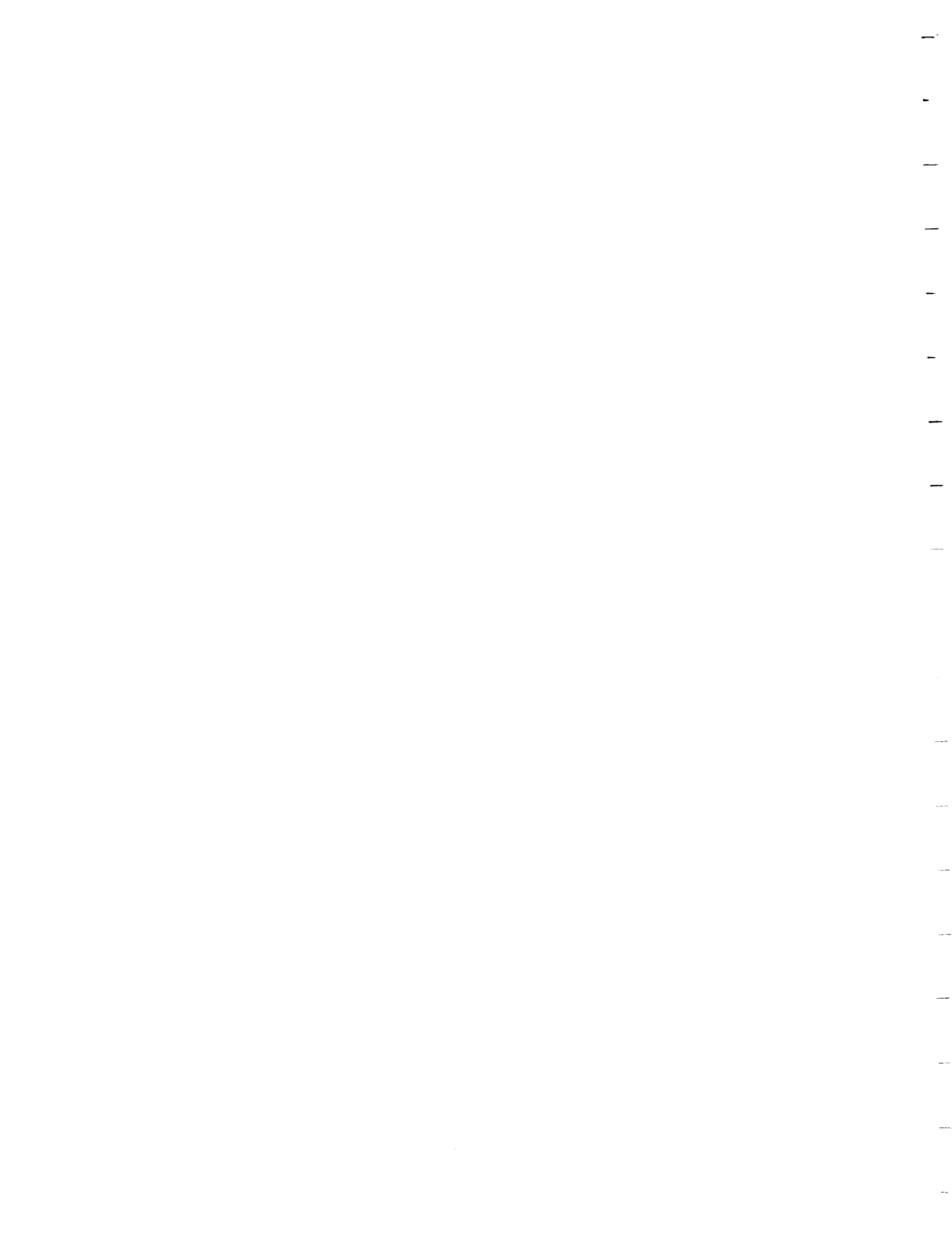
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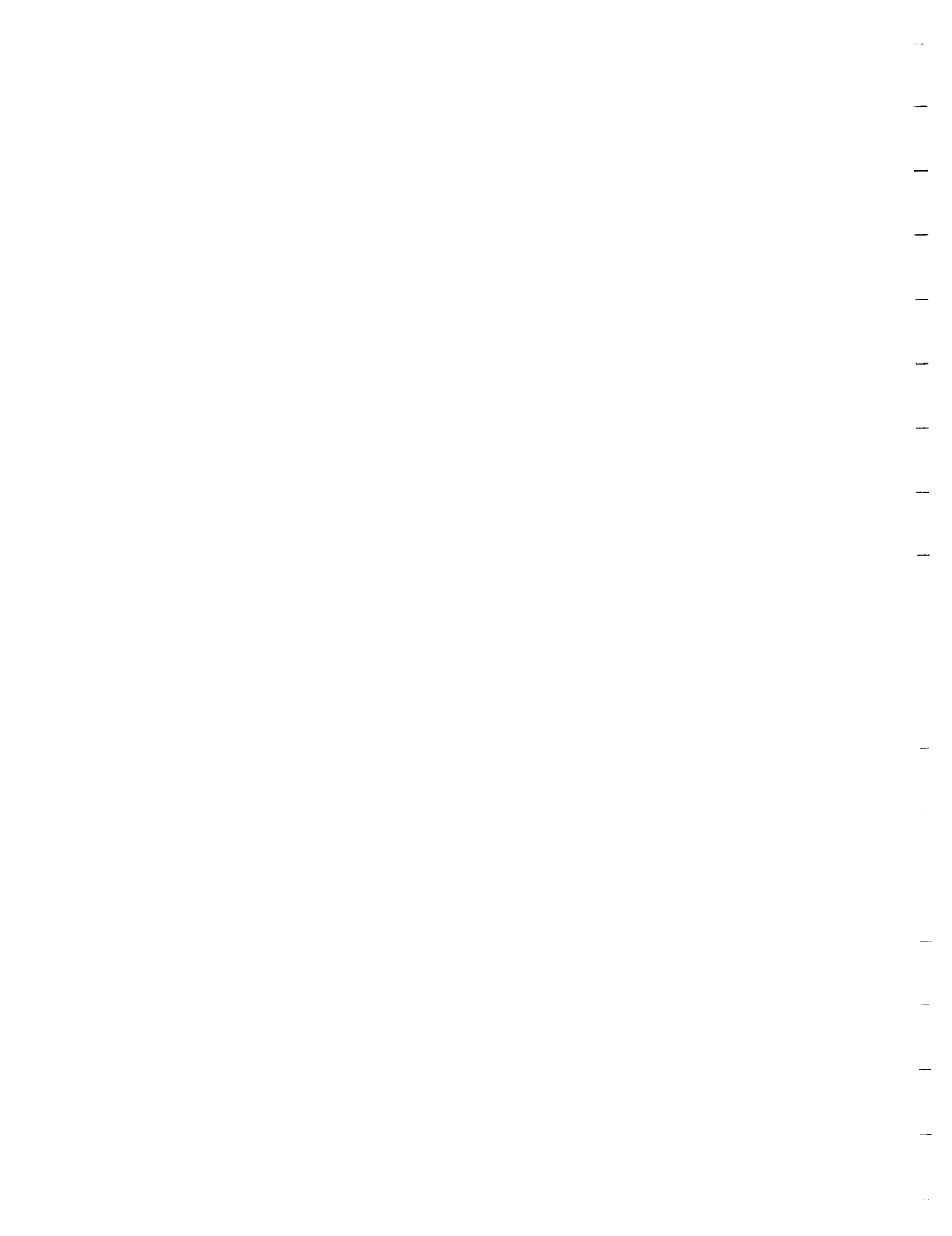


V.G. Milne, Director
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CONTENTS

ABSTRACT.....	xv
INTRODUCTION.....	1
PURPOSE.....	1
LOCATION AND ACCESS.....	1
POPULATION.....	4
CLIMATE.....	4
PREVIOUS WORK.....	5
METHODS.....	7
FIELD METHODS.....	7
LABORATORY METHODS.....	9
GEOLOGICAL SETTING.....	11
BEDROCK GEOLOGY.....	11
PRECAMBRIAN GEOLOGY.....	11
CRETACEOUS GEOLOGY.....	16
REGIONAL PHYSIOGRAPHY.....	20
LOCAL PHYSIOGRAPHY AND DRAINAGE.....	22
HIGHLAND WITH THIN DRIFT COVER.....	22
LOWLAND WITH VARIABLE DRIFT COVER.....	24
QUATERNARY GEOLOGY.....	29
STRIAE AND ASSOCIATED ICE FLOW FEATURES.....	29
DRIFT THICKNESS.....	34
CONSTRAINTS ON GLACIAL SEDIMENTATION.....	35
PROVENANCE AND THE RECOGNITION OF TWO ICE LOBES.....	36
PRE-LATE WISCONSINAN DEPOSITS.....	38
OLDER, LABRADOREAN DERIVED TILL.....	38
OLDER, KEEWATIN DERIVED TILL.....	42
SUB-TILL ORGANIC REMAINS.....	45
GLACIOLACUSTRINE DEPOSITS.....	46
LATE WISCONSINAN DEPOSITS.....	47
LABRADOREAN DERIVED DRIFT.....	47
WHITESHELL TILL.....	47
ICE-CONTACT STRATIFIED DRIFT (SURFACE DEPOSITS).....	64
RAINY LAKE-LAKE OF THE WOODS MORAINE.....	64
BURIED GLACIOFLUVIAL DEPOSITS.....	70
KEEWATIN DERIVED DRIFT.....	75
WHITEMOUTH LAKE TILL.....	76
MARCHAND TILL.....	90
GLACIOFLUVIAL DEPOSITS.....	94
GLACIOLACUSTRINE DEPOSITS AND FEATURES.....	96
PRE-LOCKHART PHASE (WYLIE FORMATION).....	99
LOCKHART PHASE (BRENNA FORMATION).....	106
EMERSON PHASE (SHERACK FORMATION).....	110
ABANDONED SHORELINES.....	114
OLDER ALLUVIAL DEPOSITS.....	125
MOORHEAD PHASE (POPLAR RIVER FORMATION).....	125
RADIOCARBON DATED SITES AND FOSSIL REMAINS.....	128
RADIOCARBON DATES.....	130
FOSSIL REMAINS.....	134



RECENT DEPOSIT.....	139
PEATLANDS AND SWAMPS.....	139
RECENT ALLUVIAL, BEACH, AND EOLIAN FEATURES....	140
SUBSURFACE STRATIGRAPHY AND CORRELATIONS.....	143
HISTORICAL GEOLOGY.....	147
ECONOMIC GEOLOGY.....	150
SAND AND GRAVEL.....	150
PEAT.....	153
DRIFT PROSPECTING.....	153
REFERENCES.....	155
APPENDIX A: SITE DESCRIPTIONS OF FOSSIL-BEARING DEPOSITS.	164

FIGURES

Figure 1. Key map showing the location of the Fort Frances-Rainy River area.....	2
Figure 2. Location of sonic boreholes, backhoe trenches and surface samples in the Fort Frances-Rainy River area.....	back pocket
Figure 3. Regional bedrock geology of north-central North America.....	12
Figure 4. Bedrock geology, Fort Frances-Rainy River area.....	14
Figure 5. Drift thickness north of Rainy River, Ontario..	18
Figure 6. Physiographic regions and drift thickness, Fort Frances-Rainy River area.....	23
Figure 7. Glacial lobes and sublobes which affected the North American mid-continent during the Late Wisconsinan glaciation.....	30
Figure 8. Location and direction of measured glacial striae, Fort Frances-Rainy River area.....	32
Figure 9. Surface tills and associated ice flow directions, Fort Frances-Rainy River area.....	48
Figure 10. Plots of grain size and carbonate content for surface samples of Whiteshell till.....	52
Figure 11. Schematic representation of the major stratigraphic units present in the drift-covered lowland of the Fort Frances-Rainy River area.....	59
Figure 12. Plots of grain size and carbonate content for borehole samples of Whiteshell till.....	62

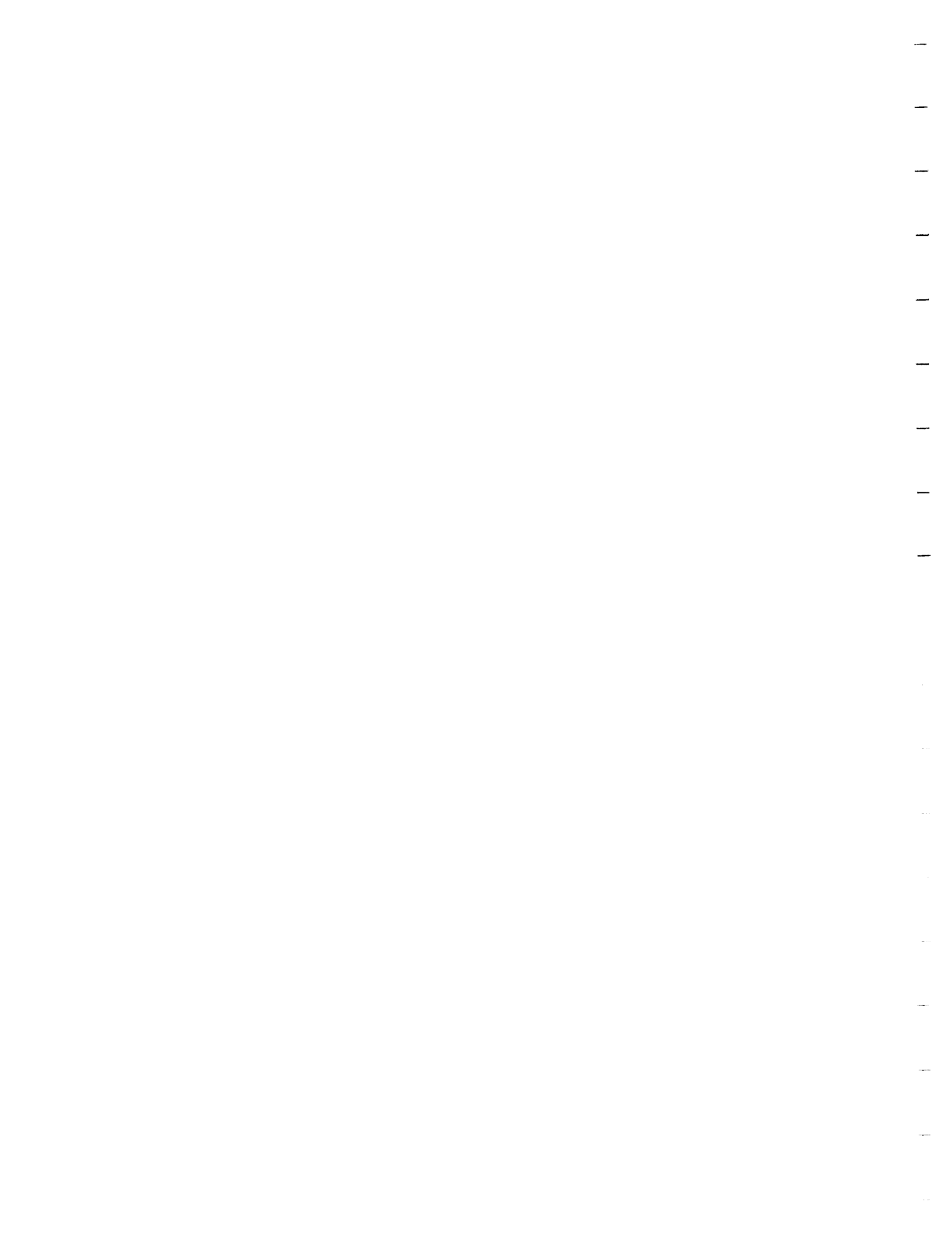
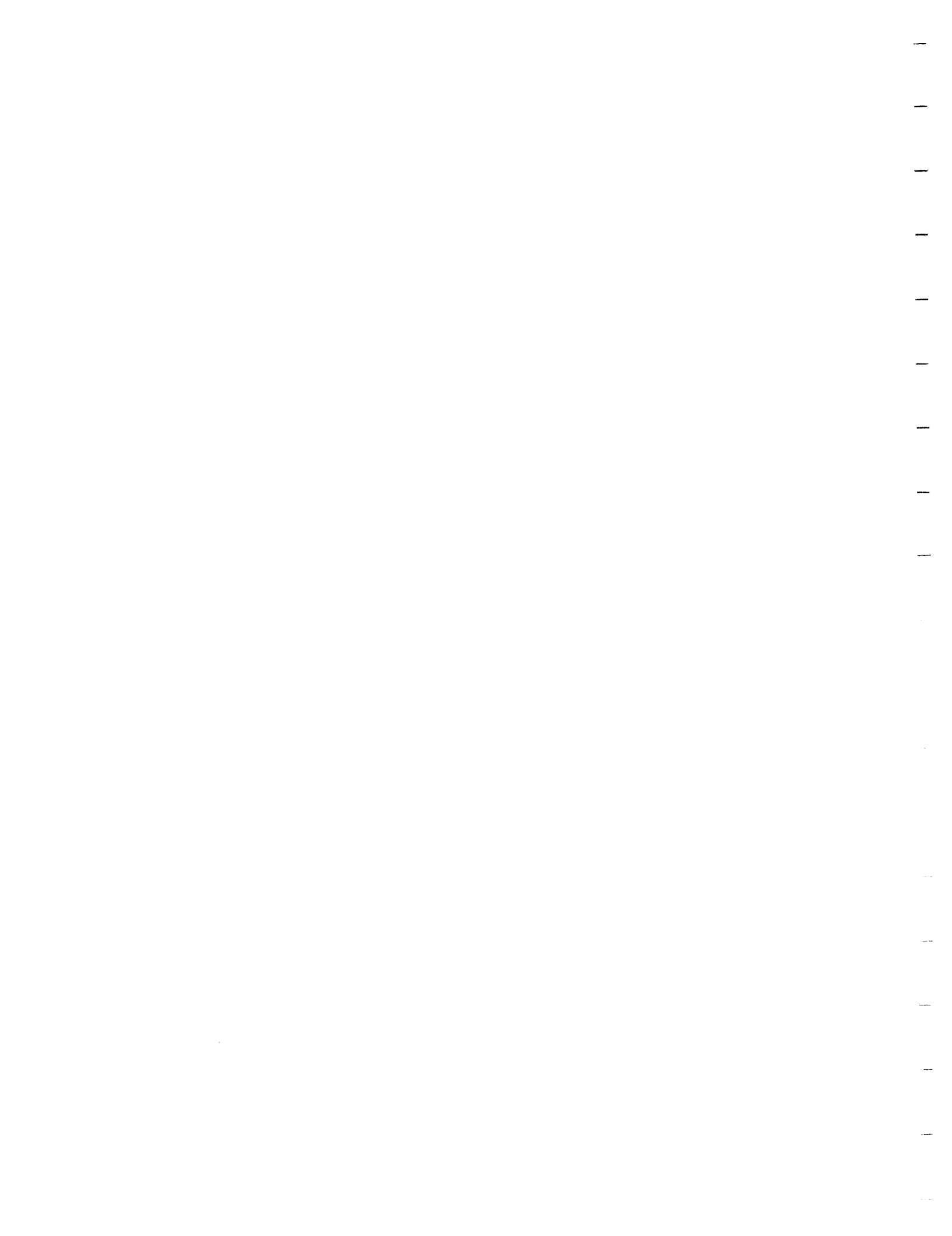


Figure 13.	Distribution of deposits comprising the Rainy Lake-Lake of the Woods Moraine.....	66
Figure 14.	Subsurface profiles and correlations obtained from sonic borehole information (western region).....	back pocket
Figure 15.	Subsurface profiles and correlations obtained from sonic borehole information (north-central region).....	back pocket
Figure 16.	Subsurface profiles and correlations obtained from sonic borehole information (central and eastern region).....	back pocket
Figure 17.	Plots of grain size for surface and borehole samples of Keewatin derived tills.....	80
Figure 18.	Calcite/Dolomite ratio versus percent carbonate; surface and borehole samples of Keewatin derived tills.....	81
Figure 19.	Pebble fabrics obtained from selected surface exposures of Marchand and Whitemouth Lake till.....	84
Figure 20.	Schematic representation of water level fluctuations affecting Glacial Lake Agassiz in northwestern Ontario.....	98
Figure 21.	Composite stratigraphic section for the Fort Frances-Rainy River area.....	102
Figure 22.	Location of shoreline features and transect line used for the construction of the strandline diagram, Fort Frances-Rainy River area.....	118
Figure 23.	Strandline diagram indicating slopes and regional correlations of water planes, Fort Frances-Rainy River area.....	120
Figure 24.	Paleogeographic reconstruction and isobase lines of the Tintah shoreline (Lockhart Phase), Fort Frances-Rainy River area.....	122
Figure 25.	Paleogeographic reconstruction and isobases of the Campbell shoreline (Emerson Phase), including locations of dated fossil sites, Fort Frances-Rainy River area.....	123
Figure 26.	Simplified stratigraphic columns of radiocarbon dated sites indicating the position of the dated horizon.....	133



PHOTOGRAPHS

- Photo 1. String bog in Blue Township with well defined surface water flow lines.....28
- Photo 2. Crossing striae on coarse grained diabase in Worthington Township.....33
- Photo 3. Inclusion of Pre-Late Wisconsinan, Keewatin derived till within Late Wisconsinan, Whiteshell till, Mather Township.....43
- Photo 4. Bedrock-drift complex; thin till over bedrock, Senn Township.....50
- Photo 5. Subglacial facies of Whiteshell till, Fleming Township.....54
- Photo 6. Supraglacial facies of Whiteshell till in the Rainy Lake-Lake of the Woods Moraine, Menary Township.....56
- Photo 7. Subaquatic fan deposits exposed in the Armstrong sand and gravel pit, town of Fort Frances.....73
- Photo 8. Clayey, Whitemouth Lake till overlying Pre-Lockhart Phase glaciolacustrine silt and clay, Armstrong sand and gravel pit, town of Fort Frances.....79
- Photo 9. Blocky, clayey silt till (Whitemouth Lake till) overlain by interbedded waterlain till and Lockhart Phase glaciolacustrine silts and clays, Dobie Township.....87
- Photo 10. River bank exposure of Marchand till, Dilke Township.....93
- Photo 11. Pre-Lockhart Phase glaciolacustrine rhythmites of silty very fine sand and clay, Armstrong sand and gravel pit, town of Fort Frances.....101
- Photo 12. Emerson Phase lacustrine silts and clays unconformably overlying Moorhead Phase fluvial sandy gravels, Morley Township.....111
- Photo 13. Campbell, wave-cut notch incised into Whitemouth Lake till, Woodyatt Township.....116
- Photo 14. Palimpsest Moorhead Phase channels associated with the proto-Rainy River, Dilke Township.....129
- Photo 15. Abandoned peat cuttings in Carpenter Township..141



Photo 16. Transgression of nearshore sand over peat deposits along the southeast shore of Lake of the Woods, Spohn Township.....142

TABLES

Table 1. Quaternary deposits of the Fort Frances-Rainy River area.....39

Table 2. Summary of grain size and carbonate content data for till samples recovered from backhoe trenches and sonic boreholes(averages and ranges).....40

Table 3. Radiocarbon dates from eight fossil sites in the Fort Frances-Rainy River area.....132

Table 4. Fossil groups recovered from eight radiocarbon dated sites in the Fort Frances-Rainy River area.....136

Table 5. Mollusc species recovered from Sites E-13, E-165 and RR-87, Fort Frances-Rainy River area.....137

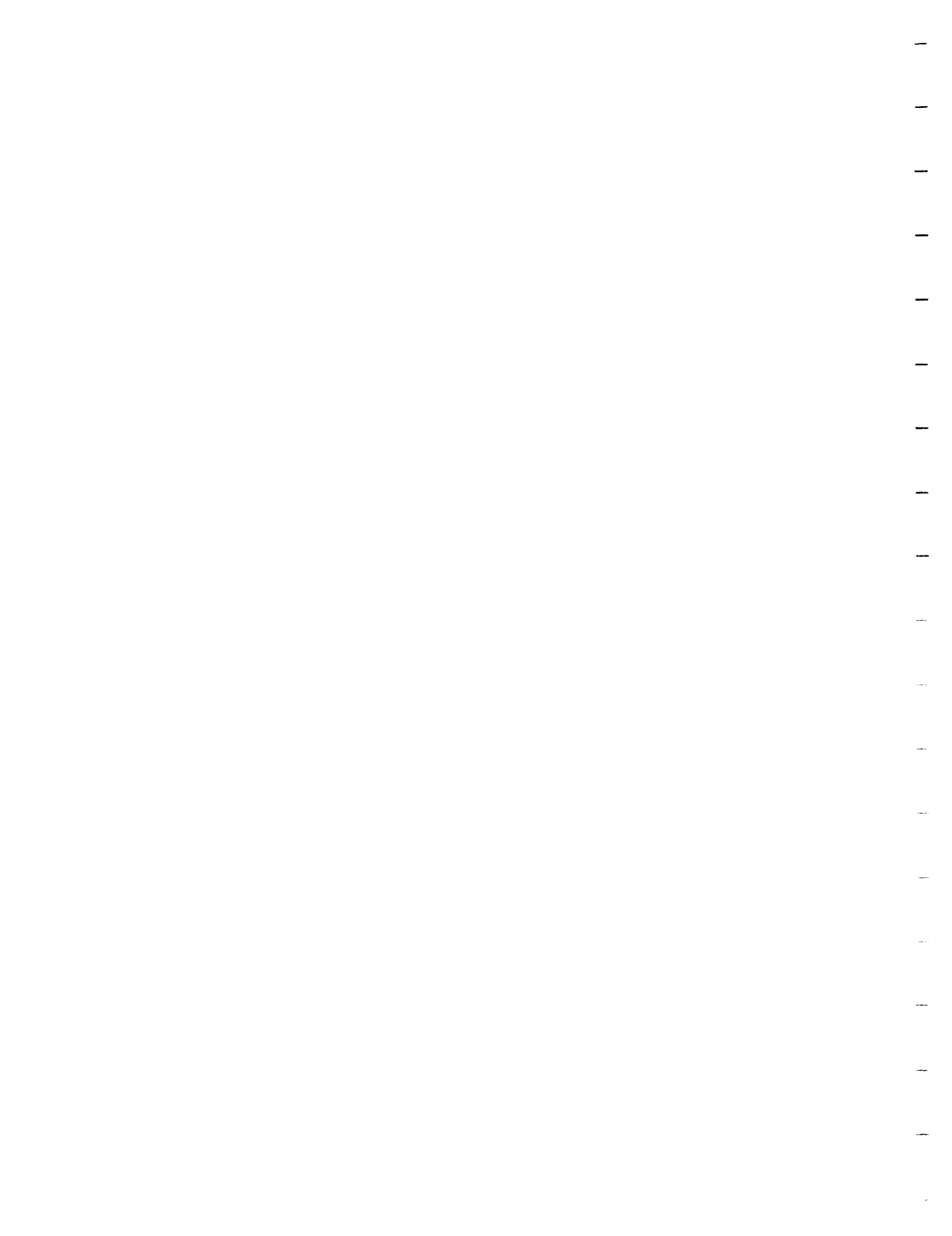
GEOLOGICAL MAPS

Map P.3065 Quaternary geology of the Rainy River area. Scale 1:50 000..... back pocket

Map P.3137 Quaternary geology of the Emo area. Scale 1:50 000.....back pocket

Map P.3138 Quaternary geology of the Northwest Bay area. Scale 1:50 000.....back pocket

Conversion Factors for Measurements.....170



ABSTRACT

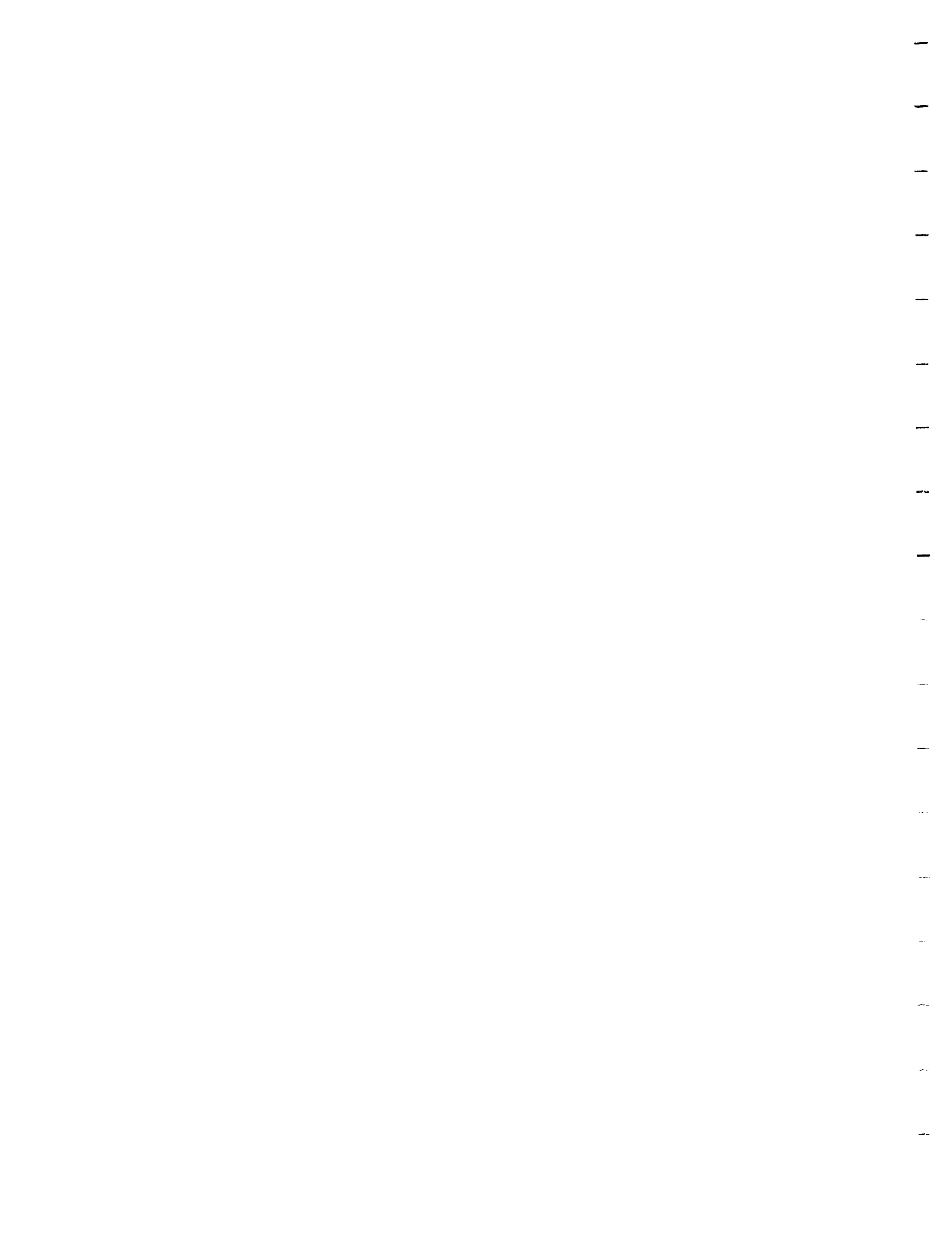
Quaternary deposits in the Fort Frances-Rainy River area were deposited by ice of both the Labradorean and Keewatin sectors of the Laurentide Ice Sheet. Up to 60 m of glacial drift, mainly of Late Wisconsinan age, overlies Cretaceous sediments and Archean supracrustal and granitic rocks.

The remnants of Pre-Late Wisconsinan glacial advances from both Labradorean and Keewatin ice centres are represented by isolated occurrences of older, possibly weathered glacial till. Weathering probably occurred during a Sangamonian or Middle Wisconsinan non-glacial interval. Wood contained within Late Wisconsinan, Labradorean derived till (Whiteshell till) was radiocarbon dated at $>47\ 410$ years B.P. The wood was probably eroded from a Sangamonian Interglacial deposit. Remnant deposits of older, glacial lakes underlie Late Wisconsinan tills across the report area. These sediments were deposited in precursors to Glacial Lake Agassiz which fronted the advancing Late Wisconsinan ice sheets.

Late Wisconsinan events began with an initial advance of Labradorean ice towards the southwest, and the deposition of stony, sandy Whiteshell till. Following the retreat of the Labradorean glacier to the Rainy Lake-Lake of the Woods Moraine, Keewatin ice advanced into the report area from the west depositing clayey Whitemouth Lake till. A late stage reactivation of the Keewatin glacier, following its retreat into the Lake Winnipeg basin, resulted in the deposition of sandy Marchand till in the extreme southwestern corner of the report area.

In low-lying areas, glaciolacustrine sedimentation accompanied and followed the deposition of these till sheets. Glaciolacustrine sediments were deposited during the Pre-Lockhart, Lockhart, and Emerson phases of Lake Agassiz; the latter two separated by shallow water and terrestrial sedimentation of the Moorhead low-water phase.

Surficial deposits of granular resources are restricted primarily to the Rainy Lake-Lake of the Woods Moraine. Buried deposits of Labradorean derived ice-contact stratified drift and subaquatic fan deposits are concentrated within buried, bedrock depressions in the area affected by the last Keewatin glaciation. Smaller reserves of low quality aggregates are found in isolated Keewatin derived glaciofluvial deposits and littoral glaciolacustrine features throughout the area.



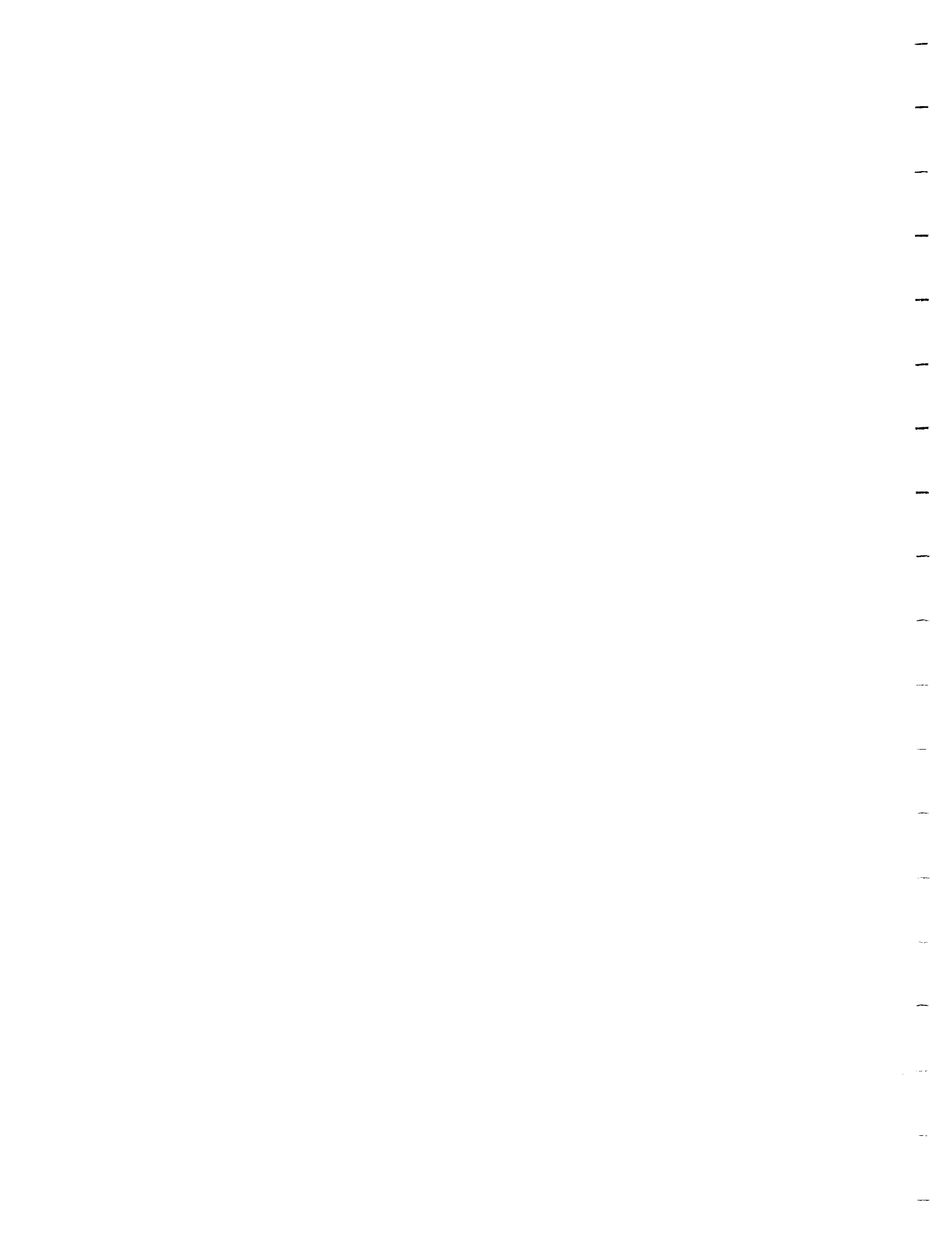
Quaternary Geology,
Fort Frances-Rainy River Area

By
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Ontario Geological Survey

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Chief, Engineering and Terrain Geology Section, Ontario Geological
Survey, April 17, 1991.

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INTRODUCTION

PURPOSE

This report presents information on the distribution and characteristics of the Quaternary deposits and features of the Fort Frances-Rainy River area (NTS 52D/15, 52D/10, 52D/9, 52D/16, 52C/13, 52C/12 and parts of 52C/11 and 52C/14). The information can be used for a variety of applications including: 1) drift prospecting programs; 2) the identification of potential sources of granular aggregates; 3) land use planning; 4) engineering and soil studies; and 5) environmental and hydrological studies.

LOCATION AND ACCESS

The Fort Frances-Rainy River map area occupies approximately 3500 km², and is bounded by the 49th parallel of latitude on the north and the Ontario-Minnesota International boundary on the south (Figure 1). Lake of the Woods and Rainy Lake form the western and eastern borders, respectively. Topographic coverage is provided by the 1:50 000 National Topographic Series map sheets: Rainy River (52D/15 & 52D/10); Pinewood (52D/9); Arbor Vitae (52D/16); Northwest Bay (52C/13); Emo (52C/12); Fort Frances (52C/11); and Mainville Lake (52C/14). The area lies entirely, within the Rainy River District and consists of thirty-eight geographic townships with additional unorganized lands in the northeast quadrant.

The towns of Fort Frances, Emo and Rainy River are the

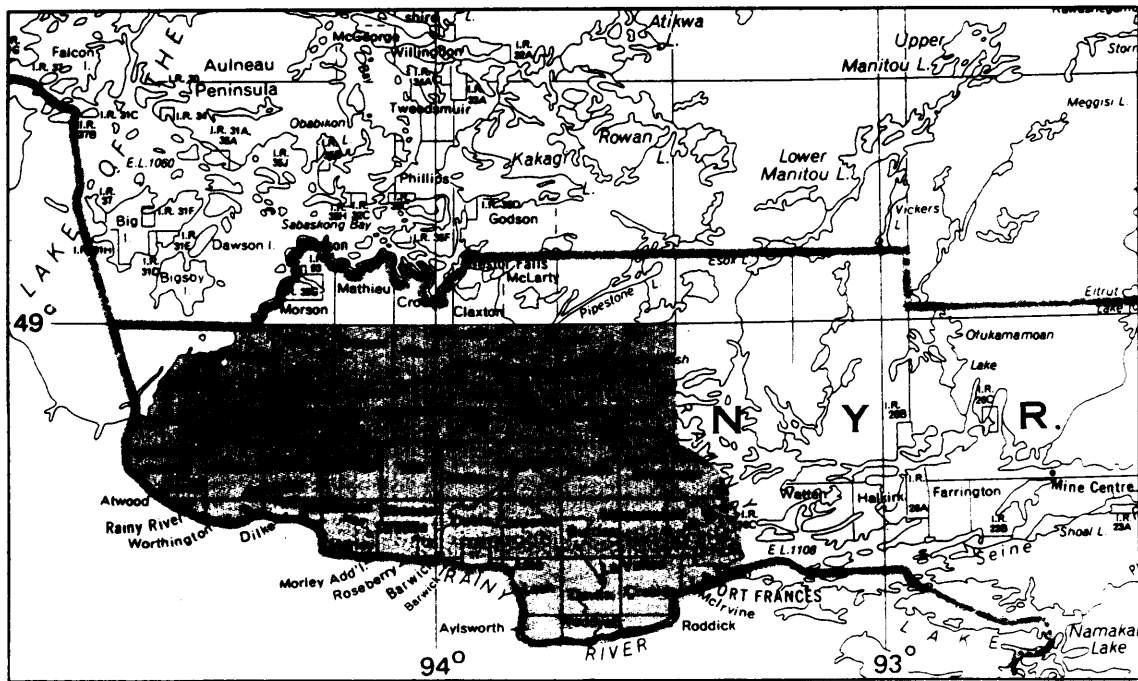


Figure 1. Key map showing the location of the Fort Frances-Rainy River area.

major population centres within the report area. Several Indian Reservations are also situated within the map area. These include: Manitou Rapids I.R. #11 (Rainy River Band); Rainy Lake I.R. #17A and #17B (Naicatchewenin Band); Couchiching I.R. #16A (Couchiching Band); and Rainy Lake I.R. #18C (Stanjikoming Band).

Provincial Highways 11 and 71 are the main transportation corridors and provide connecting routes to Winnipeg, Kenora and Thunder Bay. Major highway links to the State of Minnesota are located at Fort Frances and Rainy River. Access through the report area is provided by provincial secondary Highways 600, 602, 611, 613, 615, 617, 619 and 621. Township, concession and forestry access roads complement the existing network of roads and facilitate access to most areas. Excellent water access is provided by Rainy Lake, Lake of the Woods, the Rainy River and a series of interconnecting lakes in the northeast corner of the report area.

The southern margin of the study area is traversed by the Canadian National Railway, which follows the Highway 11 corridor between the towns of Fort Frances and Rainy River. Following a similar route, a twelve inch natural gas pipeline enters the region at Rainy River and again crosses the International border at Fort Frances. Two hydro transmission lines extend westward from Atikokan, through the report area en route to Kenora. Scheduled plane flights to Winnipeg, Thunder Bay and Dryden are available from the

Fort Frances airport which is located approximately five kilometers north-northwest of the town centre. Eight chartered airways cater mainly to the tourist and resource based industries.

POPULATION

The population of the Rainy River District has remained relatively stable over the last two decades. The rural population density is low, as slightly over half of the residents live in urban areas. The towns of Fort Frances, Emo and Rainy River are, by far, the largest population centres providing trade and retail facilities for much of the western half of the district. Residential development is greatest in close proximity to these urban centres. Numerous smaller settlements (i.e., Crozier, Devlin, Stratton, Pinewood and Sleeman) are scattered between these centres and provide additional services to the rural areas. The Canadian National Railway, Boise Cascade pulp and paper mill and tourism are the largest employers in the area.

CLIMATE

The climate of the region is dominated by continental air masses and weather systems derived from sources to the north, west and south. During the summer months, warm, moist air systems flow north from the Gulf of Mexico and interact with cool, dry air masses from central Canada to produce storm systems which frequently traverse the area. The region is affected by cold, dry arctic air masses during

the winter months, resulting in extended periods of clear, cold weather. The mean annual precipitation is 696 mm with approximately 66 percent of the precipitation occurring as rain during the summer months (May-September). Temperatures vary widely over the course of the year, from a July average of 19°C to a January average of -17°C.

PREVIOUS WORK

Discussions on geological and geographical aspects of the Rainy Lake-Lake of the Woods region date back to the mid-1800's. References to the area are included in reports by Bigsby (1851, 1852, 1854), Dawson (1859), Lawson (1885, 1888) and Parks (1898). By the late 1800's, reports on the surficial geology of the Glacial Lake Agassiz region, including the classic works of Upham (1890) and Tyrell (1896), were published. A detailed investigation of the surficial geology and soils of the Rainy River District was undertaken during the early 1900's (Johnston 1915). Since these early geological investigations, limited geological activity has occurred within the report area.

Increased interest in the bedrock geology and mineral potential of the Rainy River District during the early 1950's resulted in the implementation of organized bedrock mapping programs in the region by the Ontario Department of Mines and the Ontario Geological Survey. Initially, mapping of the Emo area was undertaken at a scale of 1 inch to 1 mile by Fletcher and Irvine (1954). The Fort Frances area,

to the east, and the Off Lake-Burditt Lake area, to the north, were later mapped at a similar scale by Davies (1973) and Blackburn (1976), respectively. Bedrock mapping of the western half of the report area was recently conducted at a scale of 1:50 000 by Johns (1988). A compilation map of the Kenora-Fort Frances region highlights the Precambrian geology and known mineral occurrences of the Western Wabigoon subprovince (Blackburn 1979).

Since the works of Johnston (1915), few geological investigations related to Quaternary geology have been undertaken within the report area. A reconnaissance soil survey of the Rainy River District was undertaken by Hills and Morwick (1944) and later updated by the Ontario Institute of Pedology (1984). Reports related to surficial geology and terrain and aggregate resource evaluation include those of Zoltai (1961, 1965), Roed (1980) and the Ontario Geological Survey (1983, 1990). Peatland evaluation and resource inventories have been completed by Graham and Tibbetts (1965) and more recently by Northland Associates Ltd. (1984).

The Geological Survey of Canada has undertaken a reconnaissance Quaternary mapping and till sampling program, encompassing six 1:100,000 scale map sheets, to the north of the report area between Kenora and Dryden, Ontario (Cowan 1987; Minning 1988, 1989; Minning et al., in prep.).

The Minnesota Department of Natural Resources has undertaken a regional survey, emphasizing drift

geochemistry, over Archean terrain in northern Minnesota (Martin et al. 1988; Martin et al. 1989). A pilot survey was undertaken by the Minnesota Geological Survey in the Birchdale-Indus area of Minnesota and in the vicinity of Emo, within the Emo map sheet, to test geochemical responses of soil, till and stream sediments in areas of known mineralization (Ojakangas et al. 1977). The geological conditions in Minnesota, where most of this work was undertaken, is very similar to conditions across the Rainy River, near Emo, Ontario.

Several B.Sc. theses emphasizing Quaternary geology and paleoecology within the Fort Frances region have been completed. A paleoecological study of the "Rainy River Bog", which is situated 8 km north of Rainy River, has yielded one of the region's first detailed pollen records, spanning the last 4600 years (Gray 1987). Theses describing the character of surface till sheets in the Fort Frances-Rainy River area were completed in an attempt to relate the physical and chemical properties of the tills to provenance and mode of deposition (McKay 1988; Halstead 1989).

METHODS

Field Methods

The field program in the Fort Frances-Rainy River area began during the summer of 1986 and consisted of two main components. Quaternary mapping, at a scale of 1:50 000, of the Rainy River (Bajc and Gray 1987), Emo (Bajc and White

1990) and Northwest Bay Areas (Bajc et al. 1990) was completed during the first two summers of field work (Maps P.3065, P.3137 and P.3138, back pocket). Follow-up programs of sonic drilling, backhoe trenching and surface testpit sampling, were completed by the fall of 1988. Stratigraphic sections were logged and samples collected at 71 boreholes, 44 backhoe trenches and 223 natural and man-made exposures. Sonic borehole and surface sample locations are shown on Figure 2 (back pocket). A map highlighting the numbers and shapes of gold grains recovered from selected samples was released in 1988 (Bajc 1988).

Field methods during Quaternary mapping consisted of digging testpits, hand augering and probing and examining available man-made and natural exposures. Bedrock outcrops were examined for striations. Approximately 1500 field stations and innumerable secondary observation sites were recorded in the study area. Field station records include observations of colour, texture, structure, thickness, nature of contacts, and vertical relationships of the sediments.

Additional information was drawn from water well records, exploration assessment files and records and reports available from various government and private agencies. Field work was supplemented by the interpretation of 1:15 840 scale (1 inch to 1/4 mile) and 1:63 360 scale (1 inch to 1 mile) aerial photographs.

The surficial geological mapping and both shallow and deep subsurface information provided by the backhoe and sonic drilling programs, respectively, has allowed the distribution, properties, and stratigraphic relationships of the various Quaternary sediments to be determined.

Sampling of glacial and non-glacial sediments for laboratory analysis was undertaken at an interval dictated by the sediment's thickness and aerial extent. Paleocurrent measurements were taken from sedimentary structures ranging from ripple-drift cross-laminated sands to large-scale, steeply-dipping foreset beds. Pebble fabrics were undertaken at selected exposures of till. At each site, the orientations of at least 50 elongate pebbles were measured. Pebbles (greater than 4.75 mm diameter) were collected for lithologic study from surface exposures of sandy till by dry sieving bulk samples. Pebbles were recovered from stone-poor, clayey sediments by collecting accumulations of pebbles concentrated on the surface as a result of snow melt and rainfall.

Laboratory Methods

Samples of glacial and non-glacial sediments were analyzed for combinations of matrix grain size and carbonate content, pebble lithologies (greater than 4.75 mm diameter), clay mineralogy, heavy mineral assemblages (greater than 3.3 S.G.), geochemistry and fossil content. Textural analyses were performed by using either a light-blockage particle

sensing system or a combined hydrometer-sieve method following the American Society for Testing and Materials (ASTM 1972) guidelines. Matrix carbonate content was determined using a Chittick apparatus following the gasometric procedure described by Dreimanis (1962). Clay mineral assemblages were determined by x-ray diffraction (XRD). Methods of heavy mineral processing and identification and geochemical determinations are discussed in an accompanying report highlighting drift composition (Bajc 1991). Datasheets containing raw laboratory data, summary statistics and aerial distribution maps for all surface and borehole samples are included in this report.

GEOLOGICAL SETTING

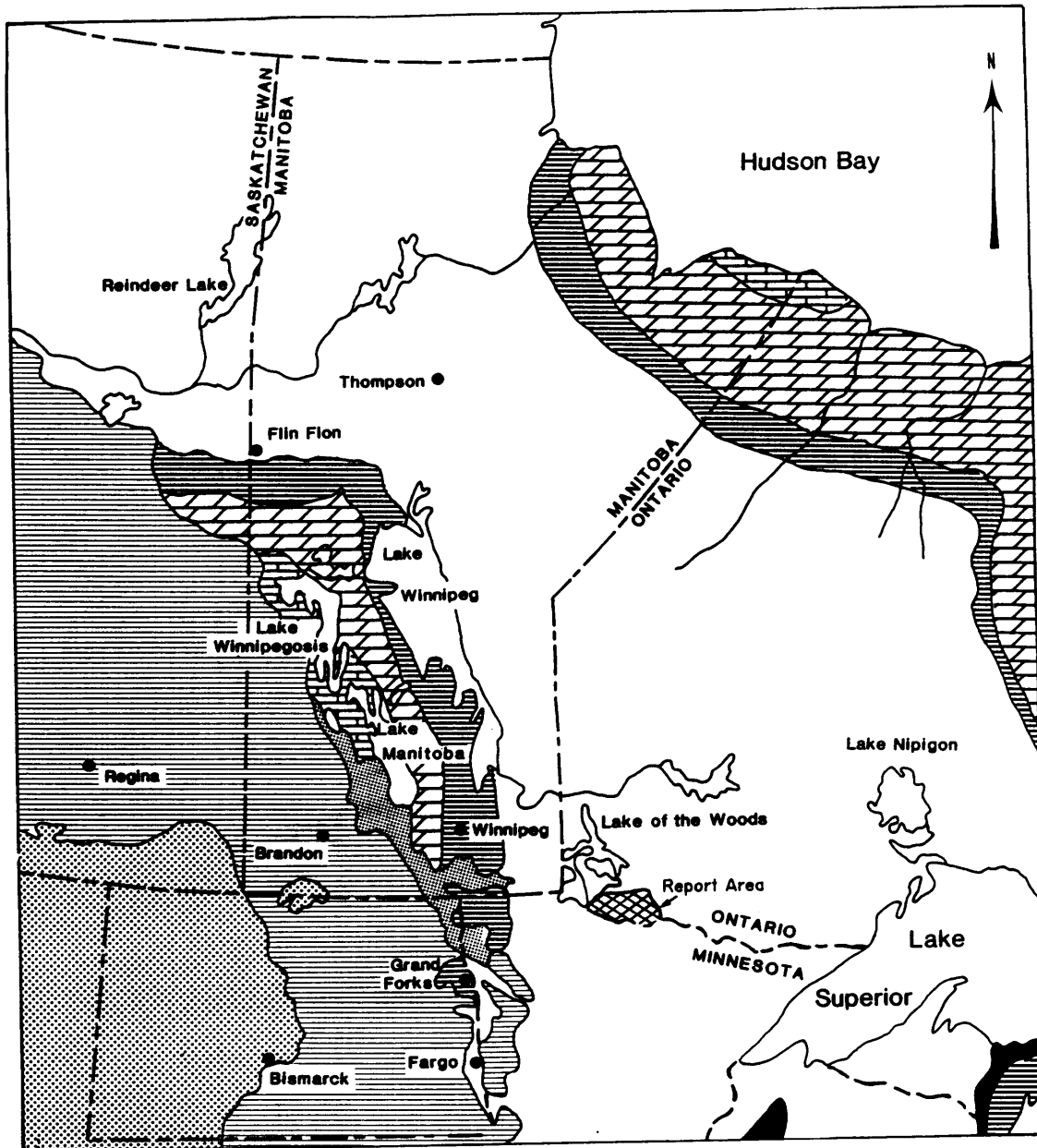
Patterns of ice flow, environments of deposition, and lateral facies relationships are strongly influenced by the geological setting. These parameters, in turn, control the types, properties and distribution of Quaternary sediments observed within the study area.

BEDROCK GEOLOGY

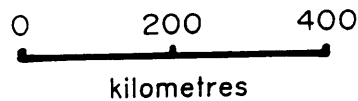
The report area lies within the Superior Province of the Precambrian Shield, approximately 100 km east of Phanerozoic rocks in Manitoba, Minnesota and North Dakota and 650 km southwest of Paleozoic rocks of the Hudson Bay Lowland (Figure 3). Rocks of the Superior Province have an easterly structural grain and are dominated by granitic lithologies with lesser amounts of supracrustal rocks. Paleozoic rocks of the Hudson Bay Basin in Ontario and the Williston Basin in Manitoba, Minnesota, and North Dakota are dominated by carbonate lithologies and dip to the northeast and west, respectively. Mesozoic and Cenozoic rocks of the Williston Basin consist primarily of shales, siltstones, and sandstones with minor amounts of lignite, anhydrite, salt and limestone (Teller and Bluemle 1983).

Precambrian Geology

Interpretation of the Precambrian bedrock geology of the southern half of the report area is hampered by the limited number of outcrops. The geology has been inferred primarily from the interpretation of these widely scattered



LEGEND











- | | |
|--|--|
|  TERTIARY (shale, clay, sand, minor, lignite) |  SILURIAN (dolostone) |
|  CRETACEOUS (shale, minor sand, sandstone and lignite) |  ORDOVICIAN (dolostone, minor shale, siltstone + sandstone) |
|  JURASSIC (shale, minor siltstone, limestone and anhydrite) |  CAMBRIAN (sandstone, minor siltstone + shale) |
|  DEVONIAN (limestone, minor siltstone, shale and dolostone) |  PRECAMBRIAN (granitic + supracrustal rock types) |

Figure 3. Regional bedrock geology of north-central North America (adapted from Teller and Bluemle 1983).

outcrops, geophysical records and exploration drill hole logs. In the northern portion of the report area, the bedrock geology is much better understood, as the cover of Quaternary sediments is thin and discontinuous and, only locally, attain substantial thicknesses.

The report area contains rocks of both the Quetico and Wabigoon Subprovinces of the Superior Province. The east trending Seine River Fault traverses the southern part of the report area and separates the rocks of the two subprovinces (Figure 4). The Quetico metasedimentary rocks, to the south of the fault, consist primarily of sandstones, siltstones, argillites and their derived schists.

To the north of the Seine River Fault, the Western Wabigoon Subprovince consists of supracrustal and batholithic rock types. A southwesterly-trending belt of metavolcanic and metasedimentary rocks bisects the report area and separates felsic to intermediate intrusive rocks of the Sabaskong Batholithic Complex from rocks of the Rainy Lake Batholithic Complex (Figure 4). The belt of metavolcanic and metasedimentary rocks are an extension of the Kakagi-Rowan and Manitou Lakes greenstone belts to the northeast.

Within the northern portions of the report area, where the supracrustal rocks are well exposed, they have been observed to consist of a lower, mafic sequence of massive, porphyritic and pillowed lavas with minor pyroclastic beds (Blackburn 1976). They are overlain, to the east, by an

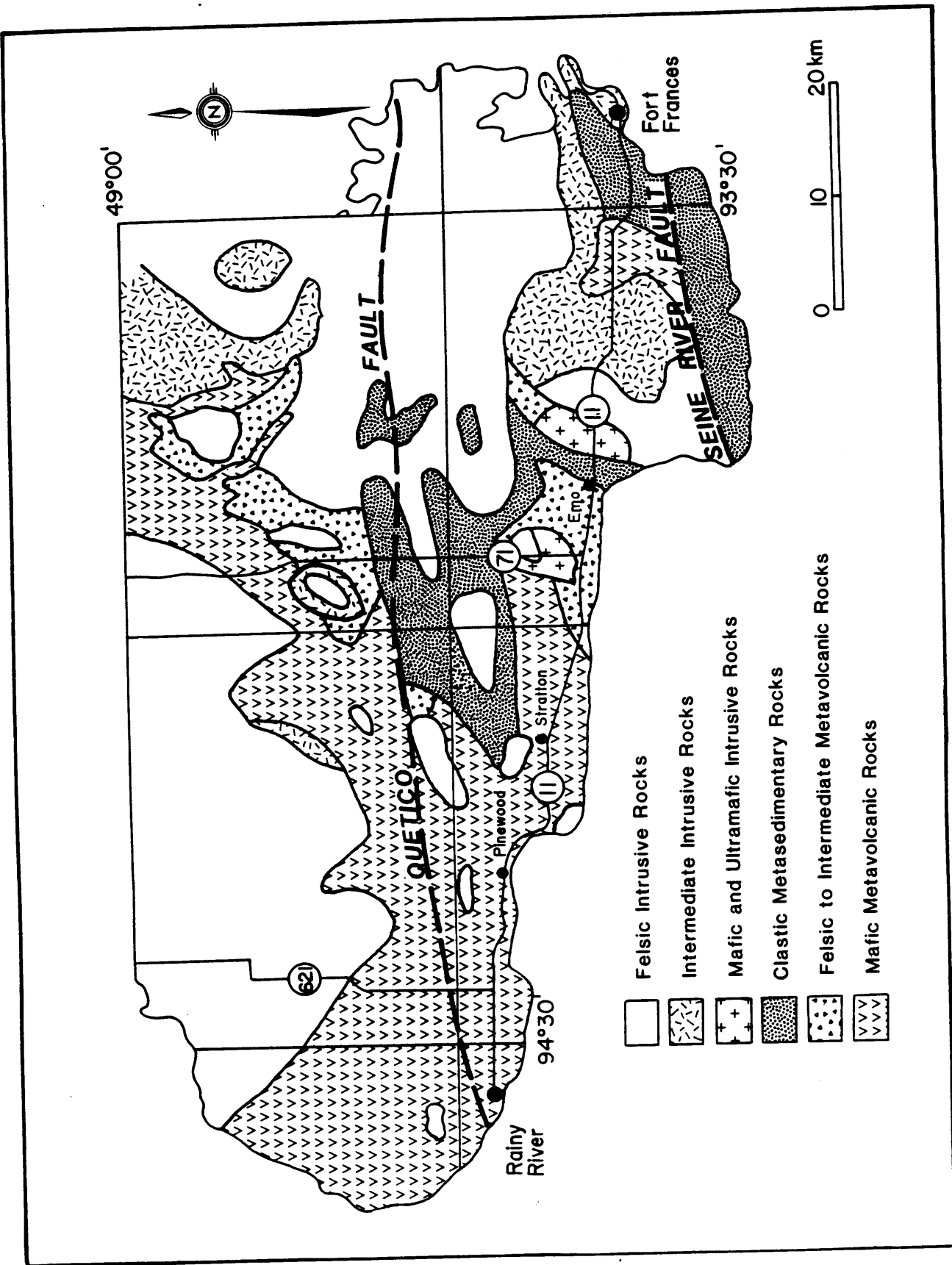


Figure 4. Bedrock geology of the Fort Frances-Rainy River area (adapted from Blackburn 1979).

upper sequence of interbedded mafic to felsic metavolcanic rocks. The felsic metavolcanic rocks consist of fine to coarse-grained pyroclastic rocks, quartz-feldspar porphyry and minor dacite and rhyolite flows. Mafic metavolcanic rocks of the upper sequence consist of massive and pillowed lavas (Blackburn 1976).

To the south and west, where bedrock outcrops are much less common, correlation of units from outcrop to outcrop becomes difficult. Only a very general interpretation of the geological units is possible. A lower unit of massive and pillowed mafic flows is conformably overlain by interbedded and interdigitated intermediate pyroclastic and metasedimentary rocks, including greywackes, banded iron formation, and reworked tuffs (Johns 1988; Fletcher and Irvine 1954). These supracrustal rocks have been intruded by the Dobie and Lash Carpenter Intrusions, which are located in the vicinity of Emo, and consist of gabbro, norite and diorite. Several small, circular stocks of felsic to intermediate composition, have also been mapped within this supracrustal sequence, however, their extent is uncertain due to poor exposure. In the southeastern portion of the report area, lesser amounts of clastic metasedimentary and mafic metavolcanic rocks are contained within the felsic to intermediate rocks of the Rainy Lake Batholithic Complex (Davies 1973).

Northwest-trending Proterozoic dikes of quartz diabase intrude all rock types. They range in width from a few

centimetres to one-hundred metres. The wider dikes display fine-grained margins grading to medium and coarse-grained centres.

The east trending Quetico fault is well exposed to the east of the report area where it transects felsic and intermediate intrusive rocks of the Rainy Lake Batholithic Complex and supracrustal rocks in the vicinity of Mine Centre. The fault is concealed by a thick cover of glacial sediments within the report area. Geophysical methods have helped to define the position of this fault. Southwest-trending splays off of the main fault zone have been inferred from widely scattered outcrops and geophysical interpretations (Johns 1988; W. Day, U.S.G.S., personal communication, 1988). These splays are interpreted to pass through the towns of Pinewood and Stratton.

Cretaceous Geology

A continuous cover of Cretaceous sediment occupies the broad lowland of the Red River Valley in Minnesota and North Dakota. Extending north into Manitoba, Cretaceous sediments blanket the Ordovician, Silurian and Devonian succession of carbonate rocks that fringe the Williston Basin of the western provinces. (Figure 3).

A small outlier of fossiliferous, marine clay of Cretaceous age has been documented in north-central Minnesota, about 65 km south of Fort Frances (Thiel 1947). This occurrence suggests the pre-existence of a more

extensive cover of Cretaceous sediments over north-central Minnesota and much of adjoining Ontario. It would not be unexpected that similar outliers occur beneath areas masked by thick glacial drift within the report area.

The effects of Cretaceous weathering, namely, the formation of thick residual soils and kaolinitization of igneous and metasedimentary host rocks, have long been recognized within Minnesota and Ontario (Ojakangas and Matsch 1982). Occurrences of Cretaceous remnants should be widespread however, either their occurrences have not been recorded and archived in assessment files or they have not been distinguished from younger Pleistocene sediments, which may, upon initial investigation, appear very similar.

An outlier of Middle Cretaceous (late Albian-early Cenomanian) non-marine clastic sediments, nearly 20 m thick, was encountered in an Ontario Geological Survey borehole (F88-33, Figure 2, back pocket) located 7.5 km northwest of Rainy River, Ontario. Seventy-five species of fossil angiosperm and gymnosperm pollen, spores, megaspores, and algal cysts were recovered and used to date the pre-Quaternary unit (Zippi and Bajc 1990). The outlier is located in a protected hollow, down ice from prominent bedrock highlands to the north and east (Figure 5). It is composed primarily of silica sand and gravel. Aside from palynological criteria, there are several distinguishing parameters which have allowed confident differentiation of

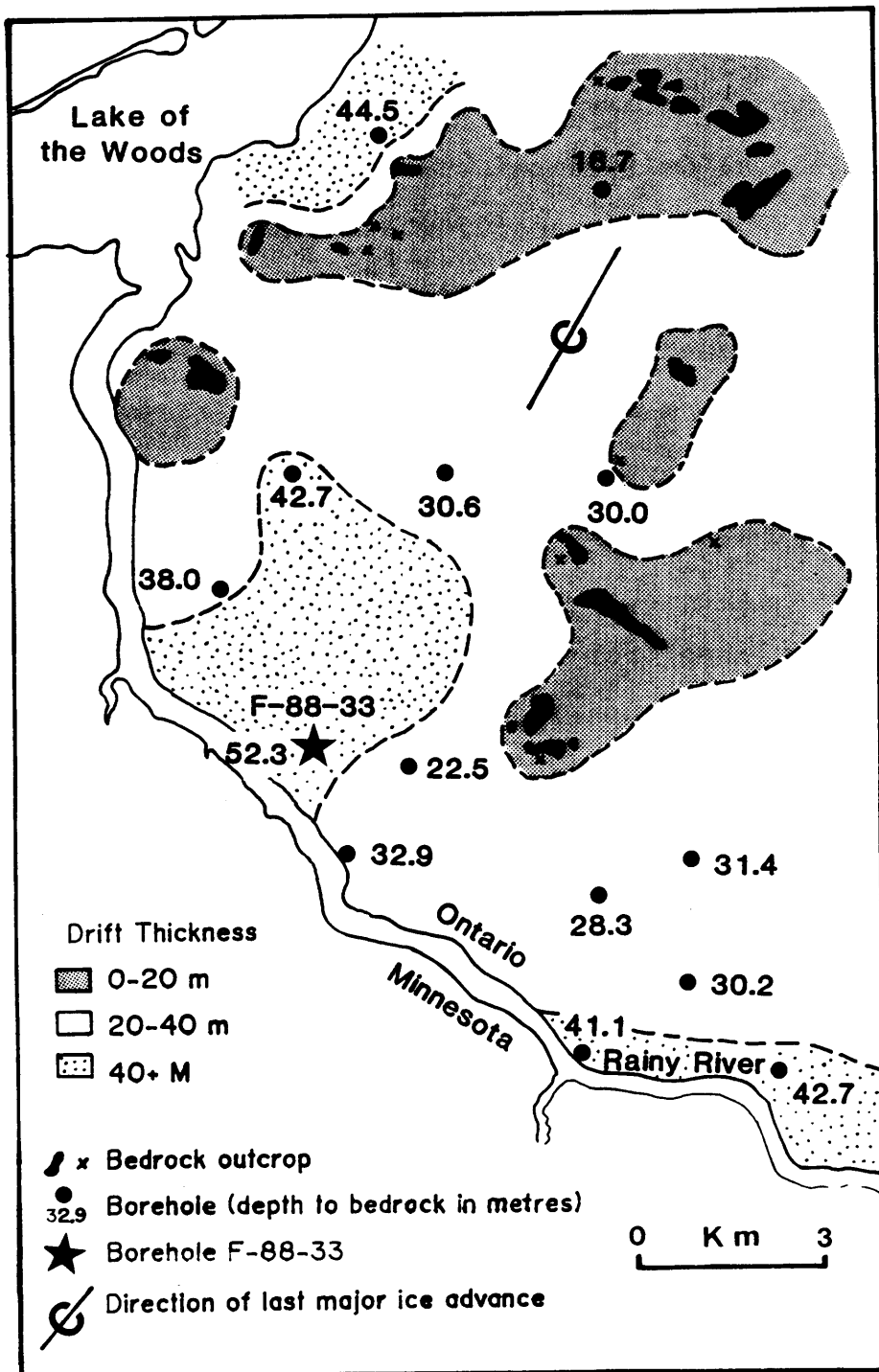


Figure 5. Drift thickness north of Rainy River, Ontario. Note the protected, leeside position of borehole F88-33.

the Cretaceous sediments from the overlying Pleistocene drift. These include heavy mineral assemblages, geochemistry and pebble lithologies (Zippi and Bajc 1990).

The Cretaceous, silica sands are typically white, non-calcareous and composed of moderately sorted, angular to subangular grains of quartz (85 to 90% by volume), with interstitial kaolinitic clay. The whole rock analysis of a sample of the silica sand yielded relatively high values of SiO_2 (87.3%). Nodular siderite is an important constituent of the non-magnetic heavy mineral sand fraction. Most of the gravel clasts are composed of well rounded, weathered, felsic and intermediate intrusive rock types, kaolinite, lignite and Paleozoic carbonate rocks (Zippi and Bajc 1990).

Thick saprolites, presumed to be Cretaceous in age, have been documented in the study area. In areas of thick drift, as exist northwest of Rainy River, borehole records suggest saprolite thicknesses in excess of 60 m. In highland areas with thin till cover, it is not unusual to encounter saprolitic zones preserved in bedrock depressions on the down ice flow sides of bedrock highs. Tension fractures in the saprolites have been observed to contain till confirming a pre-Late Wisconsinan age for the development of the saprolite.

The affects of Cretaceous weathering have been documented over a much wider portion of northwestern Ontario. Iron-rich residua along zones of accentuated jointing and brecciation have been observed within fault

zones of the Gunflint Formation in the vicinity of Thunder Bay, Ontario (Purucker, 1983). The residuum is believed to represent the product of Cretaceous weathering as indicated by paleomagnetic and paleontologic evidence. Such examples are common within the James Bay Lowland and over large areas of northeastern Minnesota. This implies the former existence of an extensive residual soil over much of Ontario's Precambrian Shield which has since been removed by the agents of Quaternary and Tertiary erosion (Feininger 1971).

REGIONAL PHYSIOGRAPHY

The Fort Frances-Rainy River area is located within the Severn Upland of the Canadian Shield (Bostock 1970). The major physiographic elements of this landscape are controlled by geological structure and bedrock lithology. The region has remained relatively stable, with only broad, gentle warpings of the Earth's crust since late Precambrian time. Subsequent modification, by the processes of Pre-Quaternary peneplanation and Pleistocene glaciation has subdued high relief features and enhanced broad, low relief structures.

The Precambrian surface, as well as the overlying Paleozoic and Mesozoic strata of Manitoba, Minnesota and North Dakota, dip to the southwest into the Williston Basin. Dips on the Precambrian surface range from 3 to 8 m/km (Teller and Bluemle 1983). The land surface between Fort

Frances and northwestern Minnesota slopes to the west at a rate of 0.3 m/km. A broad, north-trending bedrock lowland between the Manitoba escarpment and the edge of the exposed Precambrian shield is roughly coincident with the Red River valley and the Lake Winnipeg basin. This lowland helped direct preglacial rivers as well as glacier flow throughout Cenozoic time.

Intense weathering, erosion, and redeposition of Precambrian crystalline rocks over most of western Minnesota and the immediately adjacent areas of North and South Dakota and Ontario during early Cretaceous time reduced this area to a peneplain (Teller and Bluemle 1983). The outer, northeastern edge of this peneplain crosses the study area. A sharp physiographic break occurs between a Precambrian highland, with little to no drift cover and few signs of intense weathering, and a drift-covered lowland where thick saprolites are common.

The effectiveness of glacial erosion and its importance in the development of the Great Lakes basins was widely debated in the latter half of the 19th century (Newberry 1862, 1870; Whittlesey 1866; Chamberlin 1883, 1888; Spencer 1890; Davis 1882; Wright 1891, 1892; Leverett 1899, 1901). In the case of the Lake Agassiz basin, it appears that glacier ice of the Des Moines lobe and its sublobes scoured and deepened preglacial depressions, notably the Red River lowland. These depressions partly controlled glacial flow. An offshoot of the Des Moines lobe, referred to as the St.

Louis sublobe, fanned eastward into the lowland of northwestern Minnesota and adjacent Ontario before high ground to the north and east was encountered, preventing further advance.

LOCAL PHYSIOGRAPHY AND DRAINAGE

The report area is located within the Arctic watershed. The main flow is directed from Rainy Lake to Lake of the Woods via the Rainy River. Discharge from Lake of the Woods into Hudson Bay is via Lake Winnipeg and the Nelson River.

Two contrasting landscapes occur in the report area based on physiography and surface drainage patterns (Figure 6). The northeastern corner is a highland which is strongly controlled by bedrock topography (Zone 1). The remainder of the report area is a lowland (Zone 2) which can be subdivided into two subzones. In Subzone 2a, the highly irregular bedrock surface outcrops in places and imparts strong control on local topography. In Subzone 2b, bedrock outcrops are scarce and the bedrock topography is masked by thick deposits of Quaternary sediments.

Highland With Thin Drift Cover

Zone 1 of Figure 6, is characterized by abundant bedrock outcrop with drift only locally attaining substantial thicknesses. The landscape contains many irregularly shaped lakes, the levels of which are controlled by bedrock sills. The outflow from these lakes is usually via short, slow moving rivers into lower level lakes.

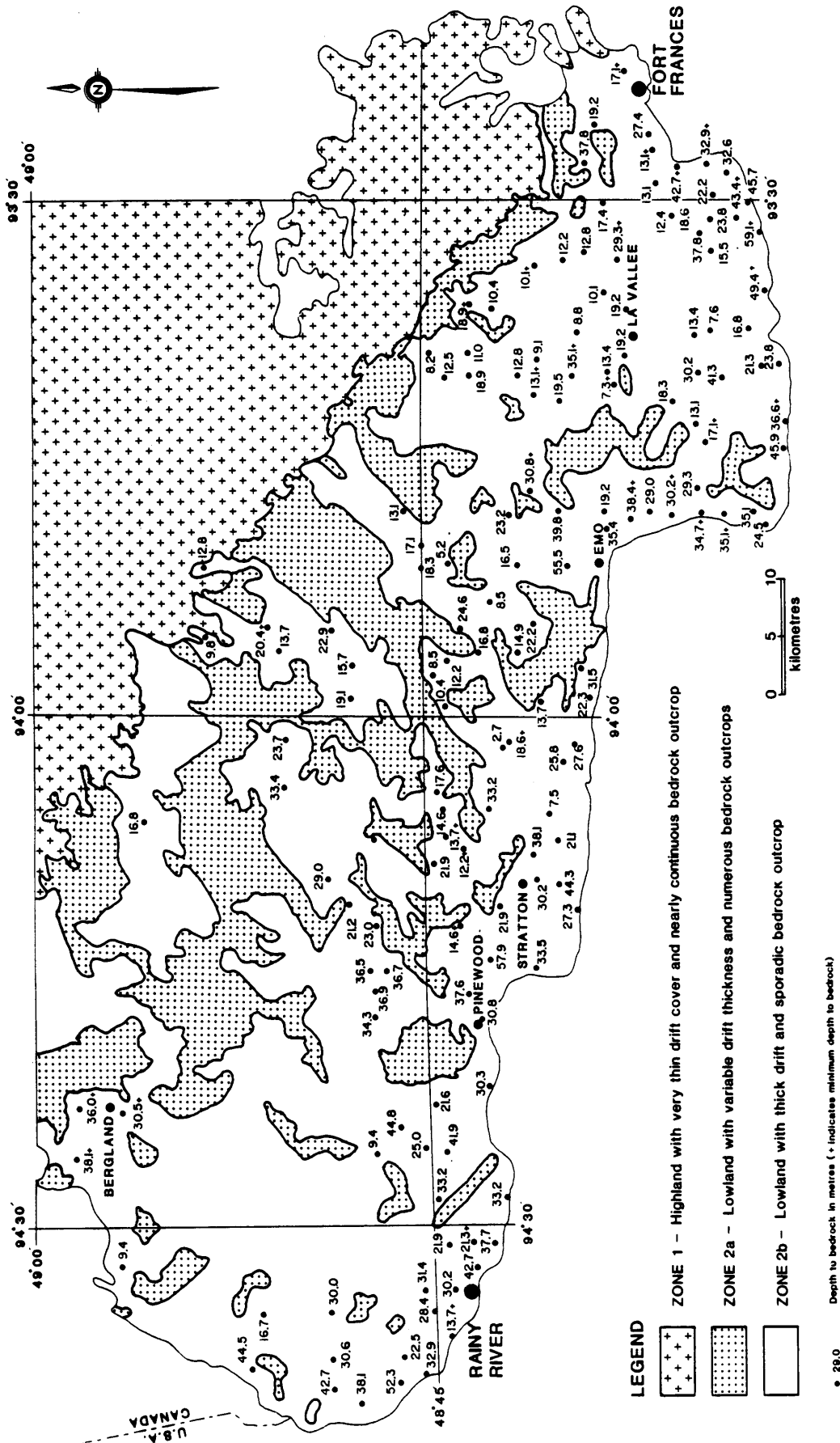


Figure 6. Physiographic regions and drift thickness, Fort Frances-Rainy River area.

Relief within this area is controlled almost exclusively by the bedrock geology. The highland is transected by a southwest-trending belt of supracrustal rocks, in the Off Lake-Burditt Lake area, which displays positive relief with respect to large batholithic complexes, to the east and west. Relief within this zone is in excess of 90 m with an elevation range of 335 to 425 m asl. Fault controlled lineations parallel to the southwest-trending greenstone belt are accentuated by elongate lake basins such as Panorama Lake, Beadle Lake and Boundary Lake.

The westerly-trending Quetico fault, which passes through the central portion of the map area is easily traced in Zone 1 where it is represented by an east-trending lineation passing through Browns Inlet, Halfway Inlet, and Lost Bay of Rainy Lake.

Surface drainage patterns tend to be controlled exclusively by bedrock topography. Following spring thaw and rainfall events, surface runoff is channelled into small ephemeral streams which feed larger lakes. The majority of these lakes ultimately flow into Northwest Bay of Rainy Lake.

Lowland With Variable Drift Cover

Zone 2 of Figure 6 is a lowland consisting of: 1) areas of moderately abundant bedrock outcrop (30 to 40% by area) with localized pockets of thick drift (Subzone 2a) and 2) areas of sporadic bedrock outcrop (<5% by area) with

overburden thicknesses commonly in excess of 30 m (Subzone 2b). Zone 2 contains few lakes. Many of those which do exist are circular in shape and surrounded by peatlands (eg. Mud Lake, Marsh Lake and Cranberry Lake).

Relief within this area of thick drift is controlled, to a large extent, by either the underlying bedrock surface or by the physiographic features produced by glacial and post-glacial erosional and depositional events. In contrast to Zone 1, variations in surface topography and relief are not a reflection of variations in bedrock lithologies. Rather, the degree of weathering and peneplanation of the bedrock surface since the Cretaceous Period appears to be the most important controlling factor.

Subzone 2a is characterized by rolling landscape with relief in excess of 45 m and a range of elevation of 350 to 400 m asl. Subzone 2b exhibits flat to gently undulating plains with relief of 25 to 30 m and a range of elevation of 325 to 350 m asl.

Fault controlled lineations, as seen within Zone 1, are not easily recognized within Zone 2. The western extension of the Quetico Fault is masked by a thick blanket of overburden. However, a series of east trending peatlands from Abbott Lake, near the centre of Kingsford Township to Browns Road, in Patullo and Nelles townships may reflect the fault trace at depth. West of Nelles Township, the fault has no physiographic expression making an extrapolation difficult.

Large peatlands occur over broad areas in the western half of Zone 2. Glaciolacustrine sediments underlie the peat in this region. The peatlands are generally flat-lying and inhibit drainage.

Where the drift thins up against or is draped over bedrock, the surface topography becomes more undulatory. Additional relief occurs where modern drainage systems have eroded down into the glacial sediments. The Rainy River has eroded down 10 to 20 m in places along its course. Incision has been greatest along its upper reaches, in the vicinity of Fort Frances. Large, dendritic river systems (eg. Kishkakoosis and Pinewood Rivers) have eroded down through large areas of peat in response to dropping base levels. In many cases, the substrate of glaciolacustrine clay has been encountered and the drainage system stabilized.

Additional relief occurs where erosional processes of Glacial Lake Agassiz cut sharp, wave-cut notches into landscapes which were previously only gently sloping. Also, constructional processes of Lake Agassiz have created bars, spits and beach ridges adjacent to and between highland areas which protruded above the then existing level of Glacial Lake Agassiz.

Surface drainage throughout the part of the map area covered by thick drift is facilitated by a dendritic system of creeks and rivers that feed into the Rainy River, Rainy Lake and Lake of the Woods. Most of these systems become deeply incised close to their mouths. Unlike the rest of

the river systems in the report area, the Rainy River flows along orthogonally-oriented river segments (i.e., north-south and east-west) which are apparently, bedrock controlled.

Surface water movement is also accentuated in large string bogs situated within Pratt and Blue townships. Remarkable flow features, enhanced by vegetation growth, indicate a consistent flow of surface water to the west into the Lake of the Woods basin (Photo 1).

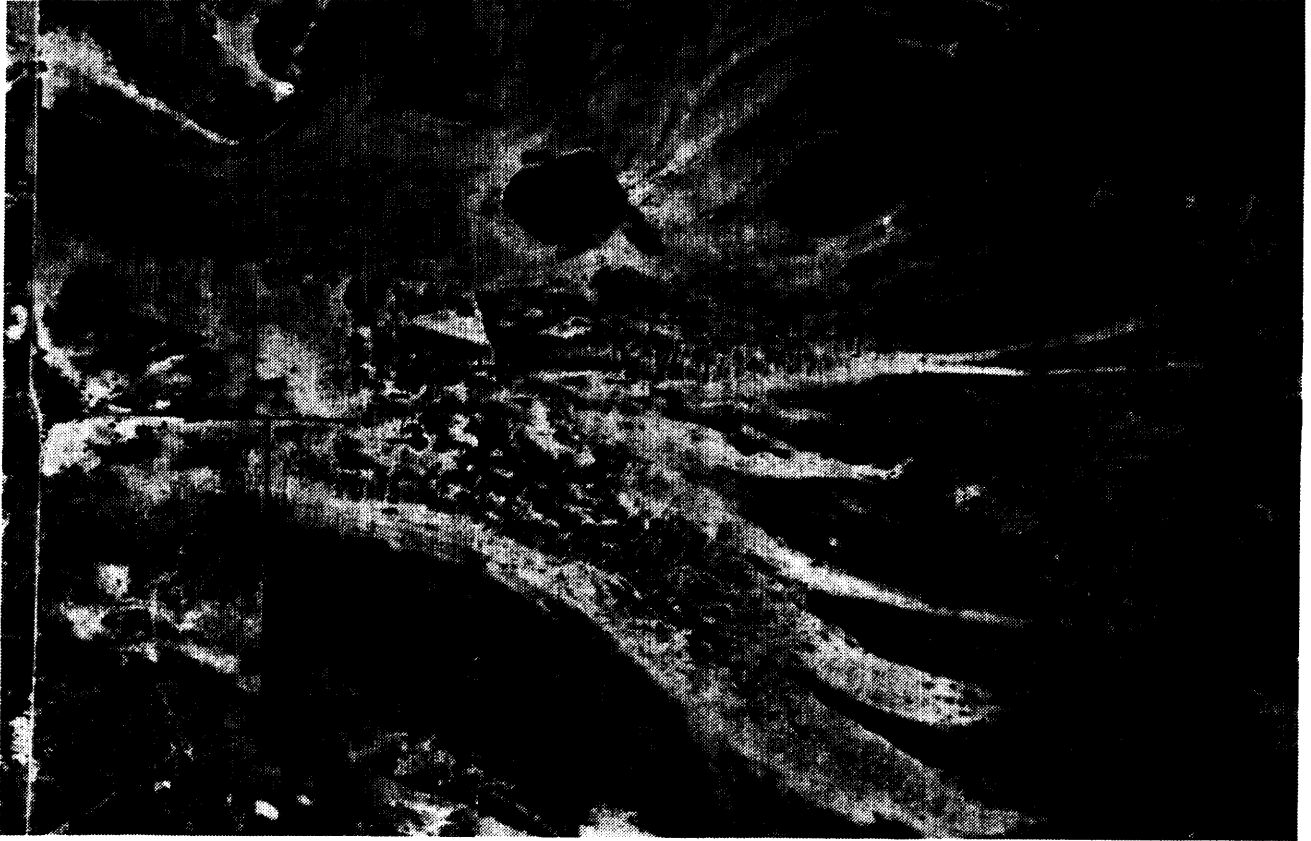


Photo 1. String bog in Blue Township with well defined surface water flow lines.

QUATERNARY GEOLOGY

STRIAE AND ASSOCIATED ICE FLOW FEATURES

Glacial striae, grooves, chatter marks, crescentic fractures and bedrock surfaces displaying stoss and lee erosional forms have been observed within the Fort Frances-Rainy River area. Glacial striae are, by far, the most common and indicate several episodes of ice advance into the study area. The relative ages of intersecting sets of striae have been determined, in most cases, by the recognition of the older erosional forms in lee positions and by cross-cutting relationships indicated by the strength and depth of striae and grooves.

As suggested by Johnston (1915) and Zoltai (1961), the Fort Frances-Rainy River area was affected by ice originating from both the Labradorean and Keewatin sectors of the Laurentide Ice Sheet (Figure 7). An initial, strong, southwesterly flow of Labradorean ice was followed by a late-glacial advance of Keewatin ice flowing from the west. Striae supporting the latter advance are uncommon. This is attributed to the abundance of soft rock types and fine-grained glaciolacustrine sediments in the basal debris layers of the glacier. Evidence of this easterly ice flow is based primarily on the composition and surface distribution of the glacial sediments associated with the advance.

Striae, grooves, crescentic fractures, chatter marks, and roches moutonnées formed by Labradorean ice indicate ice

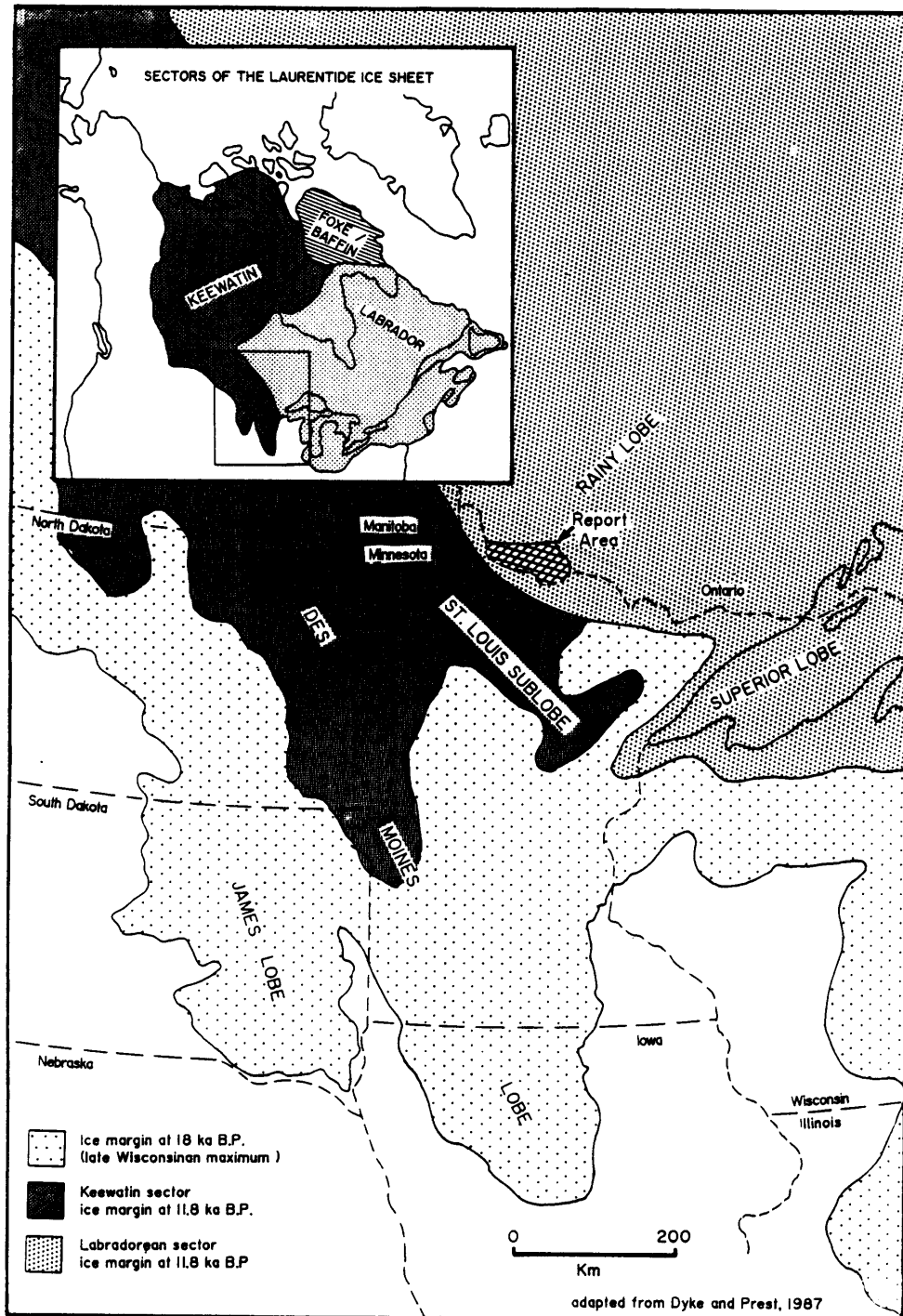


Figure 7. Glacial lobes and sublobes which affected the North American mid-continent during the Late Wisconsin glacialiation (ice margins at 18.0 and 11.8 ka B.P.). Inset map shows the major dispersal centres or sectors of the Laurentide Ice Sheet during the Late Wisconsin maximum.

movement at approximately 210° azimuth across the entire study area with local variations of 5 to 10° (Figure 8). Where greater divergences occur, topographic obstructions and bedrock lineations appear to be responsible for deviations from the regional ice flow pattern.

Striae associated with the last advance of Keewatin ice into the study area were found almost exclusively within the southern half of the study area on supracrustal rock types (Figure 8). They indicate ice flow to 90° azimuth with local deviations of 10 to 20° . To the north, near the outer limit of drift deposited by this advance, a floating ice margin may have prevented the formation of striae.

Alternatively, Keewatin ice may have fanned to the northeast producing striae which are now, easily confused with southwest trending striae associated with the previous advance of Labradorean ice. Harder, batholithic rock types, as are found over most of the northwestern and eastern portions of the report area, show few signs of glacial abrasion. Postglacial weathering has, for the most part, destroyed the remains of fine glacial polish and striae on these rock types.

Crossing striae have been encountered at several locations within the southern portions of the report area. Many of these occurrences are situated on freshly exposed bedrock surfaces as exist along roadways and in sand and gravel pits (Photo 2).

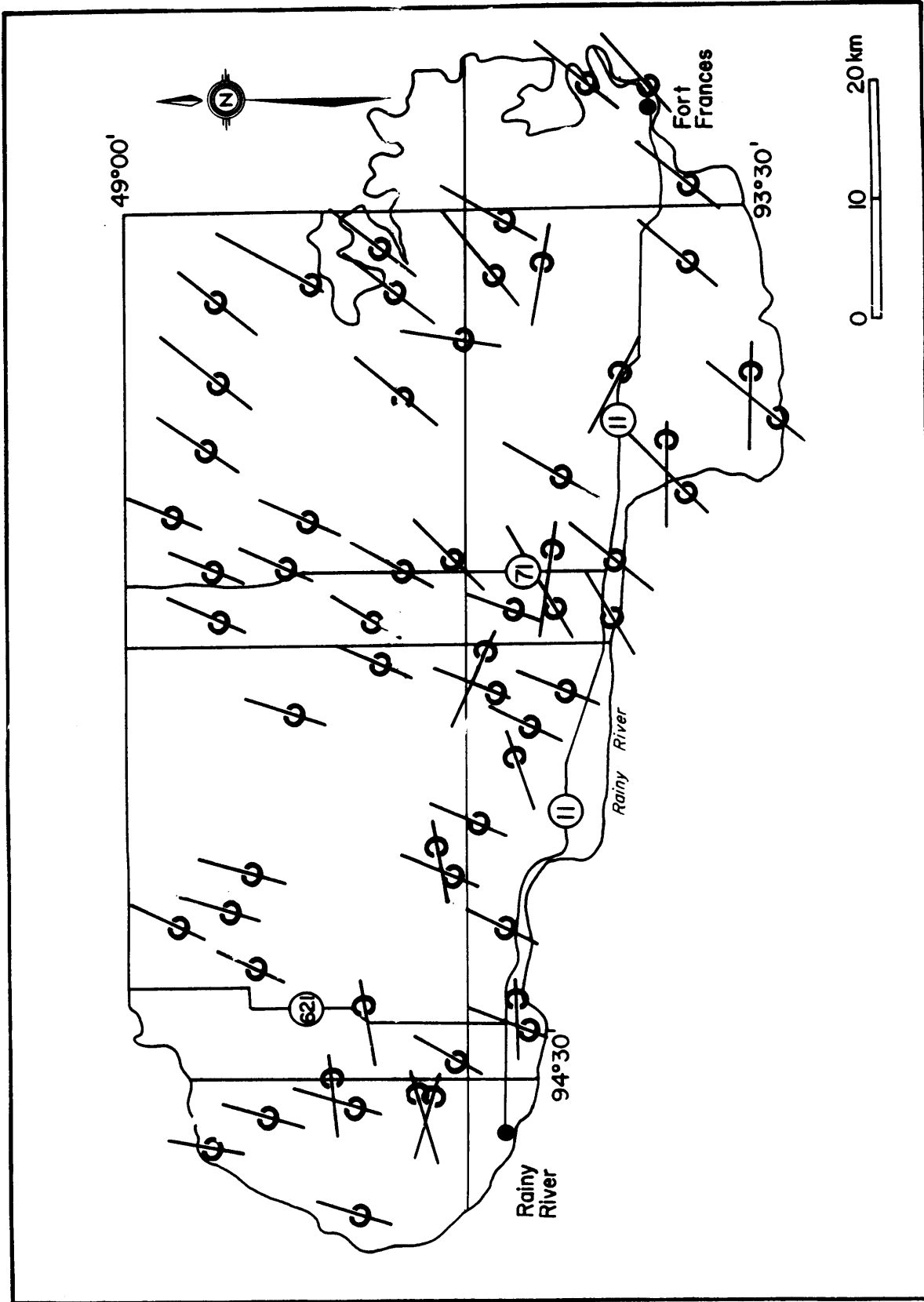


Figure 8. Location and direction of measured glacial striae, Fort Frances-Rainy River area.



Photo 2. Crossing striae on coarse-grained diabase in Worthington Township.

A few scattered occurrences of southeast trending striae have been documented, however, their significance is as yet unestablished. They may be associated with an early advance (i.e., pre-Late Wisconsinan) of Keewatin ice into the report area; an advance which deposited sediments referred to by Johnston (1915) as "old, calcareous drift".

DRIFT THICKNESS

Owing to the irregular nature of the Precambrian surface within the study area, only generalizations with regard to drift thickness are possible. As mentioned in a previous section, the study area can be subdivided into two contrasting terrain types. These areas are highlighted in Figure 6.

Depths to bedrock were compiled from water well records and sonic drill holes completed as part of this study. Subsurface information is lacking across large, uncleared tracts of land near Rainy River and Fort Frances. In these areas, peatlands have prevented agricultural development and hence, the need for water wells.

The Rainy River flows along orthogonally-oriented river segments which are probably, bedrock controlled. Quaternary sediment thicknesses tend to be greatest adjacent to the river and diminish rapidly to the north-northeast. Depths to bedrock of 40 to 50 m are common along the river's course between Fort Frances and Emo and decrease to 25 to 35 m between Emo and Lake of the Woods. In the interior of the

study area, in isolated basins (Zone 2b, Figure 6), drift thicknesses of 10 to 20 m are common, however, thicknesses in excess of 30 m have been documented. Drift thickness is much reduced and usually less than 10 to 15 m within Zone 2a, Figure 6. Depths to bedrock within Zone 1 of Figure 6 are usually less than 3 m, however, drift may locally attain thicknesses of several tens of metres in areas of ice-contact stratified drift.

CONSTRAINTS ON GLACIAL SEDIMENTATION

At its maximum extent, Glacial Lake Agassiz inundated more than 1 million km² in Saskatchewan, Manitoba, Ontario, Minnesota, North Dakota and South Dakota. Its drainage basin exceeded 2 million km² and extended from the Rocky Mountains in the west, to Lake Superior in the east.

Lake Agassiz depended on the Laurentide Ice Sheet for its existence, forming only when northward flowing rivers of the Arctic watershed were dammed by ice advancing out of the Hudson Bay Lowland from the Labradorean ice centre. The size and depth of Lake Agassiz was controlled by a series of outlets, the availability of which were controlled by the position of the ice margin.

Cycles of expansion and decline of this lake undoubtedly occurred many times during the Quaternary Period. Unfortunately, the records of earlier lake phases have been largely destroyed, leaving our present knowledge

limited to the lake stages associated with the last glacier retreat.

Precursors of Glacial Lake Agassiz formed proglacially, in low-lying areas of the report area, during the advance and retreat stages of earlier glaciations. At least two older phases of Lake Agassiz have been recognized as a result of this study. Water depths in excess of 45 m, and perhaps as great as 75 m, probably existed within these water bodies. The deposits, sedimentary sequences, and facies transitions in the Fort Frances-Rainy River area reflect this environment of deposition.

PROVENANCE AND THE RECOGNITION OF TWO ICE LOBES

Several criteria have been used to distinguish between deposits of Keewatin and Labradorean origin. These include: carbonate content, clay mineralogy and composition of the pebble fraction. These parameters are strongly influenced by the regional bedrock geology and glacial dispersal processes.

The report area is situated about 650 km southwest and 100 km east of Phanerozoic carbonate and clastic bedrock successions of the Hudson Bay and Williston basins, respectively. Carbonate debris has not been uniformly dispersed out of the Hudson Bay Lowland across the Canadian Shield. Plumes of carbonate-rich drift extend southward into the Hemlo and Geraldton areas (Geddes et al. 1985 and Kristjansson and Thorleifson 1987). To the southwest of

these belts, carbonate levels decrease rapidly in response to comminution and dilution by Precambrian crystalline and supracrustal lithologies. The carbonate content of both the pebble and matrix fractions of till samples deposited by the Labradorean sector fall to levels around 5 to 10% within 200 km to the north of the report area (Dredge and Cowan 1989).

Sediments deposited by the Des Moines Lobe (Keewatin sector) contain much higher levels of carbonate debris. This lobe traversed extensive stretches of carbonate bedrock in central Manitoba and dispersed these rock types, to the south and east, on the Precambrian Shield. Keewatin derived till samples collected from the report area contain 50 to 60% carbonate pebbles and 20 to 40% matrix carbonate.

Clay mineralogy is a useful tool for distinguishing between the two source regions as well. Cretaceous shales of the Williston Basin are rich in swelling clays, whereas the supracrustal and crystalline rocks of the Canadian Shield host inactive clay minerals such as illite, chlorite and kaolinite. The clay minerals contained within glacial sediments of the report area reflect these different lithologic provenance areas.

A rather complex record of glacial advances and retreats have been recorded in the till stratigraphy of the Fort Frances-Rainy River area. Oscillations of the Keewatin and Labradorean glacier margins have resulted in both high and low stands in the levels of Lake Agassiz and its precursors. Five distinct tills and five glaciolacustrine

sediment packages comprise the stratigraphic sequence. A summary of the main stratigraphic units is presented in Table 1. A description of these deposits is contained within the following sections of this report.

PRE-LATE WISCONSINAN DEPOSITS

Older, Labradorean Derived Till

An older, apparently weathered, till of Labradorean (northeastern) provenance was encountered in a sonic borehole about 3 km north of Sleeman (F87-23, Figure 2, back pocket). The till, which is overlain by about 40 m of Late Wisconsinan drift, is 1.4 m thick and rests directly upon bedrock. The till has a brown to olive-brown colour, is very dense and has a clayey, sandy silt texture (36% sand, 44% silt, 20% clay) and low matrix carbonate (Table 2). The elevated clay content may represent: 1) the product of insitu weathering during a non-glacial interval; 2) the incorporation of glaciolacustrine clay; or 3) the incorporation of weathered bedrock.

Chlorite, interlayered illite-smectite, illite and kaolinite are the major clay minerals present. Carbonate clasts were not observed and matrix carbonate content is low (1%). Most of the clasts recovered from the till are composed of coarse-grained, mafic intrusives (lamprophyres), many of which display a surface weathering rind.

This older till is abruptly overlain by an unoxidized light, olive-grey till of northeastern provenance. The

Table 1. Quaternary deposits of the Fort Frances-Rainy River area.

AGE	DEPOSIT	MATERIAL	MORPHOLOGIC EXPRESSION
RECENT	modern alluvium	sand, silt, minor clay, organic remains common	floodplains of existing rivers
	recent beach & eolian deposits	fine to very fine sand	spits & wind-modified spits on Lake of the Woods
	bog & swamp deposits	peat & muck	filled depressions
LATE WISCONSINAN	older alluvial deposits	sand & silt with organic remains	remnant river & creek terrace deposits
	Sherack Formation (Emerson Phase glaciolacustrine sediments)	clay, silt, sand & gravel with organic remains	lacustrine plains, beaches & bars
	Poplar River Formation (Moorhead low-water Phase sediments)	sand & gravel with organic remains	fluvial and small basinal deposits (buried)
	Brenna Formation II (Lockhart Phase glaciolacustrine sediments)	silt and clay, minor sand & gravel	lacustrine plains, beaches & bars
	Marchand till	silty sand to sandy silt till	ground moraine
	Brenna Formation I (Lockhart Phase glaciolacustrine sediments)	silt & clay, minor sand & gravel	lacustrine plains, beaches & bars (partially buried)
	ice-contact stratified drift & subaquatic fan deposits	sand & silt, minor gravel & till	ice-contact deltas, subaquatic fans (buried)
	Whitemouth Lake till	silty clay to clayey silt till	ground moraine, (partially buried)
	Wylie Formation (pre-Lockhart phase glaciolacustrine sediments)	sand, silt & clay	glaciolacustrine plain (buried)
	ice-contact stratified drift & subaquatic fan deposits	sand, gravel & boulders, minor silt & till	Rainy Lake-Lake of the Woods Moraine, kames, buried subaquatic fan deposits
Whiteshell till	silty sand to sandy silt till	ground moraine, partially buried	
PRE-LATE WISCONSINAN (IN NO PREFERRED ORDER)	older Labradorian - derived till	sandy silt till	buried ground moraine
	older Keewatin - derived till	sandy, clayey silt (loam) till	buried inclusion
	wood fragments in Whiteshell till	wood, twigs	buried inclusions
	glaciolacustrine & subaquatic fan deposits	sand, silt & clay, minor gravel	buried subaquatic fans & glaciolacustrine plains

Table 2. Summary of grain size and carbonate content data for till samples recovered from backhoe trenches and sonic boreholes (averages and ranges).

UNIT	N	TEXTURE			CARBONATES		
		% SAND	% SILT	% CLAY	PERCENT TOTAL CARBONATE	CA/DO RATIO	
MARCHAND TILL	68	37 (20-51)	40 (24-47)	23 (12-34)	29 (26-32)	0.5 (0.3-0.7)	
WHITEMOUTH LAKE TILL	160	22 (5-37)	36 (24-62)	43 (25-67)	28 (19-40)	0.5 (0.3-0.8)	
WHITESHELL TILL	176	57 (15-91)	37 (9-73)	6 (0-48)	4 (1-18)	0.5 (0.1-1.7)	
OLDER KEEWATIN DERIVED TILL	1	33	35	32	49	0.8	
OLDER LABRADOREAN DERIVED TILL	1	36	44	20	1	0.9	

overlying till is correlated with the regionally widespread, Whiteshell till of Late Wisconsinan age (Table 1). It has a silty sand texture (48% sand; 44% silt; 9% clay) and is moderately dense. Matrix carbonate values range from 2 to 6%. The composition of the pebble fraction is heterogeneous and consists of mafic, intermediate and felsic extrusive and felsic to intermediate intrusive rock types.

Weathered, Labradorean derived till has been recovered from subsurface borings in northern Minnesota (Martin et al. 1988). At one Minnesota drillhole location (OB-212), about 1 m of olive-brown, non-calcareous loamy, gravelly till was encountered at depth, resting directly on bedrock. At this site, it was unclear whether the apparent oxidized colour of the till was due to insitu weathering during a non-glacial interval or simply the extensive incorporation of the underlying weathered bedrock.

At a second site (OB-208), about 0.3 m of dark grey, loamy till was recovered immediately above bedrock. Its dark colour and loamy texture has been interpreted to represent the incorporation of a soil layer which formed on the bedrock surface prior to the Late Wisconsinan glaciation (Martin et al. 1988).

The ages of these isolated occurrences of older, Labradorean derived till are unknown although an Early Wisconsinan or Illinoian age is suspected.

Older, Keewatin Derived Till

In his report of the surficial geology and soils of the Rainy River District, Johnston (1915) referred to an occurrence of "old, calcareous drift" of northwestern provenance (Keewatin source) near the middle of Carpenter Township. Approximately 2 m of reddish, poorly stratified, highly oxidized and leached, sand and gravel containing numerous limestone pebbles was observed to overlie bedrock. This unit was overlain by 1 to 3 m of a bouldery deposit that was generally free from limestone and apparently associated with a northeastern ice source (Whiteshell till).

This occurrence was not found during the course of mapping the Emo map sheet, however, a deformed inclusion of oxidized, stone-poor, loamy till (Table 1) was discovered in a narrow, 3 to 4 m deep drainage trench excavation, near the middle of Mather Township (NB-232, Figure 2, back pocket). The inclusion, which is completely encircled by a stony, silty sand till (75% sand; 23% silt; 2% clay), has abundant carbonate clasts and calcareous precipitates along joint fractures (Photo 6). These precipitates have resulted in an elevated total carbonate value for the till sample (Table 2). The encasing till, which is correlated with the widespread, Whiteshell till of Late Wisconsinan age, contains low matrix carbonate and very few carbonate clasts.

The inclusion was probably incorporated as a frozen block into the base of the advancing Labradorian ice sheet, and subsequently overturned and rolled into its circular



Photo 3. Inclusion of Pre-Late Wisconsinan, Keewatin derived till within Late Wisconsinan, Whiteshell till, Mather Township. Note the secondary carbonate within the inclusion.

shape. Mixing of the two tills has occurred along the upper surface of the inclusion. This exposure may represent the remnant of the same stratigraphic sequence as described by Johnston (1915).

In west-central Minnesota, oxidized calcareous till, presumed to be Early Wisconsinan or Illinoian in age, has been encountered in a series of boreholes beneath the lowest, Late Wisconsinan sediment (Sackreiter 1975). This till has been correlated with the calcareous, Granite Falls till of the Wadena drumlin field in central Minnesota (Wright 1962, Goldstein 1986) and with Hawk Creek and Granite Falls tills in southwestern Minnesota (Matsch 1972). The ages of the Granite Falls and Hawk Creek tills remain unclear. Ages ranging from Illinoian to mid-Wisconsinan have been assigned to the Granite Falls till (Matsch and Schneider 1986, Goldstein 1986). It has been suggested that the Hawk Creek till may be of pre-Illinoian age (Matsch and Schneider 1986).

The occurrence of weathered, old calcareous drift in the Fort Frances-Rainy River area may represent the remnant of an Illinoian or Early Wisconsinan glaciation which has since been subjected to non-glacial weathering conditions during the Sangamonian Interglacial or Middle Wisconsinan Interstadial.

The age relationship between old, Keewatin derived till and old, Labradorean derived till has not been determined.

Only when the two tills are found together in stratigraphic context will their relative ages be established.

Sub-till Organic Remains

Wood fragments were collected from the sieved fractions of samples of Whiteshell till and associated glaciofluvial sand recovered from sonic boreholes F88-23 and F88-24 (Figure 2, back pocket). The samples come from depths in excess of 25 m (Bajc 1991). Five samples, four of which were collected from borehole F88-23, yielded wood remains (i.e., samples F88-23-03, F88-23-04, F88-23-05, F88-23-06 and F88-24-02; Bajc 1991). The fragments are well preserved, display fresh, broken edges and are up to 1 cm in length. The close proximity of the two sites to one another (about 1.5 km) coupled with the well preserved form of the wood fragments, may suggest the presence of an organic-bearing horizon at depth in the immediate vicinity. Wood fragments recovered from sample F88-23-06 (Figure 2, back pocket) were radiocarbon dated by accelerator mass spectroscopy at 47 410±990 years B.P. (TO-1593) (standard error reported to 2σ). Although a finite date is reported, the author interprets the age as >47 410 years B.P. since the limits of radiocarbon dating are close to this value. The wood is probably either Sangamonian (Missinaibi Formation equivalent; Skinner 1973) or Middle Wisconsinan in age (Table 1).

Wood recovered from stratified sand and gravel below 40 m of Late Wisconsinan till and glaciolacustrine sediment in northern Minnesota (Effie area) was radiocarbon dated at >40 600 years B.P. (Martin et al. 1989). Logs buried beneath Late Wisconsinan, glacial drift have been recovered from exposures along the Red Lake River of northwestern Minnesota. The wood yielded radiocarbon ages of >40 000 years B.P. (Ojakangas and Matsch 1982). Radiocarbon dates have been obtained from several sub-till organic sites in southeastern Manitoba. Most of the sites yielded infinite ages as well (Teller and Fenton 1980). The reported dates range from >30 000 years B.P. to >43 000 years B.P. The sub-till organic remains recovered from northern Minnesota, southeastern Manitoba and the report area may represent a single, widespread, non-glacial, stratigraphic unit of Middle Wisconsinan or Sangamonian age.

Glaciolacustrine Deposits

Glaciolacustrine sediments have been encountered below Late Wisconsinan, Whiteshell till in two sonic boreholes (Table 1). The sediments were probably deposited in a precursor to Glacial Lake Agassiz which fronted the advancing Labradorian and Keewatin ice sheets.

In borehole F87-31 (Figure 2, back pocket), approximately 20 cm of light, greenish-grey silt underlies Whiteshell till and rests directly upon bedrock. Very low concentrations of spruce pollen were obtained from a sample

of this silt. The pollen is probably long-travelled or reworked from older deposits. Further work is required to determine the significance of this interstadial deposit.

In borehole F88-05 (Figure 2, back pocket), approximately 10 cm of massive, slightly calcareous, dark greyish-brown clay underlies Whiteshell till and rests directly upon bedrock. The glaciolacustrine sediment is dominated by expanding clay minerals (illite-smectite, smectite and vermiculite) with lesser amounts of illite and chlorite. A Keewatin sediment source is suggested by the distinct Keewatin signature of the lacustrine deposit.

LATE WISCONSINAN DEPOSITS

Labradorean Derived Drift

Whiteshell Till

The oldest surface till sheet documented in the report area is Late Wisconsinan in age and is attributed to an ice advance originating from the northeast (Table 1; Figure 7; Rainy Lobe, Labradorean Sector of the Laurentide Ice Sheet). Till of this advance is widely distributed across the northeastern corner of the report area (Figure 9). It has been recognized as the surface till sheet over much of northwestern Ontario and southeastern Manitoba. In northwestern Ontario it has been referred to as Patrician "red" drift (Elson 1961) because of the abundant granitic and acid igneous rock fragments which can be found within

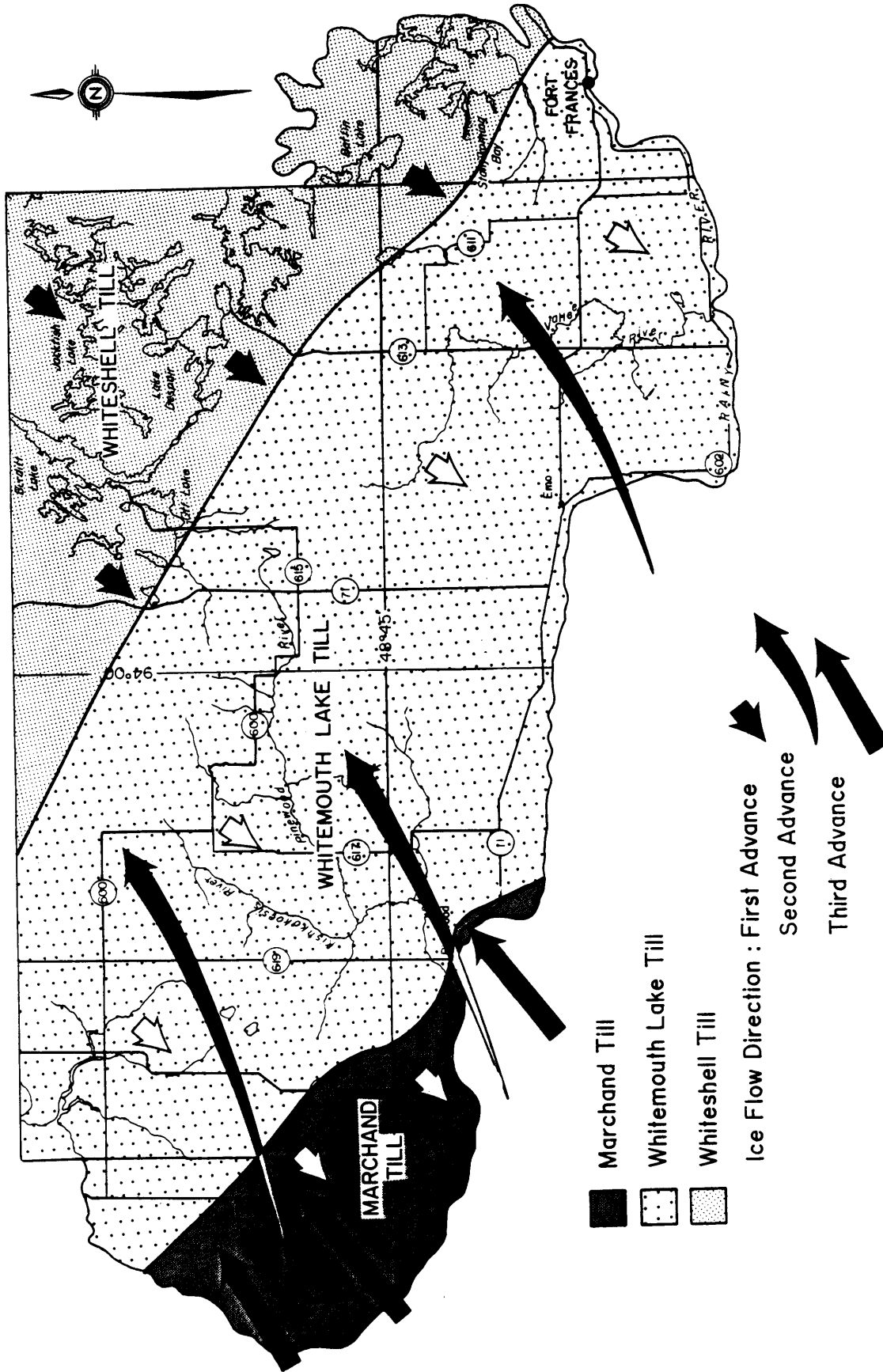


Figure 9. Surface tills and associated ice flow directions, Fort Frances-Rainy River area.

the till. In southeastern Manitoba, it has been called the Whiteshell till because of its common occurrence within Whiteshell Provincial Park (Teller and Fenton 1980). As the term, "Whiteshell till" has achieved formal ranking in the litho- and chronostratigraphic classification scheme of southeastern Manitoba, this name will similarly be applied to Labradorean derived till of Late Wisconsinan age within the report area. Stratigraphic equivalents have also been recognized in the subsurface of northern Minnesota (Rainy Lobe till), North Dakota (lower part of Red Lake Falls till) and south-central Manitoba (Senkiw till).

In the northeastern corner of the report area, the Whiteshell till is variable in thickness and tends to be concentrated in bedrock troughs or depressions transverse to ice flow and on leeward slopes of bedrock controlled topographic highs. Large areas containing abundant bedrock outcrop and a thin, discontinuous veneer of till have been identified within this area (Photo 4). These areas have been designated or mapped as a bedrock-drift complex. Fault traces, joint patterns and lithologic breaks, all of which contribute to bedrock structure and relief, are partially masked by the till cover even though they are readily identifiable on the aerial photographs.

More extensive accumulations of Whiteshell till are concentrated along the southwestern edge of the upland (Zone 1, Figure 6). This zone coincides with a belt of ice-contact stratified drift which defines the Rainy Lake-Lake



Photo 4. Bedrock-drift complex; thin till over bedrock, Senn Township.

of the Woods Moraine. The maximum documented thickness of till within this area is 9 m (Borehole F88-13, Bajc 1991).

Where extensive areas of till have been mapped and bedrock structure is concealed, local surface relief ranges from 5 to 10 m. Greater relief occurs in areas where the surface morphology is controlled by the underlying bedrock topography. Streamlined landforms have not been observed. The heavily treed surface is often littered with cobbles and boulders, many of which reach dimensions of several metres.

Exposure of Whiteshell till within the upland is poor. Till properties have been diagnosed primarily from shallow (approximately 1 m) test pit exposures. At these shallow depths, the till is extremely oxidized and weathered. It attains a reddish-brown to brownish-grey colour depending on the degree of oxidation. Unoxidized till is typically grey to olive-grey in colour. The matrix of the till is silty to sandy with little to no clay (65% sand; 33% silt; 2% clay) (Figure 10). Carbonate values usually range between 0 to 5%, however, values as high as 9% have been documented. Calcite to dolomite ratios are variable ranging between 0.1 and 1.9 (Figure 10). However, it should be noted that at low carbonate contents (i.e., less than 5%), reliable calcite to dolomite ratios are difficult to obtain.

The clast content of surface samples of Whiteshell till is extremely variable. Values ranging from 15 to 70% have been documented and are best explained in terms of local

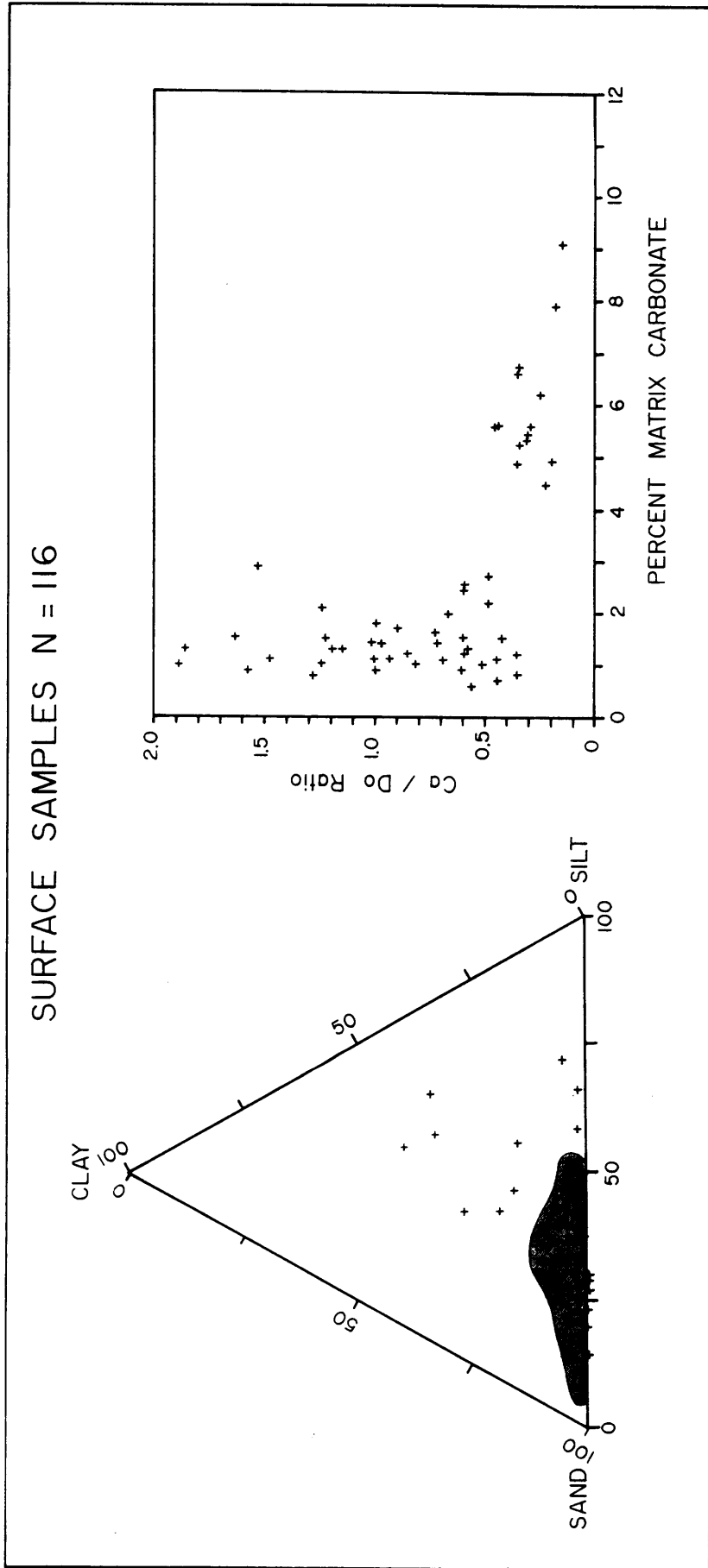


Figure 10. Plots of grain size and carbonate content for surface samples of Whiteshell till. Stipple areas represent the field of values for the majority of samples.

variability of the till sheet. Dense, compact facies tend to have a lower clast content than do loose facies.

Till exposures in Menary, Mather, Potts and Dance townships have provided some insight into till genesis. Both subglacial and supraglacial facies of Whiteshell till have been identified.

The subglacial lodgement facies is recognized by its: dense, blocky and fissile nature; striated and faceted, locally derived clasts; shear planes; and strong pebble fabrics (Photo 5). The stone content of this facies is generally 15 to 30%. The till is usually thin and concentrated on the stoss sides of rock knobs. The remains of Nye channels are often seen as ribbons of sand and gravel intercalated with the till and truncated along their upper surfaces. Fissility is accentuated by thin silt layers along low angle shear planes.

Subglacial meltout and flow till facies have been identified within the upland region. They usually occur as thick accumulations on the leesides of bedrock obstructions. The meltout facies is formed in response to the melting of debris-rich ice in low pressure zones or cavities beneath glacier ice. Remobilization, by gravitational processes, of water-saturated debris, initially deposited as subglacial meltout till or lodgement till can produce the flow till facies.

Subglacial meltout till is typically loose, sandy, stony and contains a high proportion of stratified sediment.



Photo 5. Subglacial facies of Whiteshell till, Fleming Township. Note the low-angle shear planes which rise up to the right.

Clasts are commonly striated, faceted and locally derived. The stratified sediment often occurs as thin, continuous layers of sand which drape over larger clasts and display convex upper and planar lower surfaces. Faulting is usually observed within the stratified sediments. Scours beneath small boulders are commonly infilled with pebbly sand. Unlithified clasts of stratified sediment which survived the process of till accretion are common as well. These clasts can be seen as folded, rotated, broken and stretched blocks within massive to substratified diamicton. Weak, unimodal pebble fabrics have been documented from several exposures believed to represent subglacial meltout till (Halstead 1989).

Depending upon the degree of remobilization and sorting by water, subglacial flow till may retain its integrity and display very similar characteristics to the source unit. The till may be massive or washed with distinct stratification. A deposit along the southwest shore of Off Lake is located in the leese of a bedrock high and consists predominantly of stratified drift with thin diamict layers. These layers are interpreted to represent either resedimented meltout or lodgement till.

A supraglacial meltout and flow till assemblage has been observed within the Rainy Lake-Lake of the Woods Moraine. It occurs primarily within small hummocks and ridges which attain heights of 3 to 5 m (Photo 6). The till is generally very stony, shows signs of resedimentation by



Photo 6. Supraglacial facies of Whiteshell till in the Rainy Lake-Lake of the Woods Moraine, Menary Township. Note the pod of substratified gravel, indicated by the arrow, in the lower right hand corner of the photograph.

mass movement and contains large quantities of stratified sediment. This meltout-flow assemblage is highly variable and complex as it involves a wide spectrum of genetic processes. The stratified sediments are usually intensely faulted and discontinuous. Clasts range in size from pebbles to large boulders and are usually angular in shape. Most of the boulders appear to be of distal origin.

Within isolated, low-lying areas of the upland region, a fine-grained till of northeastern provenance has been observed. Notable occurrences are located at the north end of Burditt Lake (NB-401 and NB-402, Figure 2, back pocket), on the north shore of Little Pine Lake (NB-276, Figure 2, back pocket) and one kilometre southwest of Albert Lake (NB-296, Figure 2, back pocket). The till overlies glaciolacustrine silt and clay and seldom exceeds one metre in thickness. It is a dense, stone-poor, silty clay to silty sand till with low matrix carbonate. These fine-grained till samples fall outside of the grainsize field highlighted in Figure 10.

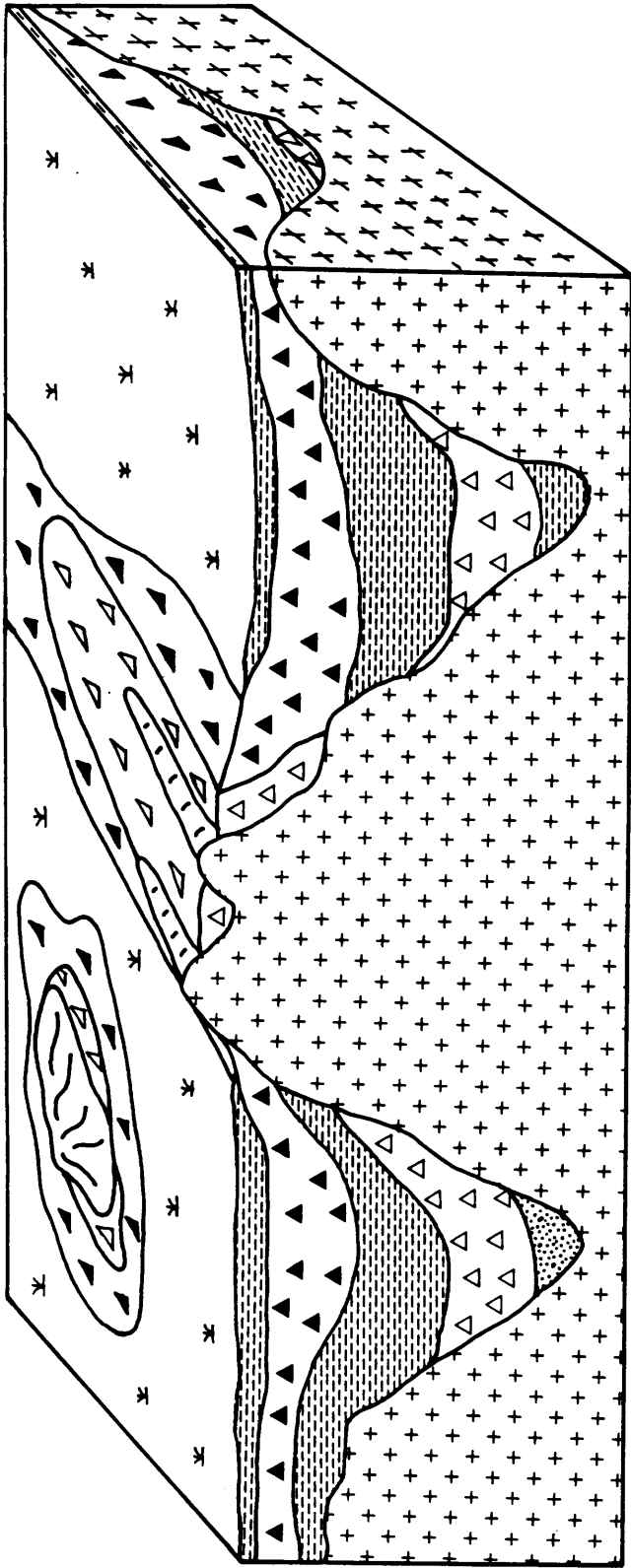
Zoltai (1961) reported the occurrence of a similar till of northeastern provenance around Sioux Narrows and along the eastern shore of Lake of the Woods in his reconnaissance survey of northwestern Ontario. To account for this fine-grained till, he suggested a late-glacial readvance of the Labradorean ice sheet to the Rainy Lake-Lake of the Woods Moraine. However, this field mapping program has not

documented the two tills in superposition (i.e., silty, clayey till over stony, sandy till).

Similar fine-textured till has been encountered southwest of the moraine below thick sequences of younger drift (Bajc 1991). The fine-grained nature of this till is probably attributed to the incorporation of silty and clayey glaciolacustrine sediment. A facies transition from silty sand to silty clay till is implied by the close association between this till and fine-grained glaciolacustrine sediments. Further subsurface investigations are necessary to refine the significance of these anomalous till occurrences.

Whiteshell till is concealed beneath thick sequences of younger sediment over most of the drift-covered lowland (Zone 2, Figure 6). However, where the bedrock surface rises and drift thickness diminishes, the stratigraphic package is compressed and Labradorean derived till approaches the surface. Where bedrock outcrops occur, it is common to encounter exposures of Whiteshell till encircling the outcrop (Figure 11). These exposures rarely exceed 50 to 100 m in width and are usually surrounded by younger deposits of till and glaciolacustrine sediment. The till surface is littered with Precambrian cobbles and boulders in contrast to the surrounding terrain.

In this setting, till properties have been obtained primarily from observations collected in backhoe trench exposures. Compositionally, the till is not unlike samples








-  GLACIOLACUSTRINE SEDIMENTS
-  KEEWATIN DERIVED TILLS
(INCLUDES WHITEMOUTH LAKE & MARCHAND TILLS)
-  LABRADOREAN DERIVED TILL (INCLUDES WHITESHELL TILL)
-  CRETACEOUS SEDIMENT
-  BEDROCK

Figure 11. Schematic representation of the major stratigraphic units present in the drift-covered lowland of the Fort Frances-Rainy River area.

collected on the upland in the northeastern corner of the report area. The till is typically, silty and sandy with variable stone content and low levels of matrix carbonate.

Trenches were placed on different sides of selected bedrock outcrops with no apparent side along which Whiteshell till is preferentially preserved. Till character, however, appears to be influenced by its relative position. The till is looser and contains more stringers and lenses of stratified sediment on the southern and western sides of the bedrock outcrops. Tills observed from these sides are interpreted as leeward till composed of debris released by subglacial melting. Tills observed from the northern and eastern sides of the bedrock outcrops are denser, fissile, appear more massive and display structures suggestive of deposition by grounded, active ice. Shear planes and extension fractures, indicating southwesterly ice flow were noted in several exposures of till on the northern and eastern sides of bedrock outcrops.

In areas of thick drift, Whiteshell till forms an almost continuous veneer over bedrock and is buried by up to 60 m of younger sediments. Whiteshell till was recovered from 64 of 71 sonic boreholes across the report area attesting to its uniform distribution. The thickest accumulations approach 22 m in the western end of the report area and 9 m in the eastern end (Bajc 1991).

The grain size characteristics of borehole samples show similar trends to surface samples collected from the

northeast corner (Figures 10 and 12). Two distinct grain size populations are recognized in the borehole samples (Population A and B). A coarse facies (Population A) consists of silty sand to sandy silt till not unlike the majority of samples collected from the upland region to the northeast. This facies contains very little clay (i.e., less than 10%) although silt values rise to about 50%. A second grain size field consists of finer-textured samples (Population B) with clay contents ranging between 20 and 60%. The textures of Population B samples are best explained in terms of local facies variability and the incorporation of glaciolacustrine silts and clays. Samples that fall into grain size field B show no preferred geographic distribution within the lowland of the report area. Fine-grained till samples from the upland region, to the northeast (Figure 10), fall into the same textural field.

The carbonate data for unweathered, borehole samples of Whiteshell till fall into a tighter field than do surface samples (Figures 10 and 12). Carbonate contents for borehole samples range from 1 to 18% (Table 2) although most samples fall into the range 2 to 8% (Figure 12). Calcite to dolomite ratios generally range between 0.1 and 1.4 (Figure 12). Several till samples display relatively high carbonate contents (i.e., 10 to 18%). These values probably reflect the incorporation of pre-Late Wisconsinan calcareous drift

BOREHOLE SAMPLES N = 176

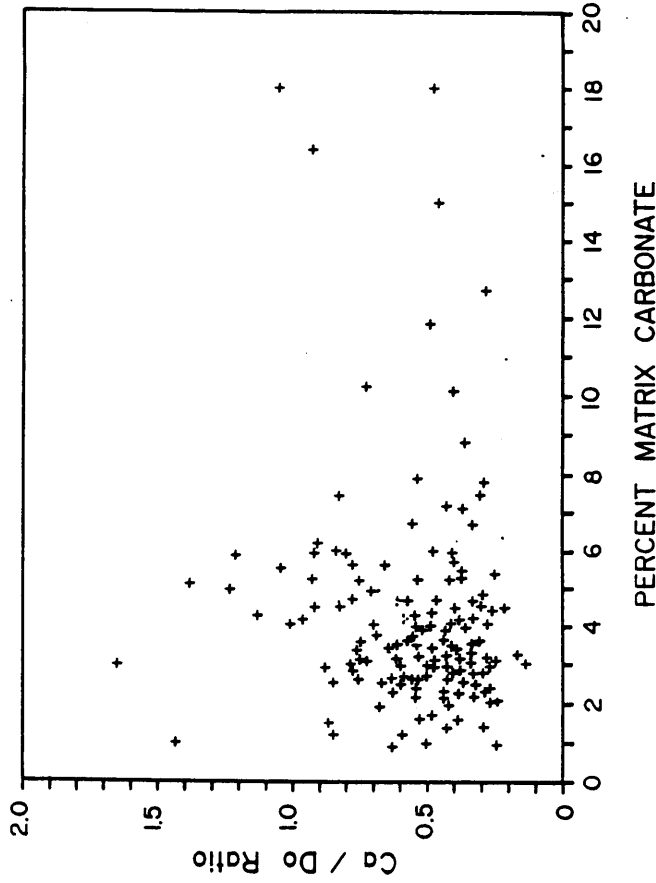
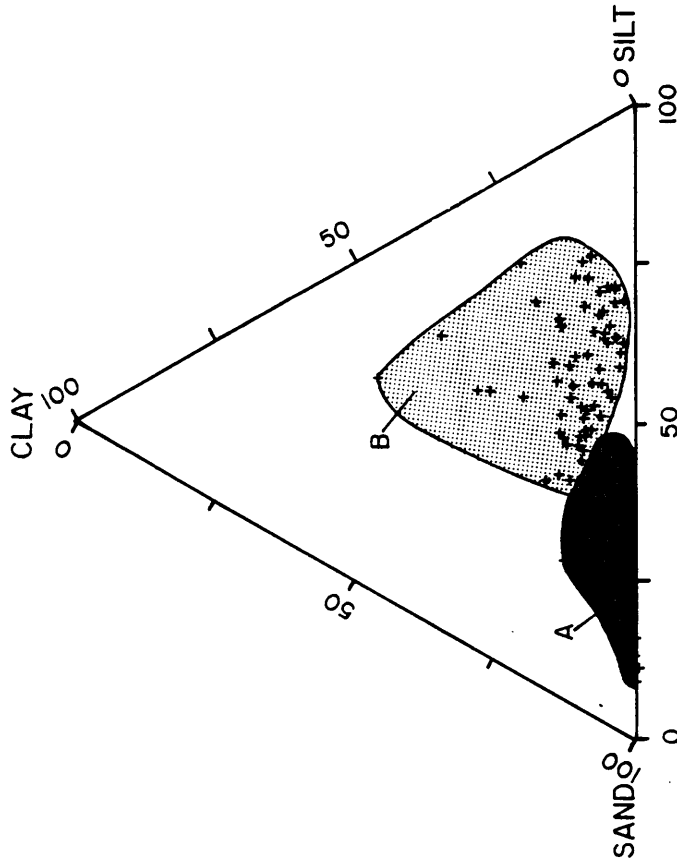


Figure 12. Plots of grain size and carbonate content for borehole samples of Whiteshell till. Zone A on the ternary diagram represents the field of grain sizes values for till samples with little or no incorporation of fine-grained glaciolacustrine sediment. Zone B samples are derived from extensive incorporation of glaciolacustrine sediment.

or bedrock which contains abundant iron carbonate and calcite veining.

Chlorite, interlayered illite-smectite, illite and kaolinite are the most abundant clay minerals present in the clay fraction of unweathered Whiteshell till. Inactive clay minerals, such as illite, chlorite and kaolinite are typically associated with Precambrian Shield tills. The interlayered, illite-smectite clays are probably derived from the incorporation of glaciolacustrine clays within the Lake Agassiz basin.

Although it is difficult to interpret till facies from 9 cm diameter sonic core, there are several criteria which have proven useful in recognizing genetic variations of till. These include: density and compaction; composition of the pebble fraction; and sediment associations. Many of the Whiteshell till sequences, especially those in the western end of the report area, are loose, massive to substratified, of variable thickness and contain interbeds of glaciofluvial sand and gravel. Clasts are generally subrounded and of semilocal derivation. These sediment sequences are interpreted as the deposits of either subglacial meltout or stacked subaquatic debris flows.

Thinner sequences of Whiteshell till are found throughout the eastern portions of the report area. In most cases, the tills are massive, dense and compact and contains striated and faceted clasts of local derivation. Pebble lithologies in till samples closely reflect the underlying

bedrock type. These tills were probably deposited at the glacier sole by lodgement processes, although subglacial meltout cannot be ruled out as an alternative.

Ice-Contact Stratified Drift (Surface Deposits)

Surficial deposits of Labradorean derived, ice-contact stratified drift are found primarily within the highland of the report area (Zone 1, Figure 6). Aside from the Rainy Lake-Lake of the Woods Moraine, they occur mainly as small, wave-modified accumulations of sand and gravel within isolated low-lying areas. Their upper surfaces are generally flat to gently undulating. The deposits probably represent accumulations associated with melting blocks of ice stranded in topographic lows.

Esker ridges have not been found in the report area. In fact, well integrated esker systems have not been found over a large portion of northwestern Ontario, southwest of the Lac Seul end moraine. It has been suggested that the absence of long, continuous esker systems over this portion of the shield may indicate that "deglaciation was characterized by active retreat... such that...subglacial drainage systems could not remain open for prolonged periods of time" (Shilts et al. 1987).

Rainy Lake-Lake of the Woods Moraine

The Rainy Lake-Lake of the Woods Moraine, extending from the southeastern shore of Lake of the Woods to Northwest Bay on Rainy Lake, was first described by Zoltai

(1961) as "a series of ridges of unsorted till often separated by outwash sand". He attributed the moraine to a terminal position associated with a readvance of the Labradorean glacier.

Quaternary mapping of the Fort Frances report area has helped to refine the extent and character of the moraine as well as to suggest an alternative hypothesis for its formation. The moraine is defined by a series of deposits of ice-contact stratified drift and associated diamicton, which form a northwest-trending belt at the edge of the bedrock dominated highland in the northeast corner of the report area (Figure 13). The moraine loses its continuity to the northwest and southeast where it consists of small, isolated deposits of ice-contact stratified drift separated by rock-dominated and glaciolacustrine terrain.

Contrary to Zoltai's (1961) observations, the moraine is composed primarily of stratified sediments ranging from boulder gravel to fine sand. The largest accumulations are located at the north end of the study area along Highway 71, on the south and east shores of Off Lake, and due south and west of Northwest Bay, Rainy Lake. Smaller deposits are located along the same trend and link the larger segments of the moraine (Figure 13).

The deposit along Highway 71, at the north end of the study area, is up to 5 km wide and is located within a northward sloping lowland along which Log Creek flows. Here the moraine consists of a complex of kames, kame terraces,

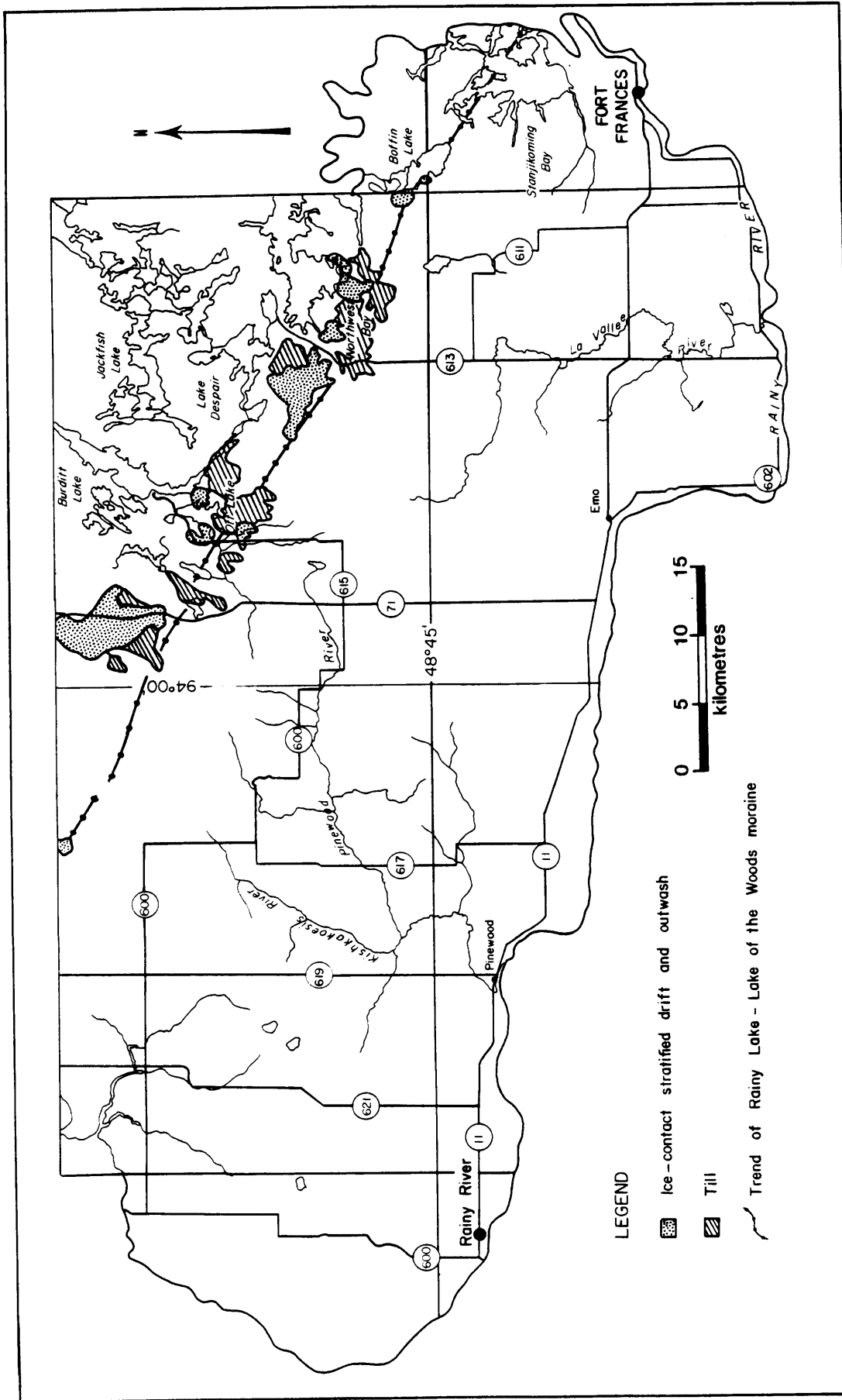


Figure 13. Distribution of deposits comprising the Rainy Lake-Lake of the Woods Moraine. Numerous deposits, too small to illustrate on this map fall along the line representing the trend of the moraine.

and morainic ridges, all of which contain varying amounts of sorted sediment. Morainic ridge segments east of Highway 71 are up to 15 m high and are composed of bouldery diamicton with lenses of sand and gravel (Photo 6). Ridges west of the highway are not as well defined and are composed almost exclusively of stratified sand and gravel. Glaciofluvial deposits can be found at the edge of the Log Creek basin, perched 20 to 30 m above the valley floor. Ice-contact slopes on the edges of these kame terraces dip to the north and northeast. Kames reach heights of 20 m and occur as well defined conical hills, composed primarily of stratified sand and gravel. Some kames contain varying amounts of boulder gravel and stony diamicton.

The complex of ice-contact stratified drift surrounding Off Lake occurs primarily as kame terraces bordering the basin. These flat-topped deposits with steep ice-contact slopes are composed of moderately sorted sand and gravel and attain thicknesses of 25 m. Thin deposits of wind-blown silt or loess, averaging 5 to 10 cm in thickness, have been observed capping sands and gravels in isolated locations within this part of the moraine. Large tracts of stony, sandy till, concentrated within southwest-trending lineaments, and broad, low relief areas are situated southeast and northwest of the lake along the morainic trend. In this area, interpretations of till genesis are based primarily on shallow, testpit exposures. However, at sites where vertical exposures were available, till

properties suggestive of deposition by flow and meltout processes at the glacier terminus were observed.

In the vicinity of Northwest Bay, Rainy Lake, large areas of ice-contact stratified drift mark the southeastern extension of the moraine. The western portion of this belt (i.e., the area due west of Government Landing, Northwest Bay, Rainy Lake) can be subdivided into two zones separated by a steep, north-facing, ice-contact slope. The southern half is characterized by an undulating plain of glaciofluvial sand and gravel with a few, shallow kettle holes, whereas the northern half consists of a hummocky, kame complex of moderate relief.

The eastern portion of the belt (i.e., the area due south of Northwest Bay, Rainy Lake) consists of gently undulating, wave-modified, ice-contact terrain composed primarily of glaciofluvial sand. A fan-shaped accumulation of sand and gravel with an ice-contact slope on its western face and a slip-surface on its southern edge marks the former ice margin.

Smaller deposits of glaciofluvial sand and gravel, associated with the Rainy Lake-Lake of the Woods Moraine, are located in the vicinity of Splitrock River (northeast corner of Dewart Township) and Boffin Lake (southeast corner of Griesinger Township).

Situated just outside of the report area, at the western end of Reef Point, Rainy Lake, a large deposit of ice-contact sand and gravel may mark the southeastern

faulted bedding and usually occur in close association with bedrock outcrop. Subangular boulders, 1.5 to 2.0 m in diameter, are commonly encountered within these sand and gravel deposits.

Rapid, lateral facies changes in the glaciofluvial deposits occur within individual exposures. Boulder gravels grade to massive, planar bedded, cross-bedded and ripple-laminated sands across very short distances (i.e., 100's of metres). Steep-sided channels infilled with massive and planar bedded pebbly, medium sands suggest erosion by sediment gravity flows. Thick units of ripple (Type A, Type B and sinusoidal) laminated and planar laminated fine to very fine sand occur both proximal and distal to the coarse-grained facies.

At the Armstrong sand and gravel pit in Fort Frances, 5 to 10 m of clayey, Whitemouth Lake till and glaciolacustrine silt and clay has been removed to uncover a thick sequence of glaciofluvial sand and gravel. An uneven bedrock surface, sculpted by glacial ice and subglacial meltwater, is exposed on the pit floor. Coarse-grained, open-framework, boulder to cobble gravel and associated stony diamicton, with crude horizontal bedding, forms the lowest unit. This facies grades laterally, to the south, into well stratified, sandy gravel and gravelly sand with channel scours 20 to 30 m wide infilled with planar cross-bedded and horizontally-bedded sheets of pebbly sand with interbeds of ripple laminated fine to very fine sand.

Buried Glaciofluvial Deposits

Within the drift-covered lowland (Zone 2, Figure 6), stratified sands and gravels associated with the Labradorean ice sheet were deposited either subglacially, in conduits, or subaqueously, in standing water beyond the ice margin. The latter appears to be the most common depositional environment for the stratified deposits. Subsequent glacial advances have concealed many of these deposits beneath thick sequences of till and glaciolacustrine sediment. Exposures of these deposits are uncommon within areas of thick drift (Zone 2b, Figure 6) as overburden thicknesses prohibit their economic extraction. In areas with variable drift thickness and numerous bedrock outcrops (Zone 2a, Figure 6), the stratigraphic sequence is compressed and the underlying sand and gravel units can be easily exploited.

Detailed sedimentological investigations were undertaken at sand and gravel pits within the drift covered lowland area to develop depositional facies models. These models were used to interpret sediment sequences encountered at depth in boreholes.

A number of isolated deposits of sand and gravel, extending from Off Lake to the southwest corner of Morley and Shenston townships, occur beneath thin caps of Keewatin derived till. These deposits consist of poorly sorted, boulder gravel to well sorted, very fine sand. The boulder gravels are massive to crudely bedded, display chaotic,

extension of the moraine. Extensive sandy outwash deposits, are located 40 km west of Kenora and may represent the moraine's northwestern extension (Zoltai 1961).

Zoltai (1961) attributed the Rainy Lake-Lake of the Woods Moraine to a terminal position of the Labradorean ice sheet following a slight readvance. Varved clays overlain by stony clay till on the north side of the moraine was used to support of this hypothesis.

The author interprets this sequence of sediments differently and refrains from invoking a readvance of the Labradorean ice sheet to the moraine. The succession of varved clays may represent an episode of glaciolacustrine sedimentation prior to the Late Wisconsinan glacial advance. The stony clay till is interpreted as a fine-grained facies of Whiteshell till which derives its fine texture from the incorporation of the underlying, clayey, glaciolacustrine sediments. To further support to this argument, it has been shown in an earlier section that a fine-grained facies of Whiteshell till extends in the subsurface, to the southwest, beyond the Rainy Lake-Lake of the Woods Moraine.

The Rainy Lake-Lake of the Woods Moraine probably marks a recessional position of the Labradorean ice sheet. The moraine was built along the flanks of a bedrock-controlled highland at the edge of Lake Agassiz. This position is consistent with an equilibrium moraine not unlike the St. Narcisse Moraine in Quebec at the edge of the Champlain Sea.

The above mentioned facies are abruptly overlain by massive and horizontally-bedded, pebbly sands which grade upwards into ripple laminated, very fine sands (Photo 7). Second order, fining upward cycles have been recognized within this unit. They are defined by couplets of medium to very fine sand with thin, clay drapes. Couplets are approximately 4 m thick near the base of the unit and decrease to only a few centimetres near the top. The couplets are interpreted as annual deposits because of their regularity.

The abundance of climbing rippled sands implies deposition from a suspended sediment cloud. Flame structures, ball and pillow structures, slump structures and dewatering pipes have been observed within this unit and suggest rapid deposition of unstable, water-saturated sediments. Either a retreating ice margin or diminishing sediment supply is responsible for the up-section decrease in couplet thickness.

The aforementioned facies suggest deposition within subaqueous fans fed by subglacial meltwater conduits (Shaw 1985). The coarse facies represents either subglacial sedimentation within confined tunnels or ice-marginal sedimentation at the mouths of subglacial conduits. The boulder gravels that were observed at many of the sites were probably transported in confined subglacial tunnels, where extremely high flow velocities were generated. The overlying, fine facies were deposited as draping sheets of



Photo 7. The Armstrong sand and gravel pit in the town of Fort Frances exposes thick sequences of planar and ripple laminated sands. These sands represent the distal and low-energy, proximal facies of a large subaquatic fan which formed along the retreating margin of the Labradorean ice sheet.

sediment beyond the ice margin. A decrease in flow competency at the mouths of subglacial conduits results in the deposition of large quantities of sediment and rapid lateral facies changes.

The northeast trending belt of buried deposits extending from Off Lake to Stratton may represent a series of subaqueous outwash fans which were built along the margin of the retreating ice sheet. These fans were fed by subglacial drainage systems originating in the Off Lake-Burditt Lake area. Water depths fronting the ice margin were probably in the order of 40 m or more.

Several sonic boreholes intersected thick sequences of glaciofluvial sand and gravel at depth. These deposits probably represent subaqueous fan systems confined to low-lying bedrock depressions. The most significant deposit was encountered along a northeast trending series of boreholes between the towns of Rainy River and Sleeman (Profile 1f, Figure 14, back pocket). The cover of younger sediments range from 5 to 24 m thick in this area.

Other isolated occurrences of buried sand and gravel include: boreholes F88-37 and F88-36 (Profile 1a, Figure 14, back pocket); boreholes F88-33, F87-29 and F87-26 (Profile 1c, Figure 14, back pocket); boreholes F88-23 and F88-07 (Profile 2a, Figure 15, back pocket); F88-10 (Profile 2c, Figure 15, back pocket); boreholes F87-12 and F87-17 (Profile 3b, Figure 16, back pocket); boreholes F88-18 and

F87-08 (Profile 3c, Figure 16, back pocket); and boreholes F87-05 and F87-02 (Profile 4, Figure 16, back pocket).

In the case of boreholes F88-37, F87-29, F88-23, F88-07 and F88-10, the glaciofluvial sediments are interbedded with and capped by layers of Whiteshell till. This interbedding of till and glaciofluvial sediment may represent either subglacial sedimentation interrupted by periods of meltwater discharge or sedimentation along an oscillating ice margin.

Keewatin Derived Drift

As the Labradorian ice margin receded to the northeast, low-lying areas were uncovered and immediately occupied by proglacial water bodies. Subsequently, Keewatin ice (St. Louis Sublobe of the Des Moines Lobe) advanced into the study area from the west, culminating at the southwestern edge of the highland. A thick, continuous cover of silty to clayey till, here referred to as Whitemouth Lake till, was deposited during this advance concealing much of the irregular bedrock surface (Figure 9).

At the Armstrong sand and gravel pit, in the town of Fort Frances, 58 glaciolacustrine rhythmites were counted beneath the Whitemouth Lake till. Sedimentological evidence suggests that the rhythmites are annual deposits and that minimal erosion occurred along the outer margin of this advance. Varved silts and clays grade upward and become interbedded with subaquatic flow tills with no apparent break in sedimentation. Massive, Whitemouth Lake till caps

the sediment sequence. It appears that the Keewatin ice mass entered the lowland vacated by the retreating Labradorean glacier after only a very short time period, perhaps as a rapidly flowing ice or by a glacial surge. The Labradorean glacier probably stood at, or close to, the Rainy Lake-Lake of the Woods Moraine during this advance. Wright et al. (1973) and Moran et al (1976) discussed the possibility of the St. Louis Sublobe overriding the waning Rainy Lobe (Labradorean glacier) along its eastern margin. No evidence for overriding was found within the report area.

The Keewatin ice margin retreated westward into southeastern Manitoba, possibly as far north as Lake Winnipeg (Teller and Fenton 1980). Glaciofluvial and glaciolacustrine sediments were deposited in low-lying areas vacated by the retreating glacier. Reactivation of the Keewatin ice mass resulted in a readvance to, and slightly beyond, the international border. A carbonate-rich, gritty and pebbly, sandy till, here referred to as the Marchand till, was deposited and can be recognized as the surface till sheet in the extreme southwestern corner of the report area (Figure 9).

Whitemouth Lake Till

The physiographic expression of the Whitemouth Lake till plain can be subdivided into two distinct zones shown as 2a and 2b on Figure 6. The till surface within Zone 2a, an area of moderate bedrock outcrop, is irregular and

strongly controlled by the underlying bedrock topography. An undulating to hummocky surface, with local relief of 20 to 30 m, is common within this zone. High contrast, mottled patterns have been identified on aerial photographs within these high relief areas. These patterns are easily confused with those produced by ice stagnation. In fact, Johnston (1915) interpreted a linear belt of low swells, 2 to 3 m in amplitude, near the outer edge of the till sheet as a terminal moraine. Bedrock topography, however, is the controlling element with regard to the swells. Analysis of borehole logs from the crests of selected knolls in these areas of irregular topography has yielded a strong correlation between surface and bedrock topography.

Within Zone 2b, drift thickness increases markedly and bedrock topography plays a subsidiary role in surface morphology. Local relief, which usually occurs as erosional forms of Glacial Lake Agassiz or as modern valley incisions, rarely exceeds 5 to 10 m. In low-lying areas, the till plain is mantled by younger glaciolacustrine sediments and peat, giving the surface a subdued and level appearance.

Within both zones 2a and 2b, streamlined landforms have not been identified. The surface of the till plain is usually strewn with subangular cobbles and small boulders. Most boulders and large cobbles consist of crystalline lithologies whereas the pebble to small cobble component consists primarily of carbonate lithologies. The largest carbonate boulder encountered in the report area was found

at the north end of Carpenter Township and measured just over 1 m in diameter.

The initial advance of Keewatin ice into the report area resulted in the incorporation of large volumes of glaciolacustrine sediment into the basal debris-rich layers of the glacier and the deposition of a dark grey, massive, silty clay to clayey silt till with abundant grits and small pebbles. Surface exposures of Whitemouth Lake till erode to form rills and runnels, patterns which are commonly associated with fine-grained deposits (Photo 8). Unusually thick till sequences (i.e., 30 m) have been documented in borehole records from the east end of the report area. Thicknesses diminish to the west where they average about 5 to 10 m in the vicinity of Rainy River (Figure 14, back pocket). The final advance of the Keewatin glacier into the southwestern corner of the report area appears to have removed part or all of this till sheet.

Unweathered till samples obtained from boreholes average 22% sand, 36% silt and 43% clay (Figure 17, Table 2). Surface samples display very similar textural trends. Matrix carbonate content of unweathered till samples is high and averages 28% with a calcite to dolomite ratio of 0.5 (Figure 18, Table 2). The carbonate contents of surface samples show the effects of weathering processes (i.e., carbonate depletion by leaching and carbonate enrichment by capillary action). The carbonate data for surface samples is much more diffuse than unweathered, borehole samples.

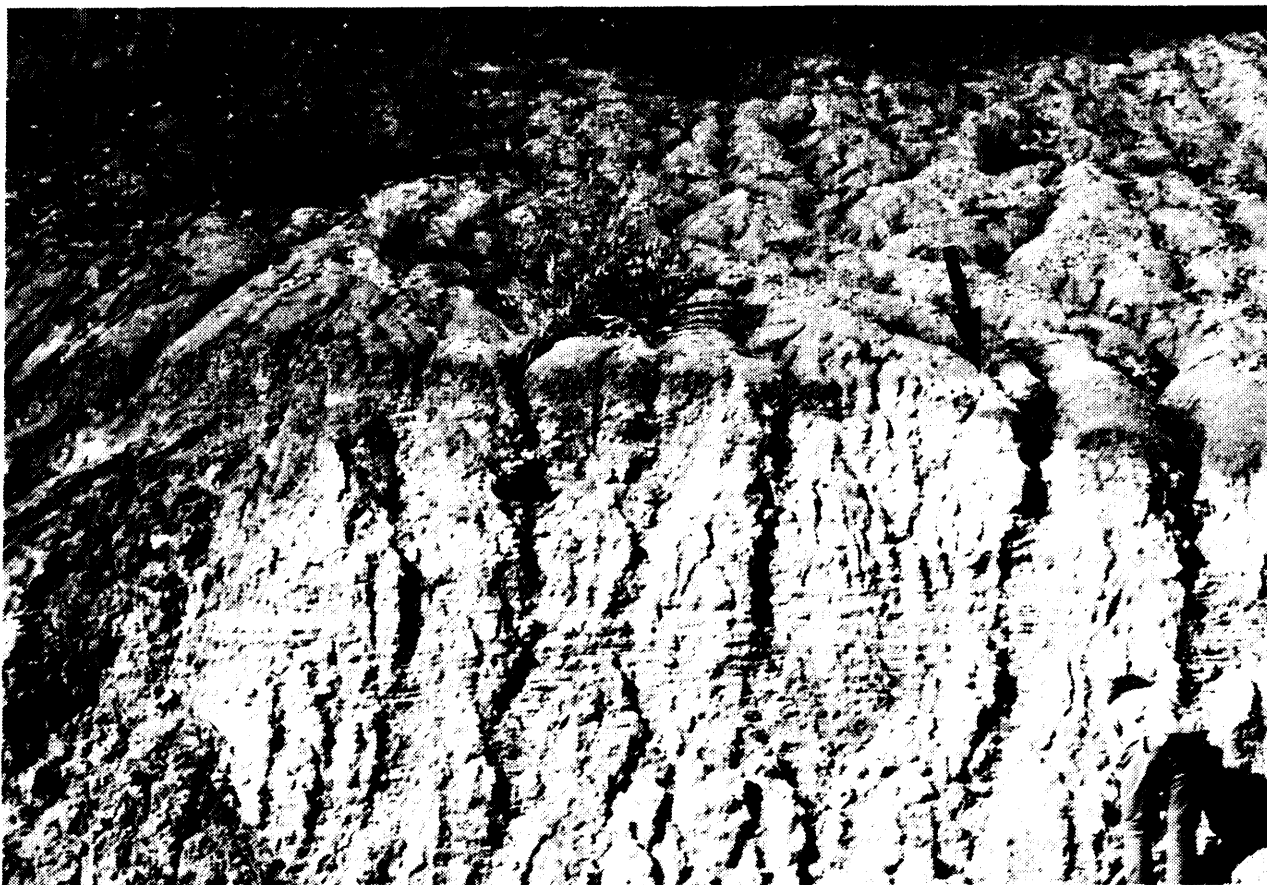


Photo 8. Clayey Whitemouth Lake till overlying Pre-Lockhart Phase glaciolacustrine silt and clay, Armstrong sand and gravel pit, town of Fort Frances. Contact occurs at break in slope. Note the small pod of glaciolacustrine silt which has been sheared up into the lower portion of the till (arrow).

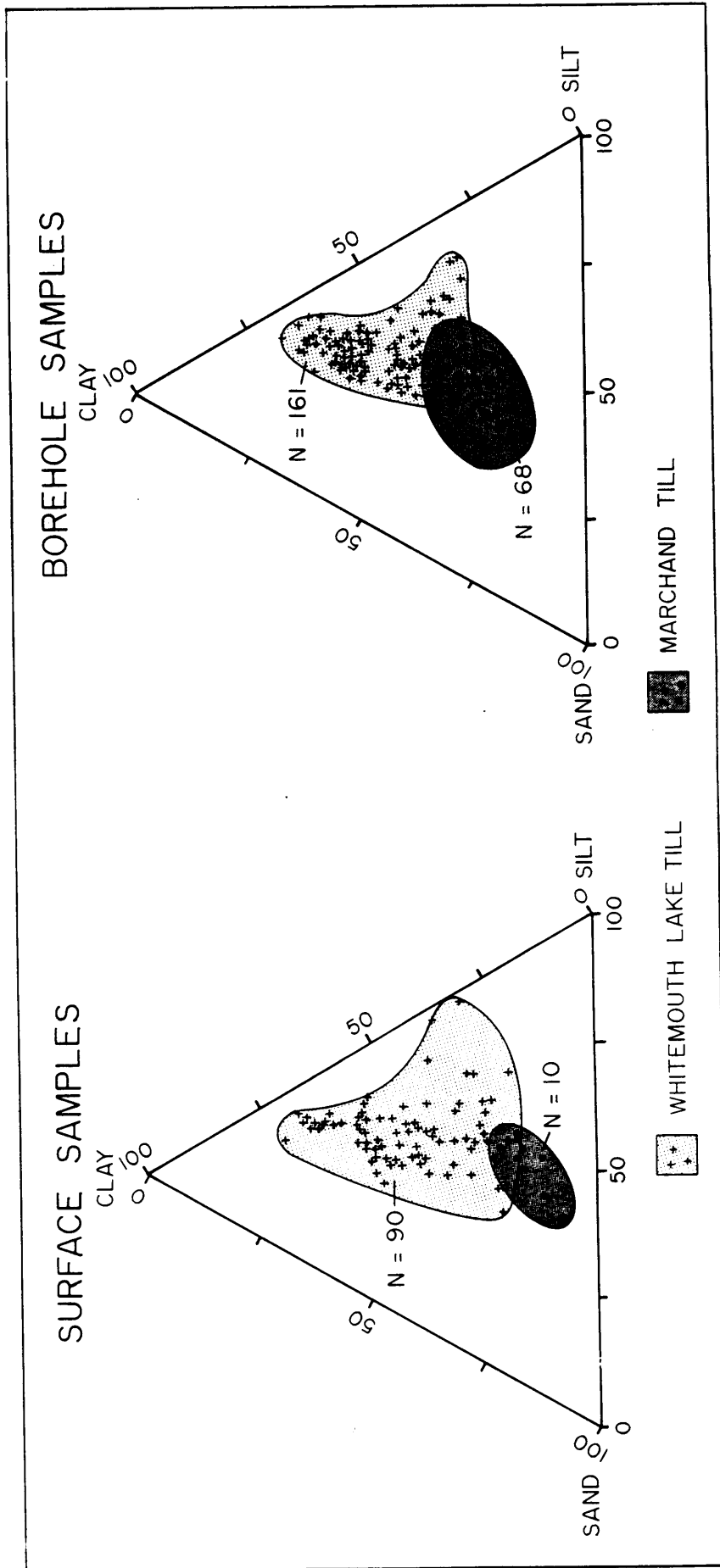


Figure 17. Plots of grain size for surface and borehole samples of Keewatin derived till. Stippled areas represent the field of values for the majority of samples.

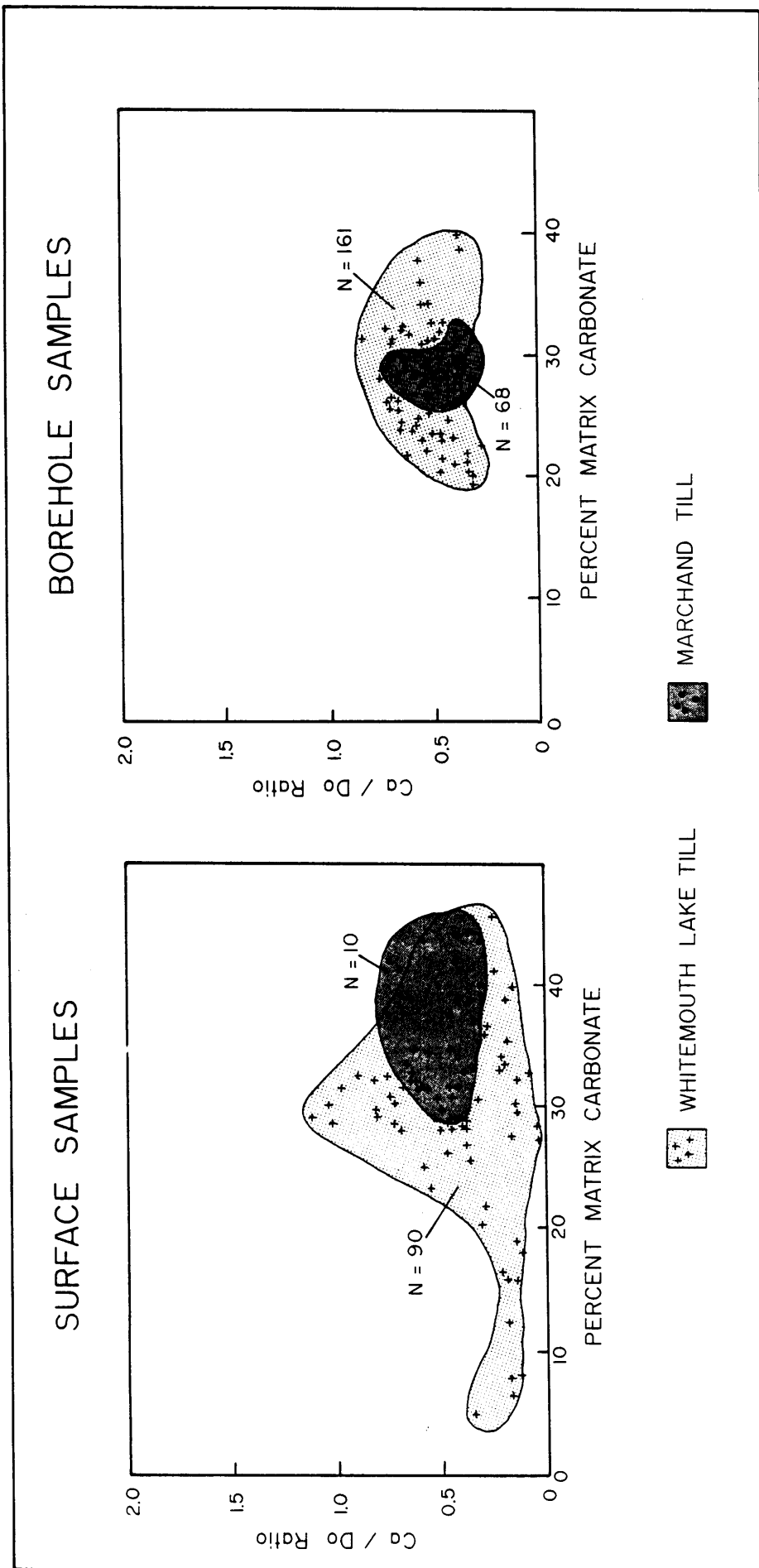


Figure 18. Calcite/Dolomite ratio versus percent carbonate; surface and borehole samples of Keewatin till. Stippled areas represent the field of values for the majority of samples.

Pebble content ranges from 2 to 10% across the report area. Subtle variations in stone content within till units have been documented in sonic drill cores (Bajc 1991). Pebbles recovered from this till indicate a distal source. Most of the pebbles are less than 5 cm in diameter and are rounded to subrounded. Up to 80% of the pebble lithologies originate from the Williston Basin to the west. Common lithologies include Paleozoic dolostone and limestone and Mesozoic shale, siltstone and lignite. Dolostone pebbles usually occur at twice the concentration of limestone pebbles. Crystalline lithologies tend to be poorly preserved and are commonly, completely rotted.

Most of the shale clasts or pebbles are light grey and siliceous. They are derived from the Odanah Member of the Pierre Shale (late Campanian to early Maastrichtian), which is distributed west of the Manitoba escarpment in southwestern Manitoba, southeastern Saskatchewan and northern North Dakota; a distance of more than 200 km to the west (D. McNeil, Institute of Sedimentary and Petroleum Geology, written communication, 1989). The lignite is Late Cretaceous in age and is probably derived from small outliers in drift-covered areas of southeastern Manitoba (P. Zippi, personal communication, 1989). Intraclasts of glaciolacustrine silt, 1 to 2 mm in diameter, are common near the base of the till sheet and are probably locally derived from underlying units.

Several depositional till facies have been recognized. Interbedded sequences of massive, subaqueous debris flows and laminated, glaciolacustrine sediments are abruptly overlain by massive diamicton units representing subglacial deposition. The subglacial facies is overlain by interbedded, waterlain, undermelt and flow till and gritty and pebbly, glaciolacustrine silt and clay. This sequence of facies is characteristic of a single cycle of glacier advance and retreat within a lake basin (Barnett 1987).

The subglacial facies of Whitemouth Lake till is massive, dense, compact, contains faceted and striated clasts, and commonly displays structural elements indicative of deposition by grounded, active ice. Very little stratified sediment has been observed within this till facies. Strong pebble fabrics have been documented at sites where stone contents are elevated (Figure 19). These fabrics indicate ice flow to the east-northeast, slightly oblique to striae measurements on bedrock outcrops (McKay 1988). Stratified, glaciolacustrine and glaciofluvial sediments underlying the till sheet often display signs of glacial overriding. At one exposure in the Armstrong sand and gravel pit in Fort Frances, silts and clays underlying Whitemouth Lake till are sheared up and incorporated into the basal portions of the till with local displacement to the east (Photo 8). Many other examples of sheared, faulted and folded strata underlying the Whitemouth Lake till sheet

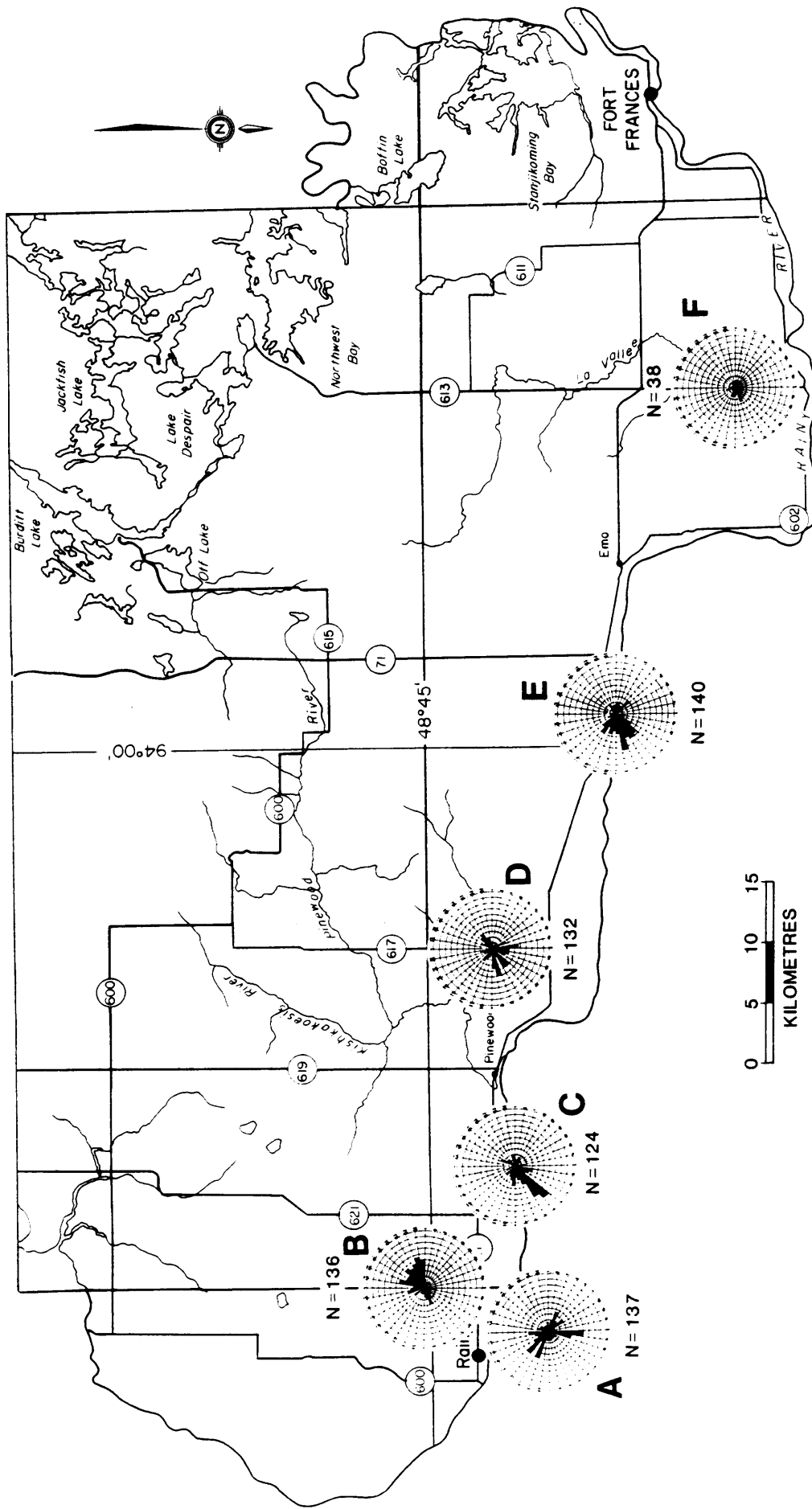


Figure 19. Rose diagrams illustrating pebble fabrics obtained from selected surface exposures of Marchand till (Sites A, B and C) and Whitemouth Lake till (Sites D, E and F).

have been observed across the report area. All indicate ice flow towards the east.

Because of its fine-grained texture and massive structure, the genesis of massive, Whitemouth Lake till is often difficult to discern. At sites where the till displays strong pebble fabrics and contains abundant glaciotectonic structures and glacially-abraded clasts, one can at least argue that the sediment was deposited under grounded, active ice. The till in these examples may have accreted by lodgement processes.

At a few sites, it appeared that Whitemouth Lake till was derived from the deformation of glaciolacustrine sediments. Remnant, convoluted laminations were visible in an otherwise massive diamicton. Low-angle shear planes were visible and indicated deposition under grounded, active ice.

The genesis of thick sequences of massive, Whitemouth Lake till recovered from sonic boreholes is even more difficult to discern. Without further study, one can probably only suggest, that the till is of a subglacial variety. Perhaps microfabrics on oriented core samples could help to further refine our knowledge of till genesis.

Subaquatic flow tills associated with the ice advance, or occurring below the massive till facies, are usually 0.5 to 1.0 m thick and display sharp upper and lower contacts. This till facies exhibits similar characteristics to the lodgement facies except that it is generally softer, less dense, may contain faint stratification and occasionally

contains small intraclasts (1 to 2 mm diameter) of glaciolacustrine silt and clay. The flow tills are probably generated at the grounding line under a floating ice margin, by remobilization of water-saturated till squeezed out from under the glacier.

A widespread unit of light buff-brown, silty, gritty and pebbly, substratified diamicton, interbedded with thinly laminated, glaciolacustrine rhythmites of silt and clay unconformably overlies the lodgement facies in localized depressions (Photo 9). Only near the outer limits of the till sheet have similar materials been observed beneath the lodgement facies.

The substratified diamicton often occurs as couplets composed of: 1) a lower layer of massive to slightly graded till-like material with winnowed, pebbly horizons, abundant rip-up clasts of glaciolacustrine silt and minor clay, discontinuous stringers of glaciolacustrine silt and numerous dropstones; and 2) thin, draping clay laminations. Couplets display remarkable lateral continuity.

The sediment package is interpreted as the deposit of subaqueous debris flows in a proglacial, lake environment. An undermelt component from either a floating ice shelf or large debris-rich icebergs has been identified as a significant contributor to the sediment package.

Each couplet represents an annual deposit. The coarse layer of each couplet may contain the deposits of several

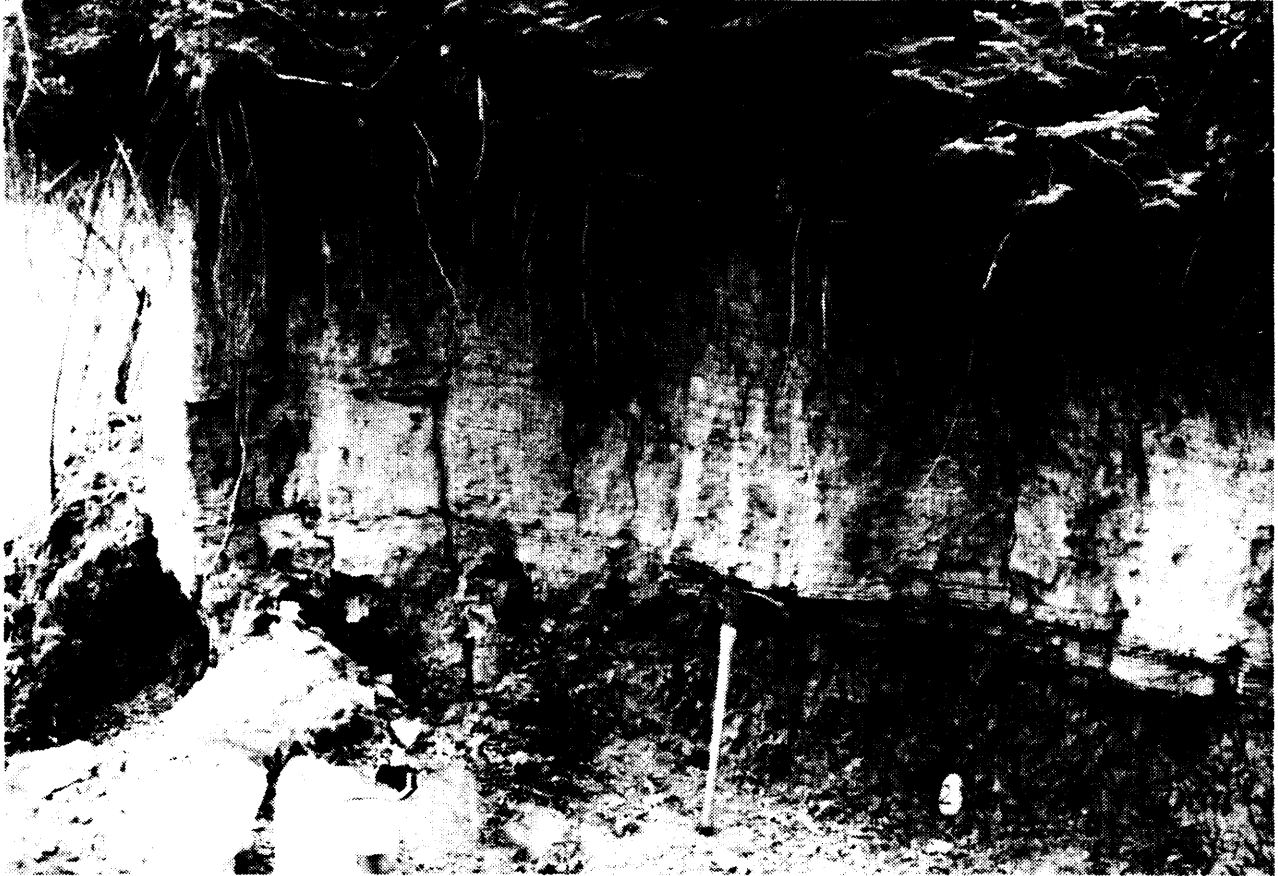


Photo 9. Blocky, clayey silt till (Whitemouth Lake till) overlain by interbedded, waterlain till and Lockhart Phase glaciolacustrine silts and clays, Dobie Township.

debris flow events. Debris flows are suggested by: 1) the concentration of deposits in low-lying areas; 2) multiple, massive to slightly graded units often separated by pebbly lags; 3) the presence of augen-shaped intraclasts of glaciolacustrine silt and clay; 4) winnowed, slightly sorted matrix; and 5) weak, pebble fabrics. Large numbers of dropstones have been observed within the debris flow units and indicate that at least some of the sediment is derived from the release of debris from floating ice. Some of the silt intraclasts may have passed through the water column as eroded remnants of loess or glaciolacustrine sediment originally deposited on the surface of the glacier. The thin, draping clay layers are the result of suspension deposition during periods of reduced melt (i.e., winter months). Couplets range from 0.02 to 1.00 m in thickness. They generally thin upward and grade into distal, varved silts and clays. A retreating ice margin is implied by this sequence of sediments.

In a few cases, thin rhythmites were observed near the bottom of the debris flow package. These sediments were probably deposited during quiet water periods between debris flow events.

The close association of this facies with the retreat phase of the St. Louis Sublobe indicates a sudden change in ice dynamics. Debris flows associated with the ice advance are very similar in character (i.e., colour and grain size) to the subglacial facies and show few signs of ice rafting.

These flow tills probably originated at the grounding line of the glacier and flowed as gravity-driven, cohesive units with little or no sorting by bottom currents (plug flow).

The retreat phase, debris flows are lighter-coloured, coarser-textured and better sorted than the subglacial facies. They contain abundant intraclasts of glaciolacustrine silt and clay, display graded beds and are always capped by a clay drape. These flows are generated at the glacier margin by traction currents associated with increased levels of melting at the glacier terminus. The coarser texture of the diamicton layer is attributed to: 1) the expulsion of fines from water saturated, more fluidized flows; 2) the winnowing of fines as vigorous, bottom-hugging traction currents pass over the flow tills; and 3) sorting of ice-rafted debris as it passes through the water column and is incorporated into the diamicton units. Fluid flow is indicated by the increased erosiveness (i.e., abundant intraclasts of glaciolacustrine silt) and lateral continuity of the flow units. Traction currents are indicated by the presence of pebble lags and thin silt stringers within the diamicton units. A dramatic increase in floating ice within the basin is indicated by the abundance of drop clasts. A thin, low-profile ice sheet, prone to calving, may have developed in response to over-extended flow during the advance of the St. Louis Sublobe into the report area.

There is no evidence to support a glacial surge during this late-stage reactivation. That is, there are no

features or deposits that imply massive ice stagnation of the St. Louis Sublobe following the advance. The progressive thinning of debris flow units and vertical gradation into distal rhythmites suggests active retreat of the ice margin following the advance. Flat-lying, fine-grained, glaciolacustrine sediments probably acted as an impermeable, deformable bed allowing rapid ice flow into the report area. Water depths of 70 m or more would have promoted rapid ice retreat by calving following the advance.

Whitemouth Lake till was deposited during the Edinburg phase of the Des Moines lobe, stratigraphically one of the best documented events in the midcontinent region (Clayton and Moran 1982). The term, Whitemouth Lake till originated in southeastern Manitoba (Teller and Fenton 1980). It is correlated with the Indus Formation of northern Minnesota (Ojakangas et al. 1977) and the Falconer and Huot Formations of North Dakota (Arndt 1977). The Edinburg Phase probably occurred shortly after 11 600 years B.P.

Marchand Till

Glaciolacustrine sedimentation continued within the report area as Keewatin ice retreated into the Lake Winnipeg basin (Teller and Fenton 1980). A late stage reactivation of the Keewatin glacier resulted in a readvance of the Des Moines Lobe down the Red River Valley and into the Red Lake Lowland of northwestern Minnesota. A moderately stony, sandy till has been recognized as the surface till in

southeastern Manitoba and northeastern North Dakota (Teller and Fenton 1980). Quaternary mapping and overburden drilling has resulted in the recognition and extension of this till unit into the southwestern corner of the report area (Figure 9). The term, Marchand till originated in southeastern Manitoba, where the stratigraphic unit was first recognized and formally named (Teller and Fenton 1980).

The outer limit of the Marchand till has been identified using information gathered during the Quaternary mapping and sonic drilling programs. The Whitemouth Lake and Marchand tills have only been observed in stratigraphic context in drill cores. Between the towns of Rainy River and Pinewood, many of the drill holes contain the two Keewatin derived tills. Marchand till thicknesses average 8 to 10 m within this area (Figure 14, back pocket). The two tills are often found in direct contact with each other and are infrequently separated by glaciolacustrine sediment. However, up to 4 m of glaciolacustrine silt and clay has been observed between the two tills.

Moderately stony, sandy silt to silty sand till has been recognized as the surface till within large areas of Blue, Worthington, Curran, Spohn and Atwood townships. The till has a blocky fracture pattern and erodes in ditches and river bank exposures to form steep, columnar jointed faces (Photo 10).

Unweathered till samples obtained from sonic boreholes average 37% sand, 40% silt and 23% clay; approximately 20% less clay than the underlying, Whitemouth Lake till (Figure 17, Table 2). Surface samples display similar textural trends. Matrix carbonate content averages 29%, only 1% higher than that of the Whitemouth Lake till. Calcite to dolomite ratios average 0.5 (Figure 18, Table 2). As with the Whitemouth Lake till, surface samples of Marchand till display a wider range of carbonate contents than do unweathered, borehole samples. Geochemically (i.e., trace elements), the Whitemouth Lake and Marchand tills are indistinguishable.

Clasts are subrounded, striated and faceted and account for 10 to 20% of the till by volume. The composition of the pebble fraction is similar to that of the Whitemouth Lake till. Lodgement and subaqueous flow facies have been identified in both sonic core and surface exposures. These facies are not unlike those identified within the Whitemouth Lake till package. Pebble fabrics from surface exposures of massive, Marchand till indicate a preferred orientation to the northeast (Figure 19). Compressive flow at Site A may be responsible for the large number of clasts aligned transverse to the dominant flow direction. Site B may in fact represent a flow facies of the Marchand till. The predominance of northeast-dipping clasts at this site



Photo 10. River bank exposure of silty Marchand till, Dilke Township. Note the steep, columnar jointed fracture pattern of the till. Moorhead and Emerson Phase deposits of Lake Agassiz overlie the till.

supports this interpretation.

The advance responsible for the deposition of the Marchand Till is not well dated. The preceding Edinburg phase of the Des Moines lobe (Whitemouth Lake till) is approximated at 11 600 years B.P. The Marchand till advance probably occurred shortly after this time.

Glaciofluvial Deposits

Isolated deposits of ice-contact stratified drift mark the outer limits of Whitemouth Lake till within the report area. Ice-contact deltas and subaqueous outwash fans have been recognized between Fort Frances and the northwest corner of Dance Township. To the northwest of these deposits, the terminal position of the St. Louis Sublobe is not characterized by deposits of ice-contact stratified drift. Rather, massive, silty and clayey tills are interbedded with substratified, subaqueous debris flows and glaciolacustrine sediment with very little associated granular material.

The deltaic deposits are located approximately 2 km east of the hamlet of Dance and 3 km south of Wasaw Lake. They occur as isolated bodies of moderately sorted sand and gravel. Steeply-dipping, foreset beds containing coarsening upward cycles of fine sand and pebbly, medium to coarse sand slope to the northeast. Paleocurrent measurements on second order sedimentary structures (i.e., ripples and trough and planar cross-beds) range from 0° - 90° Az. These flat-topped

bodies occur at elevations of 362 m and 376 m asl and provide some insight to the level of Lake Agassiz during the retreat of Keewatin ice from the Edinburg phase maximum. The sands and gravels of these deposits are extremely rich in Paleozoic carbonates derived from central Manitoba.

Deposits of subaqueous fans have been identified near the middle of Dance Township and in the south-central part of Couchiching Indian Reserve 16A. The deposit in Dance Township occurs as a flat-topped, lobate body composed of interstratified silt, fine sand and pebbly, medium sand with large, "floating" subangular boulders. The boulders, which reach dimensions of 1.5 m, were probably ice-rafted into their present position. Several interbeds of calcareous, silty clay flow till were observed in the deposit. The flow tills are massive to faintly laminated, contain numerous carbonate pebbles and attain thicknesses of 0.75 m.

In the south-central part of Couchiching Indian Reserve 16A, a large, poorly exposed deposit of ice-contact stratified sand and gravel with interbedded sandy debris flows has been exploited for mineral aggregate. This deposit has been extensively modified by proglacial lacustrine processes and now occurs as a broad, elongate feature, parallel to ice flow, that emerges through a surrounding mantle of glaciolacustrine sediment. Shallow borings suggest that a large proportion of the deposit occurs in the subsurface below the water table. This feature was probably deposited close to the ice margin,

perhaps at the mouth of a subglacial conduit, in standing water, at least 30 m deep.

Buried deposits of Keewatin derived, glaciofluvial sand and gravel are of restricted extent. Borehole F87-19 (Map 6, Profile 2a) intersected 19 m of glaciofluvial sand beneath 13 m of glaciolacustrine clay and Whitemouth Lake flow till. Thin, clayey debris flows were also encountered within the glaciofluvial sediments. The sands were probably deposited subaqueously at the mouth of a subglacial conduit. This ice-marginal sequence may mark a recessional position of the Keewatin glacier following the Edinburg phase. The southern extension of this deposit may be exposed a few kilometres southwest of Pinewood in a small borrow pit. In this pit, calcareous, sandy gravels of glaciofluvial origin display features indicating paleocurrents flowing to the east. Approximately 2 to 3 m of waterlain flow tills and glaciolacustrine silt cap the sedimentary sequence.

Glaciolacustrine Deposits and Features

Lake Agassiz was the largest of several water bodies which bordered the southern margin of the retreating Laurentide Ice Sheet during the Late Wisconsinan. The lake inundated an area of approximately 1 million km² although at no particular time did it occupy this entire area (Teller and Clayton 1983). Although, by definition, the term, "Lake Agassiz" refers to the proglacial water body which formed during the waning stages of the Late Wisconsinan glaciation,

numerous earlier phases of the lake, the records of which are incomplete, must have existed throughout the Wisconsin Stage.

Lake Agassiz was initiated around 11 500 years B.P. when ice retreat north of the continental divide, at Lake Traverse in northeastern North Dakota, uncovered north sloping land (Fenton et al. 1983). Progressive expansion of the lake into Minnesota, Saskatchewan, Manitoba and Ontario occurred with further retreat of the ice sheet margin. By 7 500 years B.P., the Labradorean ice margin had wasted into the Hudson Bay Lowland allowing final drainage of the lake and the incursion of the Tyrrell Sea (Elson 1967; Klassen 1983).

The Lake Agassiz chronology has been subdivided into five phases which represent major water level fluctuations controlled by ice-margin position and outlet availability (Figure 20). These include, from oldest to youngest: the Lockhart Phase (11 500-11 000 years B.P.); the Moorhead Phase (11 000-10 000 years B.P.); the Emerson Phase (10 000-9 200 years B.P.); the Nipigon Phase (9 200-8 500 years B.P.); and the Ojibway Phase (8 500-7 500 years B.P.) (Fenton et al. 1983). The Lockhart and Emerson Phases represent high stands of the lake with southward drainage to the Mississippi River via the Minnesota River valley. The Moorhead, Nipigon and Ojibway Phases are periods when Lake Agassiz drained to lower levels as eastern, and possibly

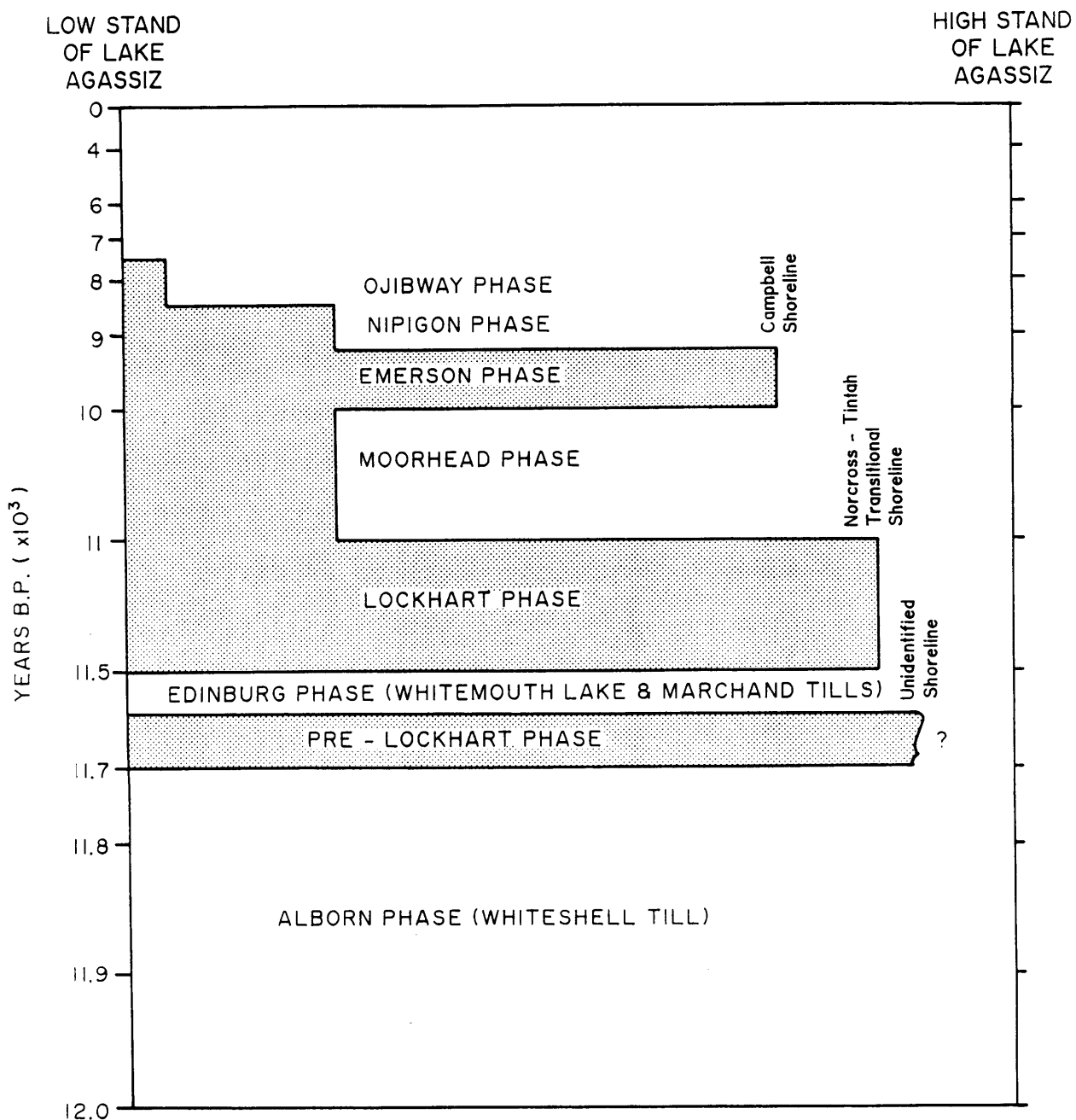


Figure 20. Schematic representation of water level fluctuations affecting Glacial Lake Agassiz in northwestern Ontario.

western, outlets were uncovered during ice retreat.

Earlier high level stands of Lake Agassiz are also recorded in the sedimentary record. Isolated occurrences of glaciolacustrine sediment have been found beneath Whiteshell till across the report area. These sediments were probably deposited in an early phase of Lake Agassiz prior to the Late Wisconsinan glacial advance, which occurred approximately 20 000 years B.P. These sediments have been described in earlier sections of this report. A widespread, glaciolacustrine unit separating the Marchand and Whitemouth Lake tills from the underlying Whiteshell till has been documented in sonic drillhole records and isolated surface exposures (Figures 14, 15 and 16, back pocket). These sediments were deposited during a pre-Lockhart Phase of Glacial Lake Agassiz (Figure 20). Glaciolacustrine sediments, separating Marchand till from the underlying Whitemouth Lake till, have been observed in several sonic boreholes across the western end of the report area. These sediments, however, appear to have been largely removed by the subsequent ice advance that deposited the Marchand till.

Pre-Lockhart Phase (Wylie Formation)

Pre-Lockhart Phase sediments were first recognized in North Dakota as glaciolacustrine sediments that immediately pre-date the deposition of the Falconer and Huot Formations (Whitemouth Lake till equivalents). These lake sediments have been formally named the Wylie Formation (Arndt 1977).

Pre-Lockhart Phase glaciolacustrine sediments have been observed within the report area in sonic drill core, backhoe trenches and at exposures within the Armstrong sand and gravel pit in Fort Frances. They occur as well to faintly laminated very fine sands, silts and clays (Photo 11). In the report area, Pre-Lockhart Phase sediments are situated between the Whitemouth Lake and Whiteshell till sheets and usually display gradational upper and lower unit contacts. Maximum documented thicknesses approach 12 m (Bajc 1991).

Areas that lie beyond the limit of Whitemouth Lake till, and within the Lake Agassiz basin, should have a continuous record of glaciolacustrine sedimentation that spans both the Lockhart (Brenna Formation) and Pre-Lockhart (Wylie Formation) phases (Figure 21). However, there is as yet, no evidence for continuous sedimentation through these phases within the report area. Perhaps, Labradorean ice stood at the Rainy Lake-Lake of the Woods Moraine during the advance and retreat phases of the Keewatin glacier thus preventing glaciolacustrine sedimentation. Certainly areas within the Red River Valley, beyond the Huot and Falconer Formation borders, contain a continuous record of sedimentation through these two phases.

The bulk of the sediment comprising the lower portions of Pre-Lockhart Phase sediments are typically Labradorean derived and coarse textured. Rhythmites are composed of relatively thick beds of pebble-free, light greenish-grey,



Photo 11. Pre-Lockhart Phase glaciolacustrine rhythmites of silty, very fine sand and clay, Armstrong sand and gravel pit, town of Fort Frances. Note the thinning upward rhythmites and the contorted slump deposit near the top of the section.

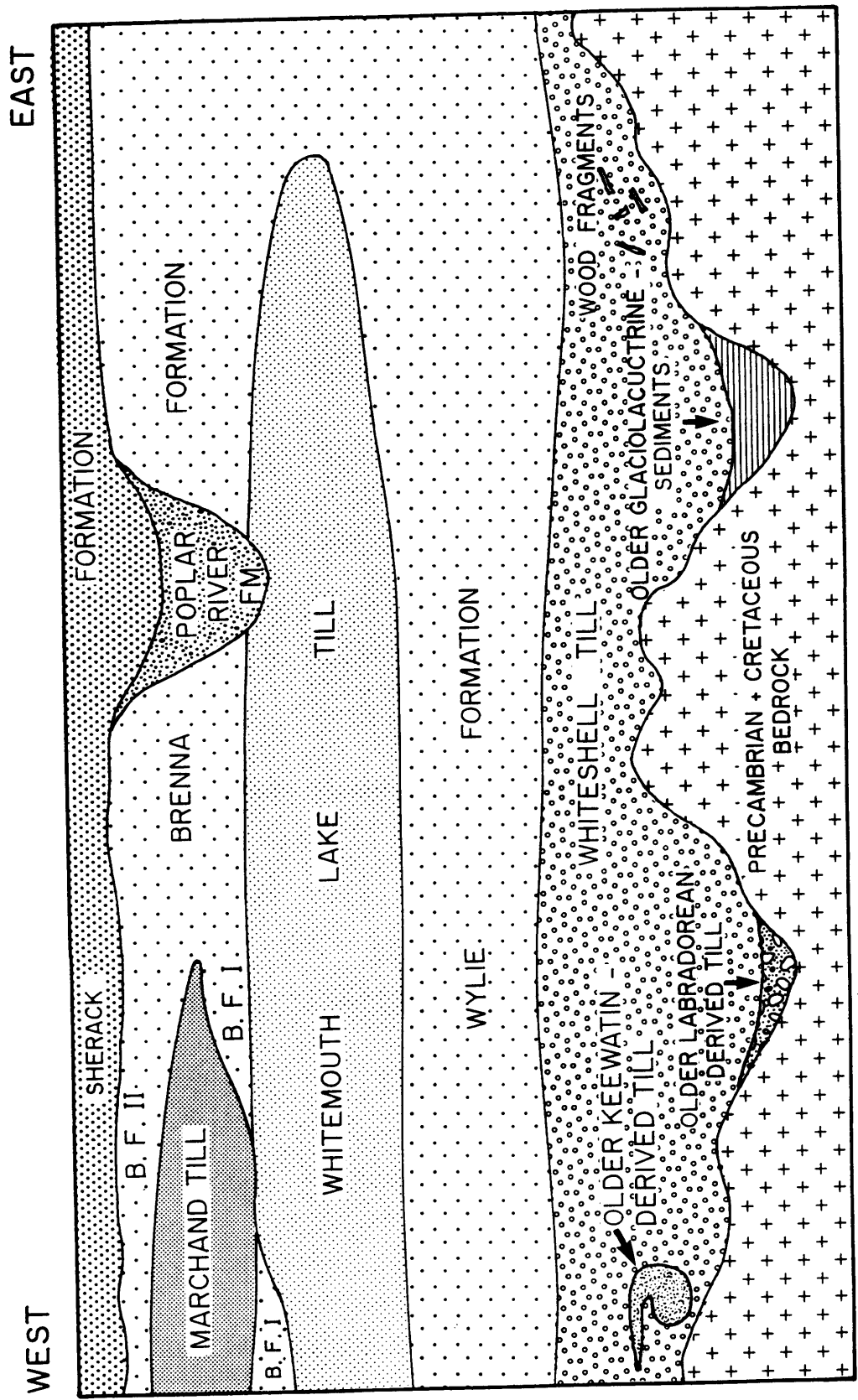


Figure 21. Composite stratigraphic section for the Fort Frances-Rainy River area.

massive to faintly laminated silt (10 to 20 cm) with thin, dark grey clay caps (1 to 2 cm). The carbonate contents of the clay layers far exceed those of the silt layers (i.e., up to 31% carbonate for the clay versus non-detectable carbonates with 10% HCl for the silt). This implies, at least, a partial Keewatin source for the clay.

The upper portion of the glaciolacustrine package reflects a change in sediment source as the Keewatin ice advanced into the report area. Rhythmites are usually finer grained and consist of thin, light grey, silt laminations (1 to 5 mm) capped by thick beds of dark grey, massive to faintly laminated clay (1 to 20 cm). The clays usually contain 20 to 30 percent carbonate and the silts contain significantly lower levels. Near the top of Pre-Lockhart Phase sediments, thin, gritty, Keewatin derived, subaqueous debris flows are frequently interbedded with the glaciolacustrine sediments. Drop clasts of glaciolacustrine silt, silty diamicton balls and carbonate pebbles are common within this zone.

Clay samples were collected from the Armstrong sand and gravel pit in Fort Frances and from selected drill cores to determine whether a change in sediment source for the rhythmites, from Labradorean to Keewatin is reflected in the mineralogy of the clay layers. It was determined that the clay component of all Pre-Lockhart Phase glaciolacustrine sediments have a Keewatin sediment source. All clay samples contain high quantities of expanding clay minerals (illite-

smectite, smectite and vermiculite) with lesser amounts of illite, chlorite and kaolinite. Varve counts from sonic boreholes and surface exposures have yielded totals numbering considerably less than 100. Even at the eastern edge of the report area, where the erosive processes of the Keewatin glacier would have been minimized, only 58 rhythmites were counted. This implies a short period of time between the retreat of Labradorean ice from the report area and the subsequent advance of the Keewatin glacier. The strong Keewatin signature registered by the clay mineralogical analyses and carbonate contents of pre-Lockhart phase sediments suggests that the St. Louis Sublobe was relatively close by.

Pre-Lockhart Phase sediments have not been dated directly. Labradorean ice covered the report area as the Des Moines Lobe (Keewatin ice) advanced down the Red River Valley and the St. Louis Sublobe spread into low-lying areas of north-central Minnesota. This advance, referred to as the Alborn Phase, occurred prior to $11\ 710 \pm 325$ years B.P. (oldest date on wood overlying Alborn Phase till in east-central Minnesota) (Wright and Ruhe 1965). Following this advance, the margins of Des Moines Lobe and the St. Louis Sublobe retreated northward beyond the International border. Glaciolacustrine sediments of the Wylie Formation were deposited within the Red River Valley in North Dakota, Minnesota and Manitoba at this time (Arndt 1977; Teller and Fenton 1980).

During this interval, Labradorean ice (Rainy Lobe) must have retreated northeastward out of the lowland to allow for the deposition of glaciolacustrine sediments within the report area. A basal radiocarbon date of $11\ 110 \pm 100$ years B.P. (WIS-1327) was obtained from a lake (Rattle Lake) which is located approximately 70 km northeast of the report area (Bjorck 1985). Nearly 200 years of barren, rhythmically laminated glaciolacustrine sediment underlies the dated horizon at Rattle Lake therefore implying a deglaciation date of at least 11 300 years B.P. for the lake basin. This is a minimum age estimate for the retreat of Labradorean ice from the report area.

The subsequent advance of the Des Moines Lobe and the St. Louis Sublobe (Keewatin glacier) into northwestern Minnesota, northeastern North Dakota and adjoining Ontario, a distance of greater than 200 km, is referred to as the Edinburg Phase and occurred prior to $10\ 960 \pm 300$ years B.P. (oldest date on wood overlying Edinburg Phase till in North Dakota) (Clayton and Moran 1982). This advance resulted in the deposition of the Whitemouth Lake till.

Based on these minimum age dates, it would appear that the Pre-Lockhart Phase sediments are greater than 11 300 years old. Clayton and Moran (1982) inferred an age of approximately 11 600 to 11 700 years B.P. for the Pre-Lockhart Phase sediments.

Lockhart Phase (Brenna Formation)

Lockhart Phase sediments, also referred to as the Brenna Formation in North Dakota (Arndt 1977) were deposited proglacially, in low-lying areas, beyond the Keewatin and Labradorean ice margins. Sedimentation began around 11 500 years B.P., following the deposition of the Whitemouth Lake till and was interrupted by a late stage reactivation of the Keewatin glacier which resulted in the deposition of the Marchand till. Glaciolacustrine sediments separating Whitemouth Lake till from Marchand till are included in the Brenna Formation (Figure 21). Sedimentation ceased around 11 000 years B.P. within the Fort Frances-Rainy River basin, when ice retreat uncovered a series of low outlets dropping water levels by as much as 150 m (Teller 1985).

Lockhart Phase sediments are restricted to low-lying areas, their upper limits defined by the 350 m contour in the southwest and the 385 m contour in the northeast. They are buried by younger, Emerson and Moorhead Phase sediments where they occur below 340 m and 360 m asl in the southwest and northeast, respectively. They usually display sharp lower contacts, when in contact with subglacial, Whitemouth Lake till (Photo 9) and sharp to gradational upper contacts when overlain by younger sediments.

The transition from Lockhart to Moorhead Phase sediments are represented by either an influx of coarse clastic sediments into the basin as high points of land became emergent and available for subaerial erosion or by an

unconformable surface, as is common throughout the southern part of the Lake Agassiz basin. In borehole F87-33 (Figure 2, back pocket), several thin interbeds of sandy silt and silt within a predominantly clay succession mark the initial drop in water level. The Moorhead Phase unconformity occurs about 2 m higher in the sequence.

Proximal, Lockhart Phase glaciolacustrine sediments occur primarily within those areas affected by the Keewatin glaciation and appear to be intimately associated with subaqueous debris flows and undermelt till. Consequently, significant variation in thickness of glaciolacustrine sediments occurs over the gently undulating till plain. Swales commonly contain the thickest accumulations whereas crests, most often, lack a veneer of glaciolacustrine silt and clay. This results in a landscape having a subdued surface expression. Lockhart Phase sediments are generally less than 8 m thick. The sediments consist of: calcareous, rhythmically laminated gritty silt and clay; faintly laminated, gritty silt; massive to faintly laminated clay; and well sorted, fine to very fine sand. Ice-proximal, coarse-grained sediments with abundant drop clasts and interbedded diamicton layers commonly grade upward to distal, fine-grained facies (Photo 9).

Unusually thick accumulations of Lockhart Phase silts and clays have been encountered in a deep, sediment basin within Nelles and Patullo townships (Profile 2a, Figure 15). Sonic boreholes in this area have intersected thicknesses,

in excess of 20 m, of massive, faintly laminated and rhythmically laminated clays with minor silt. Gritty and pebbly horizons and thin debris flows were encountered at random levels. Approximately 275 rhythmites were counted in the Lockhart Phase succession of borehole F87-18 (Figure 2).

A prolonged period of ice-marginal sedimentation within this basin was probably facilitated by a slight pause in the retreat of the Keewatin glacier. The ice margin probably stood along the present route of Highway 619. Borehole F87-19 (Profile 2a, Figure 15) intersected approximately 18 m of calcareous, Keewatin derived sand interbedded with clayey, subaquatic flow tills (Whitemouth Lake till) at depth. A small gravel pit adjacent to the Rainy River, 3 km west of Pinewood, exposes several metres of cross-bedded, calcareous, sands and gravels overlain by Lockhart and Emerson Phase glaciolacustrine sediments. Paleocurrent measurements indicate consistent flow to the east. A former ice-marginal position along the trend of these two deposits is suggested.

Lockhart Phase clays are rich in swelling clay minerals (illite-smectite, smectite and vermiculite) and contain lesser amounts of illite, chlorite and kaolinite. A Keewatin source is suggested by the clay mineral assemblages. Clay-rich, Lockhart Phase sediments often display slickensides on freshly broken surfaces. Similar fracture patterns have been observed in the Brenna Formation of North Dakota (Arndt 1977).

Lockhart Phase glaciolacustrine sand is uncommon within the report area. One areally extensive deposit of faintly laminated, slightly calcareous, fine to very fine sand is situated 2 to 3 km northwest of Little Pine Lake. The deposit is located at the southern end of a northward sloping lowland, along which Log Creek flows.

Northeastward retreat of the Labradorean glacier out of this lowland was accompanied and followed by high levels of Glacial Lake Agassiz. Stranded blocks of ice, grounded on the lake bottom resulted in a landscape which is kettled, yet subdued, due to later modification by glaciolacustrine processes, following disintegration of the ice blocks.

Rhythmically laminated gritty silts and clays and very fine sands have also been observed in low-lying areas within the northeastern corner of the report area. Noteable occurrences are located along the shorelines of Off Lake, Burditt Lake, Jackfish Lake, West Jackfish Lake and Rainy Lake. These glaciolacustrine sediments contain low levels of carbonate and appear to have a Labradorean sediment source.

The Lockhart Phase of Glacial Lake Agassiz came to an end approximately 11 000 years B.P. when low level northern outlets were uncovered with ice retreat. Water levels dropped by as much as 150 m (Teller 1985) exposing much of the lake bed over the southern part of the basin. Because of their non-glacial character, the deposits and features associated with this low-water phase (Moorhead Phase) will

be discussed in a later section describing older alluvial deposits. The Moorhead Phase came to an end approximately 10 000 years B.P. as the low level outlets were closed by a readvance of the Laurentide Ice Sheet.

Emerson Phase (Sherack Formation)

An abrupt, basin-wide transgression marked the beginning of the Emerson Phase; the last high stand of Lake Agassiz. During this transgressive event, water levels rose to the prominent Campbell shoreline. Moorhead Phase deposits and features were blanketed by glaciolacustrine sands, silts, and clays in littoral and deep-water settings (Photo 12). Emerson Phase sedimentation ceased between 9500 and 9200 years B.P. when low, eastern outlets to the Upper Great Lakes were opened with ice retreat. In North Dakota, Emerson Phase sediments have been formally named the Sherack Formation.

The Campbell shoreline occurs at an elevation of 340 m asl in the southwestern corner of the report area and at 365 m asl in the northeastern corner. Water depths of 15 to 20 m probably existed in the offshore settings. Aside from a few restricted areas of fine to very fine sand along the Rainy River, between Fort Frances and Emo and more extensive patches in the northwestern corner of the study area, around Lake of the Woods, most of the Emerson Phase glaciolacustrine sediments consist of faintly laminated silt and clay. All of the sediments are extremely calcareous and are



Photo 12. Emerson Phase glaciolacustrine silts and clays unconformably overlying Moorhead Phase, fluvial, sandy gravels, Morley Township. Note the concentration of secondary carbonate at the contact of the two units.

probably derived from the winnowing and reworking of local glacial and glaciolacustrine deposits. The Labradorean ice margin was probably at the Lac Seul Moraine at this time, over 75 km northeast of the report area (Minning et al., in prep.). An extensive, archipelago of islands separating the Wabigoon-Lac Seul and Fort Frances sediment basins restricted the southwestward dispersal of glaciolacustrine sediments into the report area. The Keewatin glacier had retreated to a position north of Lake Winnipeg by this time (Klassen 1983) and probably was not a significant contributor to the sediment supply in the Fort Frances-Rainy River area.

Emerson Phase sediments are commonly grey to buff-grey, less than 3 m in total thickness and are usually massive to faintly laminated. There is very little evidence to suggest a direct glacial influence on sedimentation. Rhythmites and dropstones have not been observed. Fossil plant, mollusc and insect remains are commonly recovered from the littoral glaciolacustrine deposits.

A distinctive unit of red clay occurs along the eastern edge of the Lake Agassiz basin within Emerson Phase glaciolacustrine sediments. The thickest accumulations have been observed in the Wabigoon-Lac Seul basin, near Dryden and in low-lying areas around Mine Centre and Atikokan (Zoltai 1961). In these areas, rhythmically laminated sequences of grey silt and red clay attain a maximum thickness of 60 cm. Grey silt and clay rhythmites, typical of Lake Agassiz

deposits, are usually abruptly overlain by 15 to 24 red clay rhythmites (Rittenhouse 1934). The upper transition back to grey rhythmites is diffuse.

Massive to faintly laminated red clay occurs along the northeast shore of Lake of the Woods, around the periphery of Rainy Lake and in low-lying areas along the Rainy River, west of Fort Frances. The red clay unit is 25 cm thick in the Rainy Lake region and decreases to 7 to 8 cm around the Lake of the Woods basin (Zoltai 1961).

In the Fort Frances-Rainy River area, the red clay unit is usually found within one metre of the ground surface, near the base of Emerson Phase sediments. Pedogenic processes have masked primary sedimentary structures although crude horizontal laminations are still visible. The stratification is defined by thin, light grey, clayey silt laminations which, at one site, numbered twenty-three. Twenty centimetres of massive to faintly laminated, red clay has been observed in the Northwest Bay and Stanjikoming Bay areas of Rainy Lake. The red clay has been found as far west as Pinewood, where it attains a thickness of 3 to 4 cm. The clay contains high levels of calcium carbonate (up to 26%) and expanding clay minerals (smectite, illite-smectite and vermiculite) with lesser amounts of illite, chlorite and kaolinite. It would appear that the main sediment supply for the red clay layer is derived from the reworking of local deposits.

Two samples collected from Wabigoon Lake near Dryden, showed the red clays to be composed primarily of quartz with lesser amounts of albite, calcite, dolomite, illite, hornblende, kaolinite and chlorite (Cowan 1987). In this case, the red clay appears to have a Labradorean sediment source.

The red clay was apparently introduced into the Lake Agassiz basin at the beginning of the Emerson Phase when ice of the Marquette advance filled the Superior and Nipigon basins, damming a glacial lake (Lake Kaministikwia) in the vicinity of Thunder Bay. Red beds of the Sibley Group give the Lake Kaministikwia sediments their red colour (Burwasser 1977). Westerly overflow of the lake into the Lake Agassiz basin over a period of approximately 24 years, resulted in the deposition of a time stratigraphic marker horizon along the eastern margin of the lake. In the Fort Frances-Rainy River basin, it would appear that the Lake Kaministikwia clays serve as a pigment for what are likely, mainly locally-derived, Emerson Phase sediments rather than as a major sediment source. The Marquette Advance of the Lake Superior basin is well dated at around 10 000 years B.P. (Clayton and Moran 1982) thus implying a similar age for the red clay within the Lake Agassiz basin.

Abandoned Shorelines

Geomorphic features associated with nearshore/beach environments of Glacial Lake Agassiz were identified and

traced on aerial photographs as part of the mapping. Field observations confirmed their presence, character, and extent. Geomorphic features identified include beach ridge and bar complexes, spits, wave-cut bluffs and notches (Photo 13), and deltas. Most of the identified features are confined to the drift-covered lowland where erodable source materials are readily available for the construction of littoral landforms. In many cases, ground checking of tree-covered areas assisted in the identification of nearshore/beach features lacking geomorphic expression (i.e., wash limits). In cleared areas, linear variations in tonal patterns on aerial photographs were checked to confirm the presence or absence of Lake Agassiz strandlines.

The largest accumulations of beach and nearshore sand and gravel occur in the western half of the report area. These sands and gravels are usually less than 3 to 4 m thick and were formed by the reworking and redistribution of Keewatin drift during the Emerson Phase. The deposits are rich in well rounded, Paleozoic carbonate and shale clasts. They are usually underlain by either glaciolacustrine clay, till or bedrock. Unionid clams are commonly recovered from the deposits.

An aneroid altimeter was used to determine the elevations of shoreline features. Measurements were calibrated at bench marks to account for diurnal variations in atmospheric pressure. Corrected elevations obtained from aneroid altimeter measurements match elevations cited on



Photo 13. Campbell wave-cut notch incised into Whitemouth Lake till, Woodyatt Township.

1:10 000 scale Ontario Basic Mapping (OBM) maps. A 2 to 3 m uncertainty in defining a water plane from an abandoned shore feature probably overrides the error inherent in an altimeter measurement.

Shoreline elevations were obtained at 72 selected sites across the report area (Figure 22). Five surveyed shorelines, extracted from an earlier publication on the area (Johnston 1946), were used in conjunction with the present dataset to construct the strandline diagram. Shoreline elevations range from about 330 to 380 m asl across the report area.

A strandline diagram depicting true waterplane slopes can only be constructed if the direction of maximum uplift is known. Johnston (1946) created the first strandline diagram for the entire Lake Agassiz basin. In the Rainy River district, the direction of maximum uplift, derived from this early work was taken as 027° (Johnston 1946). All strandline diagrams drawn subsequent to this, (i.e., Elson 1967; Teller and Thorleifson 1983) used a similar direction for the construction of the profiles.

The Emerson Phase water plane, referred to as the Campbell shoreline in this report is a prominent, easily recognized feature which formed during the last highstand of Glacial Lake Agassiz. All features formed subsequently, were short-lived and, due to their regressive nature, are not as well developed. Within the report area, 38 Campbell shorelines were identified and projected orthogonally onto

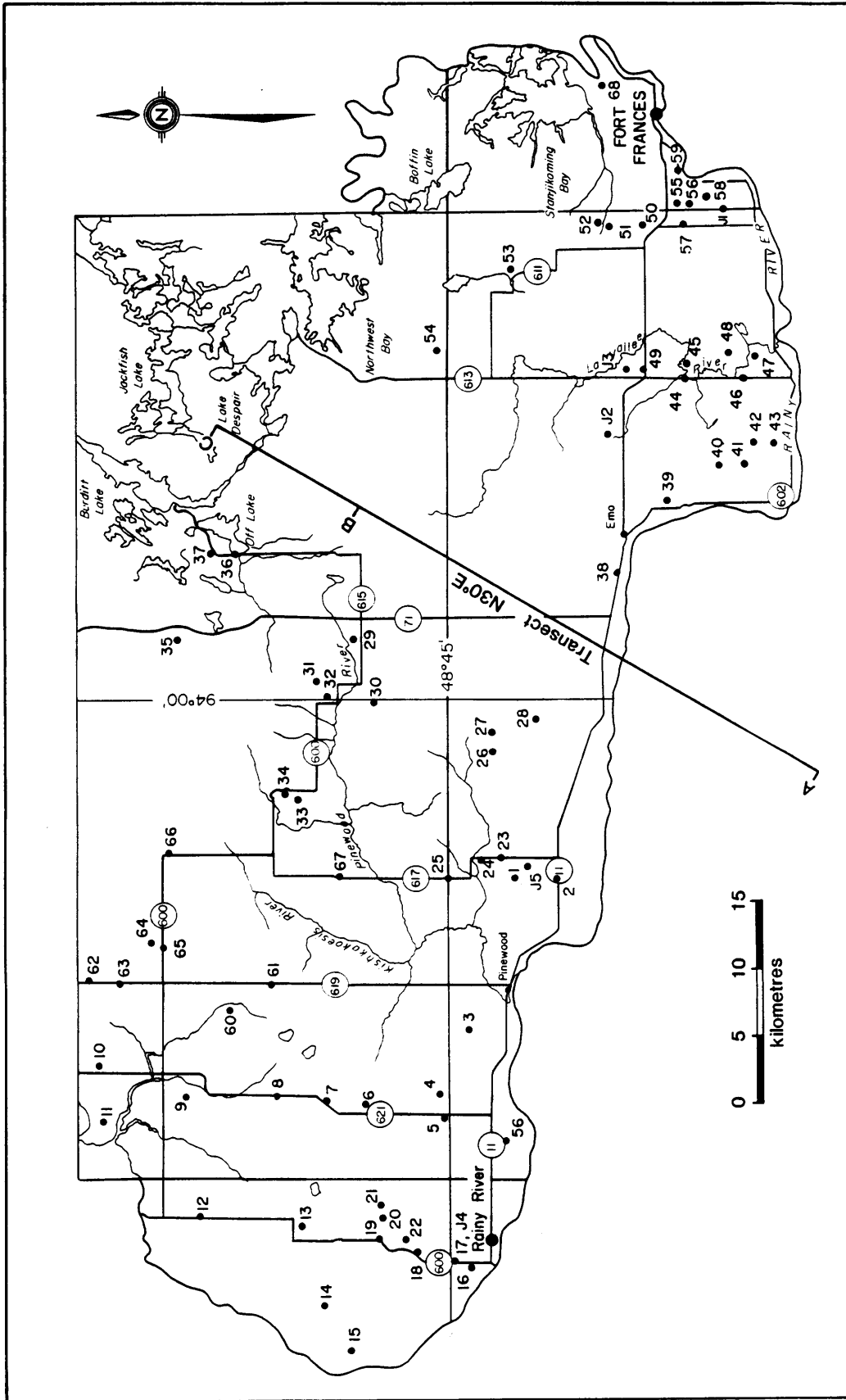


Figure 22. Location of shoreline features and transect line used for the construction of the strandline diagram, Fort Frances-Rainy River area.

ten profile lines drawn at 5° increments between 0° and 45° Az. Linear uplift is assumed to occur over the short profile length, which spans about 50 km. A least squares fit was applied to each data plot to determine the slopes and correlation coefficients for the best fit lines. Shorelines projected onto the profile line, 030° yielded the highest slope (0.39 m/km) and correlation coefficient (0.83). This direction was therefore chosen as the direction of maximum uplift.

The remaining shoreline data was plotted onto a profile line with a bearing of 030° (Figure 23). The author assumes that the direction of maximum uplift has not changed since deglaciation. Shorelines situated above and below the Campbell level are discontinuous and difficult to correlate. Nevertheless, an attempt has been made to identify discrete water planes. As is the case with the Campbell shoreline, linear uplift is probably suitable for the representation of the strandline data.

Four distinct levels have been identified, two of which occur above the Campbell water plane. These shorelines are correlated with the Tintah and a transitional Tintah-Campbell water plane defined by Johnston's (1946) strandline diagram. The Tintah and Tintah-Campbell water planes have true slopes of 0.68 m/km and 0.60 m/km, respectively and probably formed during the Lockhart Phase of Glacial Lake Agassiz. A beach ridge, situated nine metres above the Tintah shoreline, was identified in the central portion of

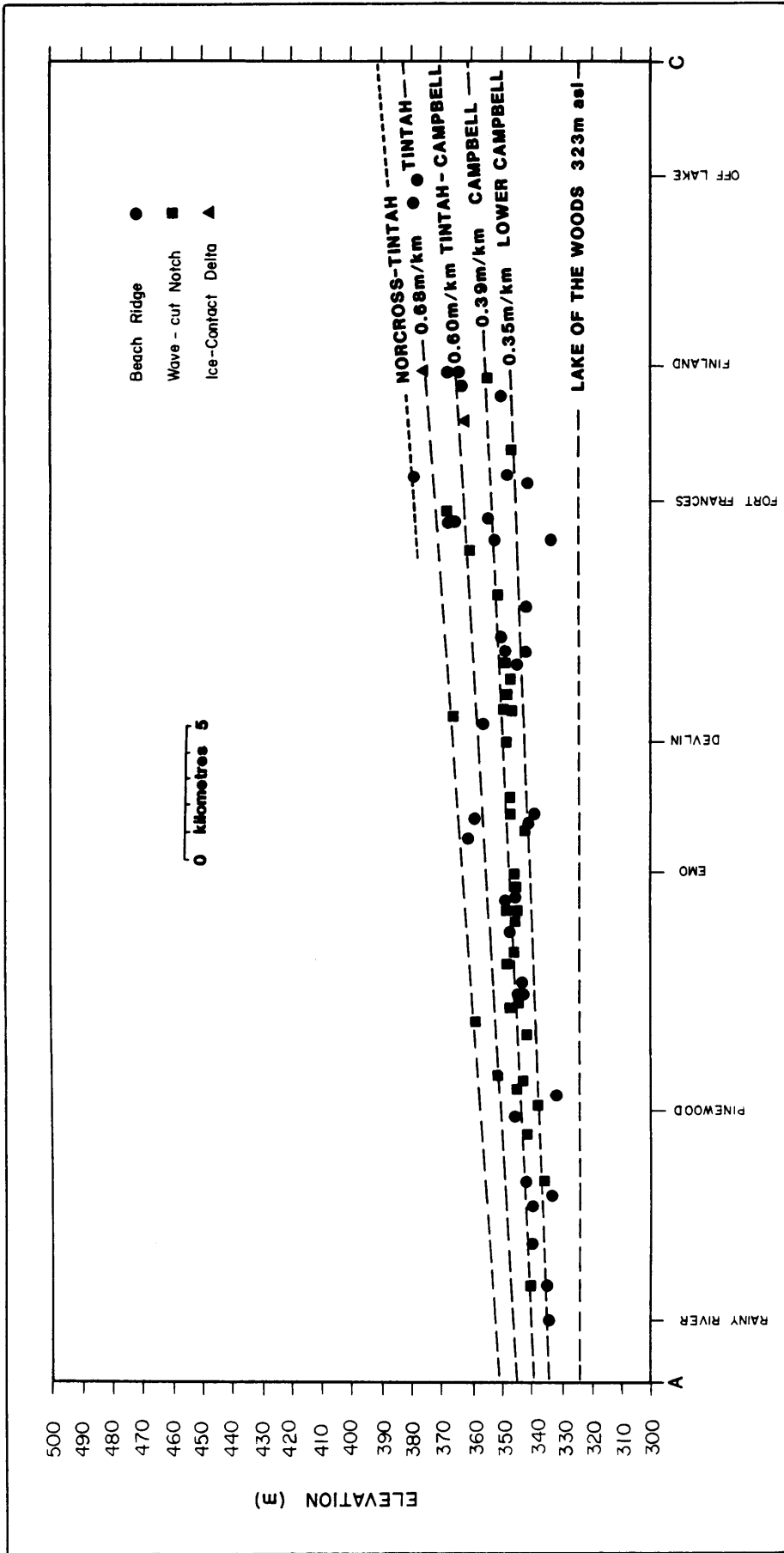


Figure 23. Strandline diagram indicating slopes and regional correlations of water planes, Fort Frances-Rainy River area.

the report area (Figure 22, site 31), however, remnants could not be found elsewhere. This feature probably belongs to one of a series of shorelines between the prominent Norcross, also a Lockhart Phase level, and Tintah water planes. Glaciolacustrine deposits or features have not been identified at higher elevations within the report area. Water levels may have dropped below the Norcross level, in response to downcutting of the southern outlet at Lake Traverse, South Dakota, by the time the ice margin had retreated to the International Border.

Numerous shore features were identified below the Campbell beach. Some of these define a water plane which is correlated with the Lower Campbell shoreline (Johnston 1946). The Lower Campbell shoreline has a slope of 0.35 m/km. Beach ridge and bar forms situated below this level are attributed to short-lived regressive phases associated with the final draining of Lake Agassiz from the report area.

Isobase diagrams were constructed for the Tintah and Campbell shorelines using the projected elevations presented in the strandline diagram (Figures 24 and 25). All isobases trend orthogonal to the direction of maximum uplift (ie. 120°). Linear uplift is represented by equally spaced isobase lines.

Topographic maps with 10 m contour intervals were used to construct paleogeographic maps of the report area for the Tintah (Lockhart Phase) and the Campbell (Emerson Phase)

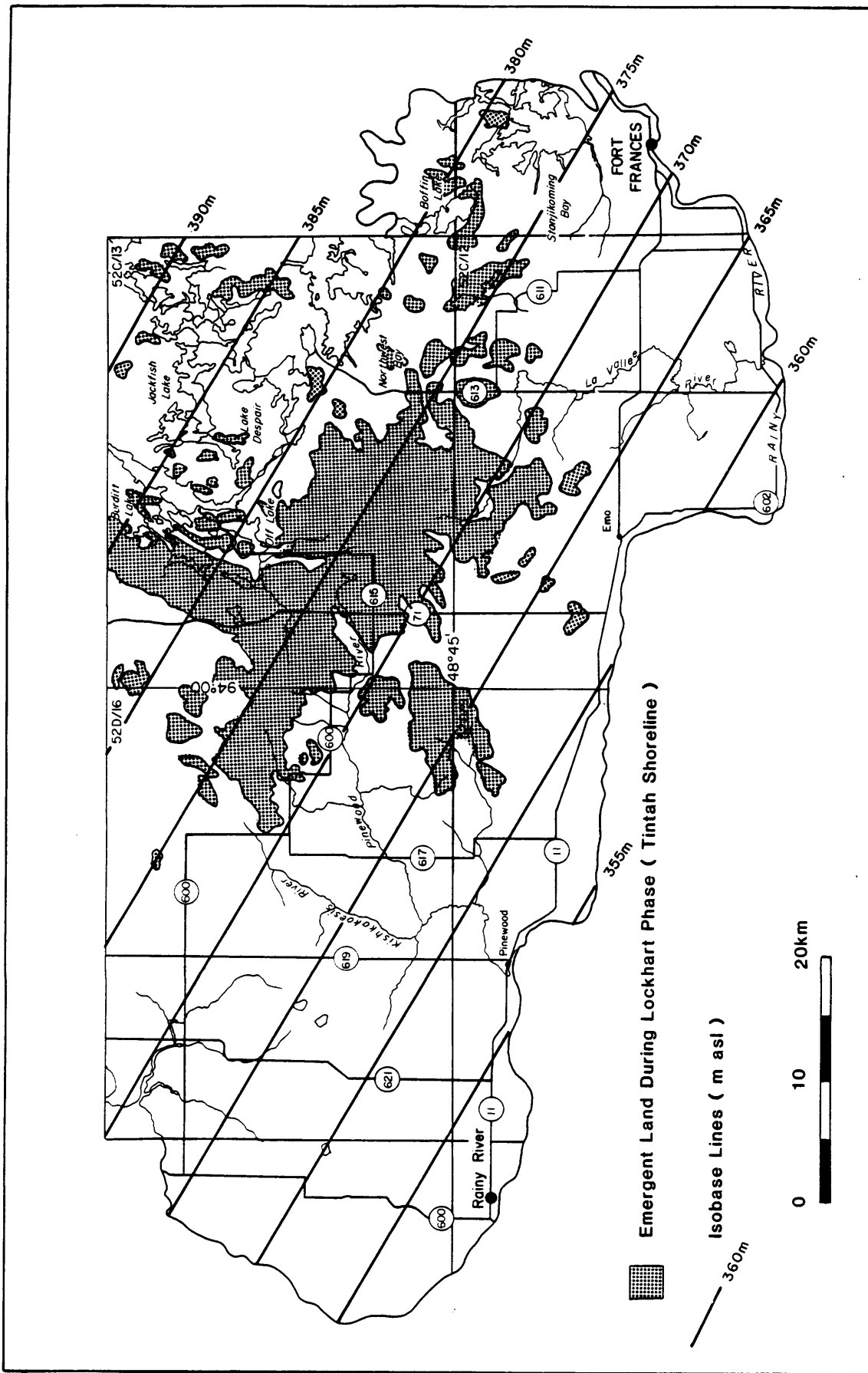


Figure 24. Paleogeographic reconstruction of the Tintah shoreline (Lockhart Phase), Fort Frances-Rainy River area. Isobase lines are superimposed on the diagram.

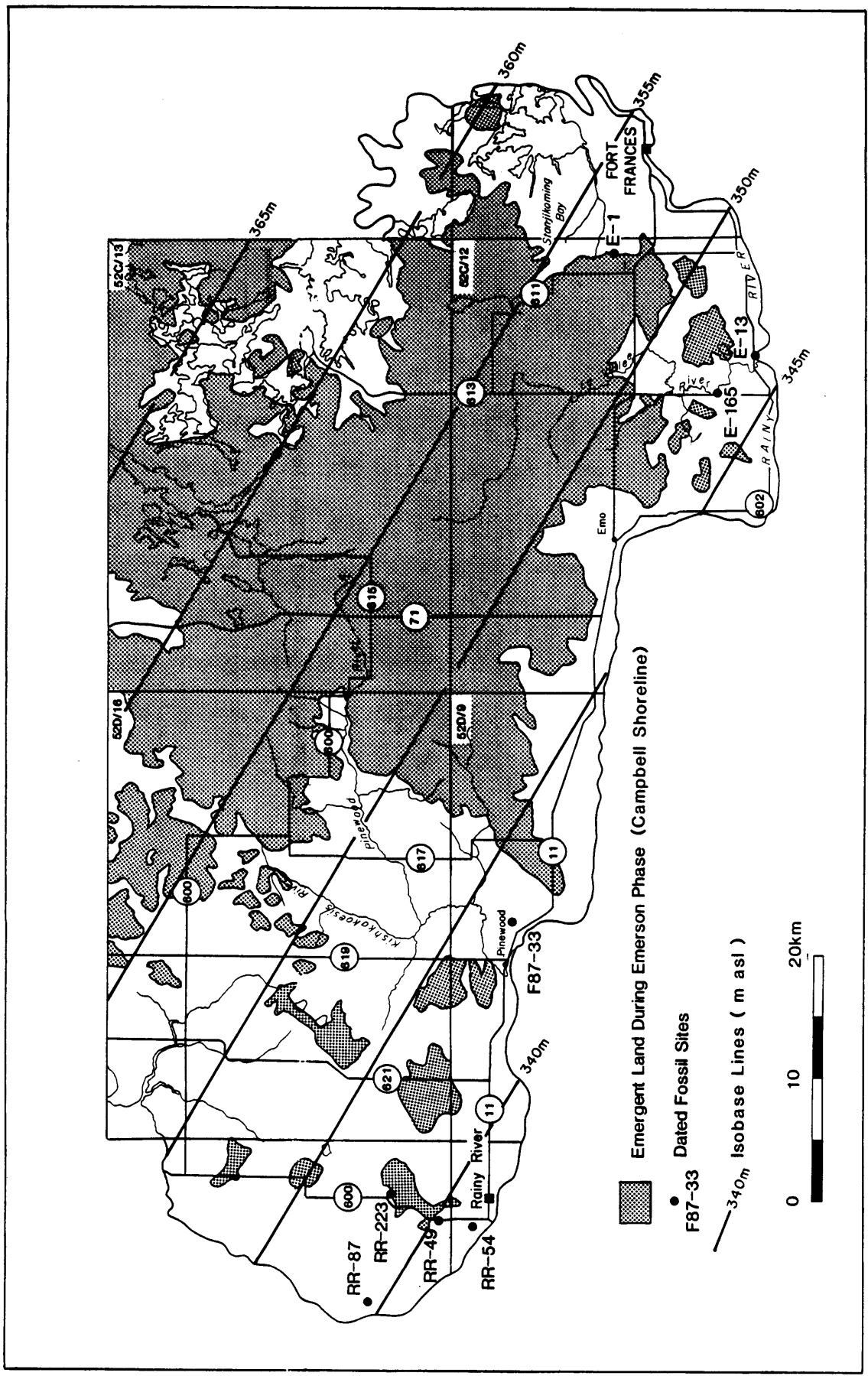


Figure 25. Paleogeographic reconstruction of the Campbell shoreline (Emerson Phase), Fort Frances-Rainy River area. Isobases and location of radiocarbon dated fossil sites are superimposed on the diagram.

shorelines of Lake Agassiz (Figures 24 and 25). Much of the Campbell paleogeographic map is based on actual field data since most of the strandlines can be traced for long distances. Due to the discontinuous nature of the Tintah shoreline record, the paleogeographic reconstruction is based almost exclusively on extrapolated shoreline elevations from the strandline diagram.

The paleogeographic reconstructions for these two important phases of Lake Agassiz are markedly different. Much of the report area was submerged during the Lockhart Phase when the Tintah shoreline was constructed (Figure 24). A large, irregularly shaped island, nearly 40 km long, 25 km wide, and fringed by an archipelago of islands on its southern and eastern margins, occupied portions of the Northwest Bay, Arbor Vitae, and Emo NTS map sheets. Deep, open water conditions existed in the western and southeastern portions of the report area.

Tintah shorelines have been extrapolated into the Wabigoon basin of northwestern Ontario. Water levels fell from the Tintah shoreline, shortly after 11 000 years B.P., as the ice margin receded from the Eagle-Finlayson Moraine and opened low-level outlets through either the Kashabowie-Seine or the Dog River valleys west of Thunder Bay (Prest 1970; Teller and Thorleifson 1983).

During the Emerson Phase, high stand of Lake Agassiz, there was a marked increase in the amount of emergent land within the report area. The prominent, Campbell shoreline

delimits an irregularly-shaped island, the northern and eastern shores of which extend beyond the limits of the report area. The large, open water areas, which existed during the Lockhart Phase, became interspersed with islands which provided protected, quiet water environments.

Older Alluvial Deposits

Along the course of Sturgeon Creek in Shenston Township, older alluvial terraces of unknown age, have been identified several metres above the modern floodplain. The older alluvial deposits consist primarily of well stratified, pebbly sands and silts with scattered mollusc remains.

Moorhead Phase (Poplar River Formation)

The opening of low level, eastern outlets to the Upper Great Lakes has long been accepted as the mechanism for the onset of the Moorhead Phase of Lake Agassiz. It is believed that water levels dropped in a series of steps by as much as 150 m, as progressively lower outlets were uncovered with ice retreat (Teller 1985).

Recent investigations of varve records from the Wabigoon basin in northwestern Ontario have reinforced conclusions drawn from earlier observations at Steep Rock Lake (Antevs 1951) and Dryden (Rittenhouse 1934). The varve sequences fail to record a period of low water during the interval 10 000 to 11 000 years B.P. (Minning et al., in prep.). The Moorhead unconformity has been identified as

far north as the International Boundary along the Red River Valley (Arndt 1977) and to the Fort Frances-Rainy River basin in Ontario. Warman (1990) states that arguments favouring a basin-wide unconformity are speculative and based on questionable radiocarbon dates.

The Clearwater outlet in northern Saskatchewan, has been considered as an alternative for Lake Agassiz drainage (Teller and Thorleifson 1983; Warman 1990). By altering the slope of the Moorhead Phase water plane, to accommodate the Moorhead delta in North Dakota and the Clearwater outlet in Saskatchewan, a slope similar to that of the Herman shoreline, an early, Lockhart Phase water plane is produced. Within the main part of the basin, water levels would have remained at a position considerably higher than that produced by the opening of eastern outlets to the Upper Great Lakes. At the same time, subaerial conditions would have prevailed along the southern parts of the basin. Further work in the vicinity of the proposed outlet and intervening areas is necessary to confirm this hypothesis.

The Moorhead low-water Phase lasted approximately 1000 years and came to an around 10 000 years B.P. Much of the lake floor in the southern part of the Lake Agassiz basin was exposed and subjected to subaerial and shallow water processes of erosion and deposition. In North Dakota, fluvial sediments deposited during this low-water phase have been named the Poplar River Formation (Arndt 1977).

Johnston (1915) was the first to recognize the Moorhead Phase unconformity and its associated fluvial and organic remains within the Fort Frances-Rainy River area.

Radiocarbon dating of fossil mollusc shells recovered from a Moorhead Phase alluvial sequence in Woodyatt Township was used to infer an age for the close of the low-water stage and the onset of the Emerson Phase transgression (Nielsen et al. 1982). The radiocarbon date obtained at this site was unusually old ($11\ 400 \pm 410$ years B.P.) and probably suspect due to contamination by recycled, old carbon.

Many features and deposits associated with the Moorhead Phase have been identified within the report area.

Erosional surfaces, boulder lags, paleosols, channel-fills and organic remains are preserved in low-lying areas below the prominent Campbell shoreline. Most of the Moorhead-aged fossil-bearing sites were found close to the Rainy River beneath sandy and silty glaciolacustrine deposits.

A proto-Rainy River, following much the same course, and standing 7 to 10 m above the modern river, braided its way to the west on the newly exposed lake plain. Palimpsest channels have been identified and grade from an elevation of 340 m asl near Fort Frances to about 330 m asl around Pinewood beyond which they cannot be traced further. The channels probably terminated at the McCauleyville level of Lake Agassiz which stood about 7 m above the present level of Lake of the Woods. The incision of the present Rainy River channel probably occurred shortly after the Emerson

Phase and the final decline of Lake Agassiz from the report area.

Subdued channel scars with 3 to 4 m relief, and masked by younger, Emerson Phase glaciolacustrine sediments can easily be identified on aerial photographs (Photo 14). Where these channels intersect the modern course of the Rainy River, Moorhead Phase fluvial sands and gravels, with paleocurrents indicating flow to the west, are sandwiched between Emerson Phase glaciolacustrine sediments and older, glacial deposits.

Fossil molluscs are commonly encountered in the fluvial deposits. Sandy deltaic sediments, 1 to 2 m thick, were deposited over a large area northwest of the town of Rainy River, when water levels stood at the McCauleyville level. Many of these deposits contain fossil wood, fine-grained plant detritus and mollusc remains.

Radiocarbon Dated Sites and Fossil Remains

Several studies have been undertaken in northwestern Ontario and northern Minnesota to determine the deglacial chronology and the late-glacial water level and vegetational history of the Lake Agassiz basin. Many of these studies rely on the dating of gyttja, fine-grained organic detritus and shell material for their chronologies. The validity of these dates is questionable and must be tested with more reliable dating material and substantiating field evidence.

The oldest, reliable, radiocarbon date from the Lake

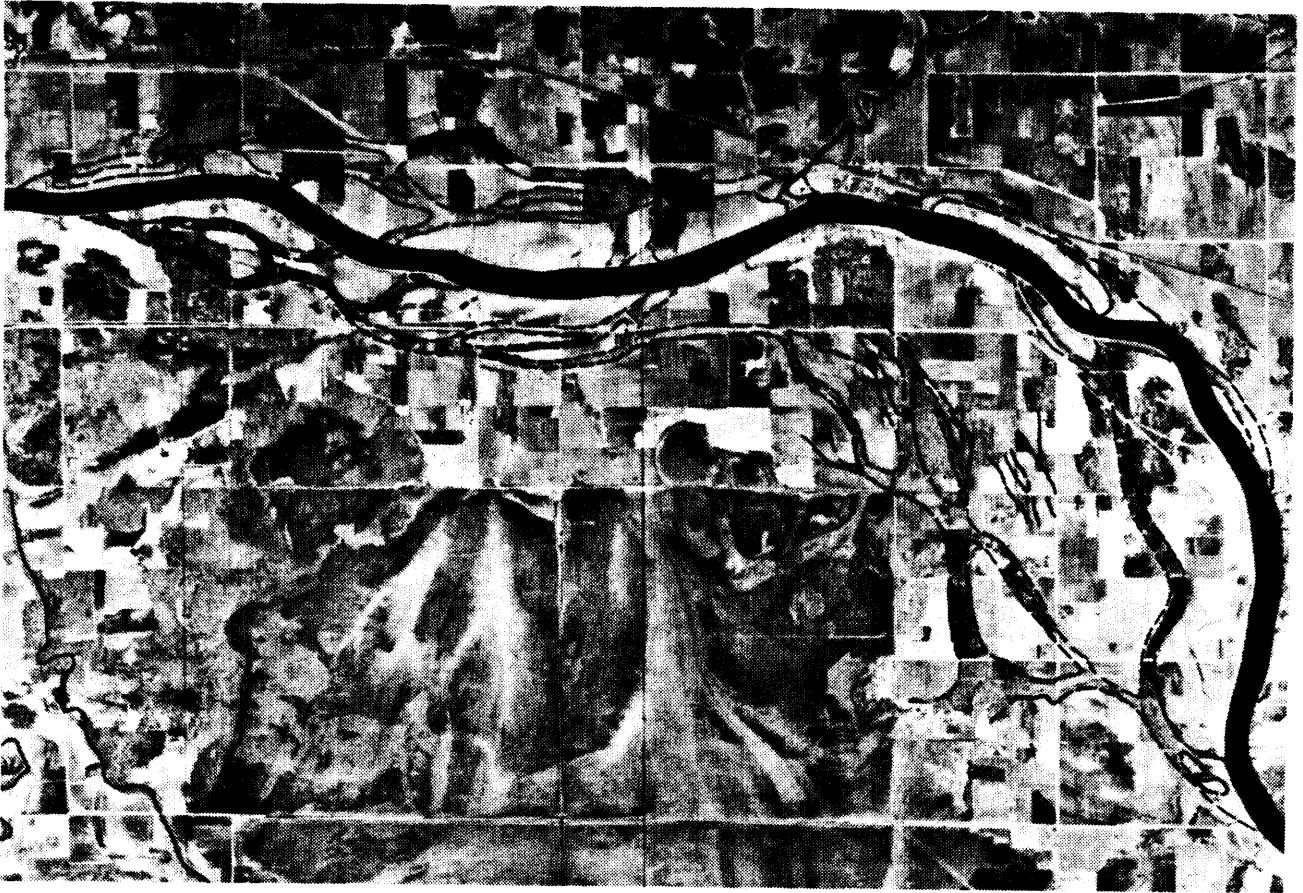


Photo 14. Palimpsest Moorhead Phase channels associated with the proto-Rainy River, Dilke Township. Note the braided nature of these channel remnants.

Agassiz basin was obtained on a sample of wood recovered from a post-Lockhart Phase beach in North Dakota (Clayton and Moran 1982). The wood was dated at $10\ 960 \pm 300$ years B.P. This date has served as a basis for defining the onset of the Moorhead low-water Phase within the Lake Agassiz basin. The preceding Lockhart Phase is not well dated. A wood date of $11\ 530 \pm 170$ years B.P. was obtained from post-glacial sediment, located just outside the Lake Agassiz basin, in north-central Iowa. This date is taken as a close approximation for the initiation of the Lockhart Phase (Kemmis et al. 1981).

The youngest dates related to the Moorhead Phase all centre around $10\ 000$ years B.P. The Emerson Phase transgression began at this time as indicated by several dates from wood in beach and offshore sediment in North Dakota, Minnesota and Manitoba (Clayton and Moran 1982). The transgression is also correlated with the Marquette Advance of Upper Michigan and Wisconsin which has been well dated at around $9\ 900$ years B.P. (Drexler et al. 1983). The youngest date obtained from Emerson Phase nearshore sediment is $9\ 200 \pm 600$ years B.P. (Wright 1972). The Nipigon Phase and final decline of Lake Agassiz from the report area probably began shortly after this point.

Radiocarbon Dates

Eight sites with dateable organic remains were discovered during the mapping program and chosen for further

study because of their clear stratigraphic associations. All of the sites are located below the Emerson Phase, Campbell shoreline which occurs at approximately 340 to 350 m asl in the southern part of the report area (Figure 23). Site descriptions are included in Appendix A.

The majority of the radiocarbon dates obtained from these fossil sites yield ages which fall within Moorhead Phase time period (11 000-10 000 years B.P.) (Table 3). Sites RR-87, RR-223 and E-1 (Figure 25) yielded Emerson Phase radiocarbon dates. The dates are taken, for the most part, as accurate, with the exception of site RR-223 (8 560±190 years B.P.). At this site, a highly humified soil layer, with finely disseminated charcoal fragments is overlain by Emerson Phase nearshore sands. The charcoal fragments, which appear to have been of Moorhead Phase age, yielded a radiocarbon age which is at least 1 500 years too young. Contamination from modern rootlets and humic acids is suspected.

The radiocarbon dates obtained from the eight sites place tight constraints on the timing of the Moorhead and Emerson Phases along the eastern margin of Lake Agassiz. Organic remains contained within Moorhead Phase fluvial and lacustrine sediments and overlain by Emerson Phase glacio-lacustrine sediments have yielded dates ranging between 10 810 and 9 920 years B.P. (Figure 26). Red clays overlying the organic-bearing horizons at Sites E-13 and E-165 mark the overflow of Glacial Lake Kaministikwia into the

Table 3. Radiocarbon dates from eight fossil sites in the Fort Frances-Rainy River area.

Site	Dates	Material Dated
E-1	9,530±140 years B.P. (WAT-1934)	wood
E-13	10,100±200 years B.P. (WAT-1689) 10,400±160 years B.P. (WAT-1749)	wood wood
E-165	10,100±180 years B.P. (WAT-1936)	charcoal
F87-33	10,080±160 years B.P. (BGS-1302) 10,810±120 years B.P. (TO-1594)	wood wood
RR-49	9,920±110 years B.P. (BGS 1305)	fine plant detritus
RR-54	10,050±180 years B.P. (WAT-1935) 10,020±120 years B.P. (BGS-1303)	wood wood
RR-87	10,500±200 years B.P. (WAT-1760) 9,750±170 years B.P. (BGS-1304)	wood wood
RR-223	8,560±190 years B.P. (BGS-1301)	charcoal

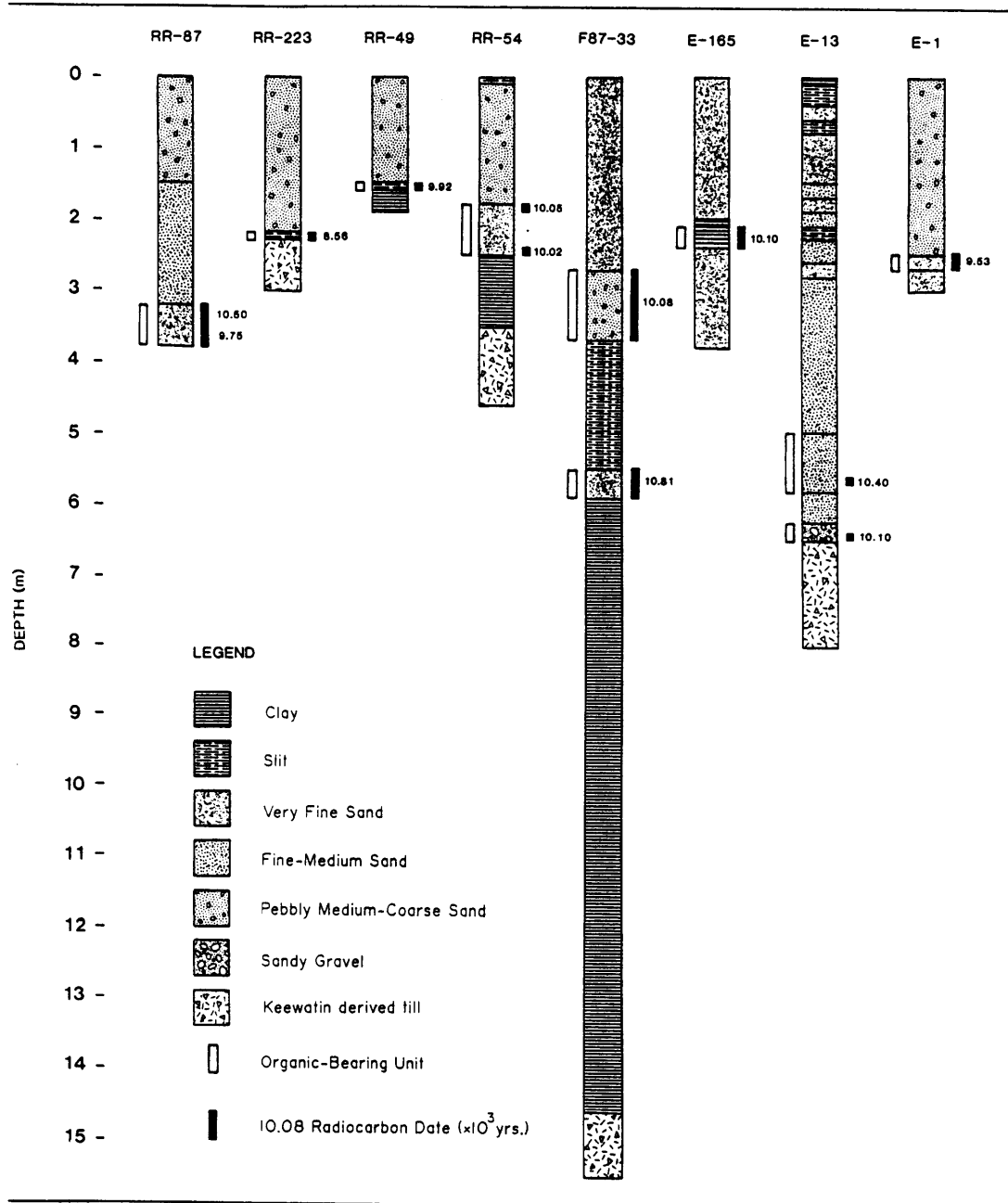


Figure 26. Simplified stratigraphic columns of radiocarbon dated sites indicating the position of the dated horizons.

Lake Agassiz basin at the start of the Emerson Phase. At both sites, the stratigraphic relationships and radiocarbon dates indicate the red clays are less than 10 100 years old, reinforcing the hypothesis that these clays represent a basin-wide time line or marker horizon.

It is difficult to place the dates obtained from site RR-87 into stratigraphic context. The wood samples were recovered from flotsam layers in nearshore sands underlying a Nipigon Phase beach/bar deposit. The nearshore sands are related to the Emerson Phase transgression as indicated by the younger radiocarbon age of 9 750 years B.P. The Nipigon Phase beach/bar deposit probably began to accumulate shortly after this time. The wood that yielded a radiocarbon date of 10 500 years B.P. was probably reworked from an older, Moorhead Phase deposit.

At site E-1, an Emerson Phase beach deposit overlies sands and silts containing wood fragments dated at 9 530±140 years B.P. This date suggests that Lake Agassiz remained at the Campbell level until at least this time.

Fossil Remains

In the Fort Frances-Rainy River area, Lockhart Phase sediments were deposited at variable water depths (i.e., 0 to 40 m) in a large proglacial lake. They have not been observed to contain macroscopic organic remains and usually contain low pollen concentrations. Moorhead Phase sediments were deposited in progressively shallower water environments

and terrestrial settings distal from large proglacial water bodies. Emerson Phase sediments represent a transgressional sequence in a large proglacial water body (i.e., water depths of 0 to 25 m). Both Moorhead and Emerson Phase sediments contain abundant macroscopic organic remains as well as high pollen concentrations. Table 4 highlights the main fossil groups which were recovered from eight sites. All of the sites were processed for plant macrofossil, pollen and mollusc remains. Only sites RR-54 and E-13 were processed for insect remains. Table 5 lists the mollusc species recovered from Sites E-13, E-165 and RR-87.

The geological setting, sedimentology and radiocarbon dates obtained from the fossil sites suggest that long-distance transport, sorting and reworking of older deposits have affected the composition of the fossil assemblages. Most of the fossils are contained within either fluvial or nearshore deposits and represent an accumulation from a wide spectrum of terrestrial and aquatic habitats brought together during high-water periods. Glaciolacustrine deposits underlying the main organic horizons often contain spruce and pine pollen at low concentrations thus providing a secondary pollen source. High proportions of Pre-Quaternary palynomorphs in the main fossiliferous zones further indicate reworking from local tills and other glacial deposits which are known to contain Cretaceous palynomorphs (Zippi and Bajc 1990).

The faunal and floral remains recovered from the eight

Table 4. Fossil groups recovered from eight radiocarbon dated sites in the Fort Frances-Rainy River area.

Site Number	Plant Macros	Pollen	Coleoptera	Molluscs
RR-54	X	X	X	
RR-49	X	X		
RR-223	X	X		
RR-87	X	X		X
F87-33	X	X		
E-165	X			X
E-13	X	X	X	X
E-1	X	X		

Table 5. Mollusc species recovered from Sites E-13, E-165 and RR-87, Fort Frances-Rainy River area.

SITE NUMBER	E-13	E-165	RR-87
FRESHWATER GASTROPODS:			
<u>Valvata sincera</u>	X	X	X
<u>Valvata tricarinata</u>	X	X	X
<u>Probythinella lacustris</u>			X
<u>Amnicola limosa</u>			X
<u>Fossaria modicella</u>			X
<u>Fossaria parva</u>		X	X
<u>Bakerilymnaea dalli</u>	X		
<u>Stagnicola elodes</u>	X		
Lymnaeidae (gen. indet.)	X	X	
<u>Gyraulus parvus</u>	X	X	X
<u>Promenetus exacuus</u>		X	
PISIDIID CLAMS:			
<u>Sphaerium striatinum</u>	X		X
<u>Musculium securis</u>	X		
<u>Musculium transversum</u>			X
<u>Pisidium casertanum</u>		X	X
<u>Pisidium compressum</u>	X		X
<u>Pisidium fallax</u>	X		X
<u>Pisidium lilljeborgi</u>		X	X
<u>Pisidium subtruncatum</u>			X
<u>Pisidium variabile</u>	X	X	X
<u>Pisidium ventricosum</u>		X	
UNIONID CLAMS:			
Unionidae (gen. indet.)	X		X
TERRESTRIAL GASTROPODS:			
<u>Catinella avara</u>	X	X	
<u>Oxyloma retusa</u>	X		

sites suggest conditions not unlike those that occur in the region today (southern boreal). The newly exposed lake floor (Moorhead Phase), following the Lockhart Phase, was wet and poorly drained for the most part, supporting a large suite of wetland types. Fens and bogs supporting stands of spruce, tamarack and fir, with diverse shrub and herb communities, were common. Shallow marshy environments with abundant vegetation and muddy substrates probably occupied the peripheral zones of lakes, ponds, streams and rivers. Submerged vegetation thrived in deeper water habitats. Pollen assemblages indicate that open forests of spruce and birch, with lesser amounts of poplar and oak, thrived on well drained soils in higher relief areas. Such forests were probably not widely distributed at the time. Birch and poplar may have been concentrated along lakeshores, on dunes or upper beach strands, where dry, sunny habitats existed (Bajc et al., in prep).

There is a distinct faunal and floral component whose modern, continuous range is much farther north or west of the study region. In this respect, the assemblages are similar to the mixed communities described from other late-glacial sites of the mid-continent. Such a composite of faunal and floral elements is to be expected within a region that was undergoing such rapid physical changes following deglaciation. The tundra-forest and western species represent relict populations associated with transitional habitats. In fact, many of these disjuncts continue to

exist throughout the Great Lakes Region today, their origins stemming from late-glacial time. Their modern distributions may simply reflect accidents of their history, persisting in special microenvironments inimical to local vegetation communities.

RECENT DEPOSITS

Peatlands and Swamps

Throughout the study area, extensive deposits of peat occupy large, low-lying tracts of land on the Lake Agassiz plain. Smaller deposits occur at higher elevations within isolated, rock-controlled basins. Peat depths in excess of 8 m have been documented in the eastern end of the map area near Fort Frances. In the western portion of the report area, peat depths diminish significantly, usually averaging less than 2 m.

Most peat growth was initiated in isolated basins following the drainage of Lake Agassiz and, later, through paludification, spread into adjacent, low-lying areas resulting in extensive deposits. Basal radiocarbon dates from peatlands in northern Minnesota as well as within the study area confirm a relatively young age, (i.e., less than 5,000 years old), for most of the deposits situated below the Campbell shoreline. The Rainy River bog, which is located 8 km north of Rainy River, has a basal age of $4\ 600 \pm 70$ years B.P (Gray 1987). In isolated basins at or above the highest levels of Lake Agassiz, there is the

potential for a continuous record of sedimentation dating back to the time of deglaciation (11,500 years B.P). No basal radiocarbon dates are currently available from these areas.

The peat resources of the report area have been studied by the Ontario Geological Survey (Northland Associates Limited 1984). Sphagnum moss was determined to be an important and commercially valuable component of these peatlands. Small scale peat harvesting operations have been undertaken throughout the report area within the last three decades but are inactive at present (Photo 15).

Along the southeast shore of Lake of the Woods, rising water levels are responsible for the erosion of peat and the transgression of nearshore sands over peatlands which fringe the modern shoreline (Photo 16). Differential uplift of the Lake of the Woods basin due to isostatic processes is responsible for a rising base level and flooding of the southern end of the basin.

Recent Alluvial, Beach, and Eolian Features

Accumulations of modern alluvium, consisting of organic-rich sand, silt, and clay are found along the floodplains of major water courses. The Pinewood, Kishkakoosis, Splitrock, and LaVallee rivers and Sturgeon, Everett, Kitchen, Frog, Crazy Jack, Log, Bremner, Christie, Stamp, and Lost creeks are the major waterways along which deposits of modern alluvium are accumulating.



Photo 15. Abandoned peat cuttings in Carpenter Township. The peatlands are trenched to lower the ground water table prior to harvesting.

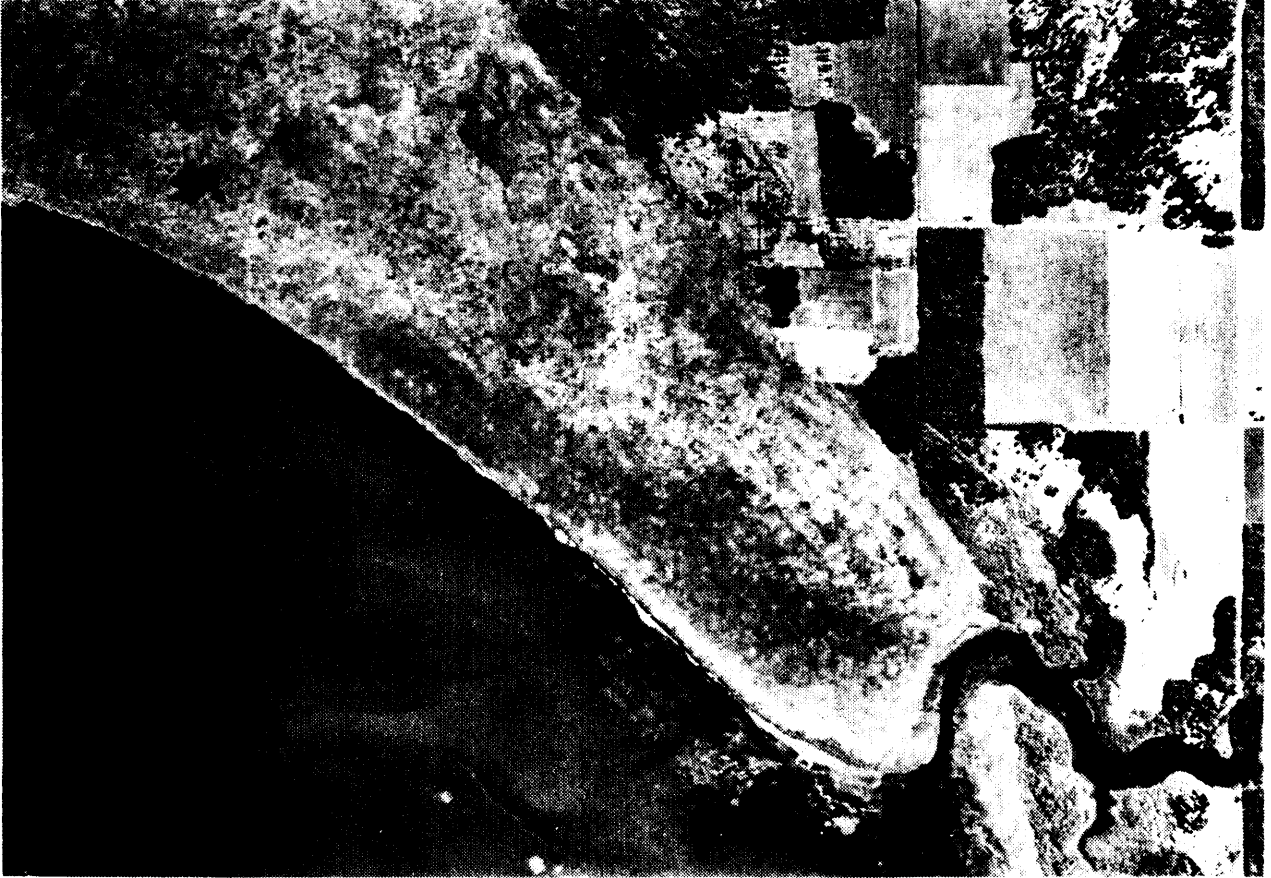


Photo 16. Transgression of nearshore sands over peat deposits along the southeast shore of Lake of the Woods, Spohn Township. Sands are visible in the lower, left hand corner of the photograph.

Large longitudinal and point bars are also present along the modern course of the Rainy River. These features are being continuously modified by erosional and depositional processes that occur during high and low water stages.

Longshore beach and bar processes and modern eolian activity operate along the southeast coast of Lake of the Woods. Large quantities of fine sand, originating at the mouth of the Rainy River, are being transported northward by longshore drift forming the Sable Islands and Windy Point. Subsequent modification by wind, has resulted in the development of large dune systems, especially along the southern end of the Sable Islands.

SUBSURFACE STRATIGRAPHY AND CORRELATIONS

Profiles of subsurface stratigraphy were constructed for four areas within the report area (Figures 14, 15 and 16, back pocket). The profiles illustrate the thickness and lateral extent of the major stratigraphic units. They have applications, including: the search for buried aggregates; environmental hydrogeology; locating buried aquifers for groundwater supply; and understanding the glacial stratigraphy for drift prospecting programs.

The stratigraphy at the western end of the report area is rather complex (Figure 14). Two Keewatin derived tills are recognized within this area. A moderately stony, silty sand till (Marchand till) overlies a stone-poor silty clay

till (Whitemouth Lake till). There is little or no intervening glaciolacustrine sediment between the tills. In some locations, either the upper or lower till is absent. The Marchand till can be traced as far east as Pinewood (i.e., up to borehole F87-20, Profile 1d). Keewatin derived tills account for 30 to 50% of the stratigraphic sequence in the western part of the report area.

Pre-Lockhart Phase glaciolacustrine sediments are thinnest in the extreme western end of the report area and thicken to the east. This is attributed to a shorter non-glacial period between glacial advances along the west end of the basin and the incorporation of large volumes of glaciolacustrine sediment for the formation of the clayey, Whitemouth Lake till.

Whiteshell till occurs in most boreholes and attains thicknesses of 26 m in places (i.e., F88-34, Profile 1b, Figure 14). The till often contains interbeds of stratified sand and gravel and tends to be less dense and more disaggregated than the Keewatin tills. Buried, Labradorean derived, glaciofluvial deposits are common in the western end of the report area. Notable occurrences have been documented in Profiles 1a, 1e and 1f (Figure 14). In Profile 1a, glaciofluvial sediments underlie Whiteshell till and attain a thickness of 32 m. A northeast-trending system of glaciofluvial sand and gravel appears to exist northeast of Rainy River (Figure 14, Profile 1f).

Interbedding of Labradorean and Keewatin derived drift occurs in boreholes F87-26 and F88-33 (Figure 14, Profiles 1e and 1b). A northwest-trending suture zone between the Labradorean and Keewatin ice sheets probably sat north of the town of Rainy River during the deposition of the Late Wisconsinan, Whiteshell (Labradorean) and Roseau (Keewatin) tills of southeastern Manitoba. Fluctuations of the suture zone resulted in the superposition of till and glaciofluvial deposits with marked differences in provenance.

A unit of Cretaceous sand and gravel with minor kaolinitic clay, nearly 21 m thick, was encountered in borehole F88-33 (Profile 1a, Figure 14). A similar outlier was intersected in a sonic borehole several kilometres southwest of Rainy River in Minnesota (D. Martin, personal communication, 1990). Outliers should be expected in other protected, low-lying areas.

Profiles 2a, 2b and 2c (Figure 15, back pocket) are located in the central part of the report area and display a stratigraphy which is somewhat variable. Profiles 2a and part of 2b are unusual in that clayey, Whitemouth Lake till is exceptionally thin or absent from most of the boreholes. Those holes located along Browns Road (F87-19 to F88-20 and F88-20 to F88-21) are situated within a protected sedimentary basin and contain thick sequences of Lockhart Phase glaciolacustrine clays with thin interbedded debris flows. A thick sequence of Keewatin derived glaciofluvial

sand was encountered in borehole F87-19 and is probably derived from an ice-marginal position not far to the west.

Rocky, irregular terrain along the eastern half of Profile 2a makes hole to hole correlations difficult. Massive, clayey, Whitemouth Lake till is present in substantial thicknesses within two of the four holes confirming the presence of grounded, active ice at this position.

Whiteshell till is present within all boreholes of Profiles 2a and 2b. This has important implications for programs of till sampling and mineral exploration as the east trending Quetico Fault, which has enhanced mineral potential, closely parallels this profile line. Whiteshell till is the preferred sampling medium for programs of drift prospecting within the report area (Bajc 1991). The uniform distribution of Whiteshell till across this area of enhanced mineral potential is desirable till sampling surveys.

In profile 2c (Figure 15), both Whitemouth Lake till and Whiteshell till are well represented. Clayey, Whitemouth Lake till is up to 12 m thick in this area. Whiteshell till is interbedded with thick sequences of glaciofluvial sand in borehole F88-10. These sands may have been deposited during minor oscillations of the retreating Labradorean glacier.

Profiles 3a, 3b, 3c and 4 (Figure 16, back pocket) are located within the eastern half of the report area and display the simplest stratigraphy. Depths to bedrock are

variable and range from 7.5 to 55.5 m. Emerson, Lockhart and Pre-Lockhart Phase glaciolacustrine silts and clays and clayey, Whitemouth Lake till form a large portion of the stratigraphic sequence. Labradorean derived deposits usually occur as thin remnants resting directly upon the bedrock surface. Thicker sequences of glaciofluvial sand and gravel have been encountered at depth in boreholes F87-05 and F87-08. Whiteshell till usually accounts for less than 5% of the stratigraphy; an important consideration for a drift prospecting program.

HISTORICAL GEOLOGY

Pre-Late Wisconsinan deposits of glacial and non-glacial origin have been identified within the report area, however, their ages have not been well established. Isolated occurrences of older, possibly weathered, Keewatin and Labradorean derived tills have been observed in sonic core and at surface exposures although not in the same stratigraphic sequence (Figure 21). These older tills are tentatively correlated with the Hawk Creek or Granite Falls tills of southwestern Minnesota. An early Wisconsinan (Napolean Glaciation) or Illinoian age (Clearwater Glaciation) is inferred for these glacial deposits (Moran et al. 1976).

Non-glacial deposits, including wood recovered from Late Wisconsinan, Whiteshell till (Figure 21), have been radiocarbon dated at greater than 47 410 years B.P. The

wood is probably of Sangamonian or Middle Wisconsinan age. Glaciolacustrine silts and clays, containing spruce pollen, underlie Whiteshell till (Figure 21) and are probably of Middle Wisconsinan age.

The Late Wisconsinan glaciation began approximately 25 000 years ago and culminated in northern Iowa about 20 000 years B.P. The ice margin began its final retreat northward, following a series of minor fluctuations, at about 14 000 years B.P. Carbonate-poor, stony, silty sand, Whiteshell till and associated glaciofluvial sediments were deposited across the report area by Labradorean ice during the retreat phase. At about the same time, the Keewatin glacier was depositing the carbonate-rich, loamy, Roseau till in southeastern Manitoba and northern Minnesota.

By about 11 700 years B.P., the Labradorean ice margin retreated to the northeastern corner of the report area. A slight pause in its retreat resulted in the formation of the Rainy Lake-Lake of the Woods Moraine. Low-lying areas vacated by the retreating ice were immediately occupied by a precursor of Glacial Lake Agassiz. Glaciolacustrine deposits, referred to as the Wylie Formation in North Dakota, were laid down at this time. Sedimentation continued within the basin for several hundred years prior to the advance of Keewatin ice from the west and the deposition of a thick sequence of calcareous, silty clay to clayey silt till, referred to as the Whitemouth Lake till in the report area and southeastern Manitoba and the Falconer

and Huot Formations in North Dakota. The Labradorean ice margin probably stood to the northeast of the Rainy Lake-Lake of the Woods Moraine during the retreat of the Keewatin glacier from the report area.

Proglacial sedimentation beyond the Keewatin ice margin was probably strongly influenced by a calving, floating ice margin. Deposits of interbedded subaquatic flow till, undermelt till and glaciolacustrine rhythmites with abundant ice-rafted debris are widespread and overlie massive till in low-lying areas. The glaciolacustrine rhythmites represent Lockhart Phase sediments of Lake Agassiz.

Retreat of the Keewatin ice margin to the northwest, into the Lake Winnipeg basin was followed by a readvance into southern Manitoba, northeastern North Dakota, northwestern Minnesota and the extreme southwestern corner of the report area. This readvance resulted in the deposition of a calcareous, moderately stony, silty sand till referred to as the Marchand till. The outer limit of this till sheet is poorly defined within the report area because of limited subsurface information. The till appears to extend as far east as Pinewood and 10 to 15 km north of the International Border.

Lockhart Phase sedimentation continued within the report area until about 11 000 years B.P. when low level outlets were opened by retreating ice. Water levels stood at the Tintah shoreline prior to the initiation of the Moorhead low-water Phase. During the Moorhead Phase,

fluvial deposits containing organic remains accumulated in low-lying areas along the southern edge of the Lake Agassiz basin. The Moorhead Phase came to a close around 10 000 years B.P. when low level outlets in either Ontario or Saskatchewan were closed by a glacial readvance or isostatic uplift.

This event marked the beginning of the Emerson Phase transgression of Lake Agassiz, a period when water levels rose to the prominent Campbell level and remained there for 500 to 800 years. Faintly laminated red clays, derived from Glacial Lake Kaministikwia in the vicinity of Thunder Bay, are well dated at around 10 000 years B.P. and form a basin-wide marker horizon in the glaciolacustrine sequence. Ice retreat into the Lake Nipigon basin opened eastern outlets to the Upper Great Lakes at approximately 9 200 years B.P. marking the final drainage of Lake Agassiz from the report area. Non-glacial processes of erosion and deposition have affected the area subsequently.

ECONOMIC GEOLOGY

Sand and Gravel

Information on the aggregate resources of townships immediately adjacent to the town of Fort Frances and of a larger region north and east of Burditt Lake are available in Aggregate Resource Inventory Papers (ARIP) 92 and 150, respectively (Ontario Geological Survey 1983, 1990).

Sand and gravel is primarily extracted for local uses in the Fort Frances-Rainy River area with greatest demands near the population centres. Labradorean derived deposits are preferred as they contain durable clast lithologies. Keewatin derived deposits contain high percentages of deleterious, soft carbonates and shales thus making them less desirable.

A buried deposit of glaciofluvial sand and gravel, locally referred to as the Armstrong sand and gravel pit, has provided large amounts of crushable gravel and blending sand for the city of Fort Frances since the early 1900's. Up to 25 m of well stratified sand with lesser amounts of gravel underlie a thick cap of clayey, Whitemouth Lake till and glaciolacustrine sediment. Although most of the coarse aggregate has been exhausted, dredging of certain areas below the water table has yielded additional reserves. The deposit is related to an ice-marginal position of the Labradorean glacier. There is potential for further discoveries of buried aggregate along ice-marginal trends. Some of these have been described in earlier sections of this report.

A constraining economic factor which must be considered in searching for and assessing buried aggregate is the thickness of the overburden which must be removed to gain access to the reserves. At the Armstrong pit, up to 8 m of clayey overburden has been stripped from the deposit.

A northeast-trending belt of isolated, buried deposits extending from Off Lake to Stratton may represent a series of subaquatic fans. These fans were built along the margin of a retreating ice sheet and were fed by subglacial drainage systems originating in the Off Lake-Burditt Lake area. The fans supply many of the smaller communities between Barwick and Sleeman with aggregate. There is potential for further discoveries along this trend.

Deposits along the trend of the Rainy Lake-Lake of the Woods Moraine account for a large proportion of the available aggregate reserves in the Fort Frances-Rainy River area. Unfortunately, these deposits are located long distances from demand areas. As reserves in the immediate vicinity of Fort Frances become depleted, demand pressures may require the exploitation of these deposits.

In the extreme western end of the report area, shoreline deposits of Glacial Lake Agassiz provide the primary aggregate supply. The deposits consist of thin accumulations (3 to 4 m) of beach and nearshore sands and gravels derived from the winnowing of Whitemouth Lake and Marchand till. The gravel component consists almost entirely of limestone, dolostone and shale making it unsuitable for a variety of applications. Deposits of beach and nearshore sands and gravels are of limited extent throughout the remaining parts of the report area.

Peat

Reports dealing with peatland evaluation and resource inventories within the report area include those of Graham and Tibbetts (1965) and the Ontario Geological Survey (Northland Associates Limited 1984). Small scale peat plants producing horticultural grade peat products have been in operation in the Emo area but are inactive at present. These include an operation northeast of Emo which was operated by Arctic Peat Moss Corporation Ltd. and another south of Crozier which was operated by Polar Bear Peat Moss Products Registered. A small scale peat operation for horticultural grade peat exists further to the west in the vicinity of Barwick. Renewed interests in the peat resources of the area has raised the possibility of expansion of the local peat industry through production of peat for fuel as well as horticultural and forestry applications.

Drift Prospecting

The field work has revealed two important factors to be considered for drift prospecting programs in the Fort Frances-Rainy River area. Firstly, it is the Labradorian derived, Whiteshell till which is the preferred sampling medium as opposed to the younger, Keewatin derived till sheets. Secondly, as thick deposits of Quaternary sediments conceal much of the underlying bedrock and the Labradorian derived till sheet, deep overburden drilling techniques,

such as sonic or reverse circulation drilling, are necessary to intersect and sample the lower till package. Shallow sampling techniques can be used in the bedrock-dominated upland within the extreme northeastern corner of the report. Whiteshell till is exposed on surface in this area. Additional information with regards to till composition and mineral exploration applications are contained within an accompanying report entitled, "Till sampling survey, Fort Frances area; results and interpretation" (Bajc 1991).

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APPENDIX A

SITE DESCRIPTIONS OF FOSSIL-BEARING DEPOSITS

Site RR-87

Site RR-87 is located in a gravel pit (Elevation: 333 m asl), approximately 13 km northwest of the town of Rainy River. Organic remains, including plant and insect macrofossils and pollen, are contained within a minimum of 0.6 m of grey, ripple laminated to massive, silty very fine sand, sandy silt, and silt. A high ground water table would not allow visual inspection of this unit in section. Samples of wood and fine detrital organic remains were recovered from spoil piles on the pit floor. Probing into the pit floor confirmed the presence of an organic-bearing unit in the subsurface. This unit is conformably overlain by 1.7 m of organically barren, well sorted, faintly rippled to massive fine to very fine sand. About 1.5 m of well sorted, horizontally bedded, open-framework, fine to medium sand and sandy gravel caps the sedimentary sequence (Nipigon Phase beach sediments). Molluscs were recovered from the lower part of this upper unit.

Site RR-223

Site RR-223 is located in a ditch along Highway 600 (Elevation: 341 m asl), approximately 8 km north of the town of Rainy River. A 1 to 3 cm thick horizon of black, highly humified, silty, organic detritus with abundant charcoal lies unconformably upon 0.7 m of well stratified, gritty, pebbly, clayey silt, fine sand, and pebbly fine-medium sand.

The upper 15 cm of this lower unit appears weathered and leached of carbonate. Modern rootlets are concentrated along its upper surface. The organic-bearing horizon is unconformably overlain by 2.2 m of well stratified pebbly, fine to very fine sand which represents a beach-nearshore environment.

Site RR-49

Site RR-49 is located in a roadside ditch on Highway 600 (Elevation: 335 m asl), approximately 4 km north of the town of Rainy River. About 0.3 m of dark grey, well laminated, gritty, silty clay and clay (Lockhart Phase) is overlain by approximately 5 cm of humified, dark brown to black silty organic detritus which contains a few small wood fragments (Moorhead Phase soil). This unit is overlain by 1.5 m of faintly bedded, pebbly gravel and fine to medium sand which forms part of an offshore bar or spit.

Site RR-54:

Site RR-54 is located within a gravel pit (Elevation: 335 m asl), approximately 2.5 km northwest of the town of Rainy River. The organic-bearing unit is up to 0.7 m thick and consists of ripple-laminated very fine sand with varying amounts of silt (Moorhead Phase fluvial sediments). Thin horizons of fine, detrital peat and woody, flotsam (3 to 5 cm thick) are interbedded with the sands and host the plant and insect macrofossils discussed in this report. Calcareous, clayey silt till (Whitemouth Lake till) is

present beneath the organic-bearing horizon. In isolated locations, an intervening unit of gritty, rhythmically laminated silt and clay separates the two units (Lockhart Phase). The organic-bearing horizon is overlain by approximately 2.5 m of open framework, horizontally bedded, sandy gravel and pea-sized gravel which forms part of a large Nipigon Phase, offshore bar complex. A thin cap of sandy silt, 10 to 20 cm thick, veneers much of this unit

Site F87-33

Site F87-33 is a sonic borehole (Elevation: 336 m asl), located on a township sideroad approximately 4 km due east of the town of Pinewood. The stratigraphy encountered, base to surface, consists of approximately 30 m of dark grey silty clay, Whitemouth Lake till overlain by 8.7 m of massive to well laminated dark bluish-grey silty clay and clayey silt with minor silt (Lockhart Phase). This unit is in turn overlain by 0.4 m of well laminated, dark bluish-grey silt and very fine sand with thin compressed laminae of fine plant detritus and small twigs (lower Moorhead Phase). This unit is overlain by 1.8 m of well laminated clayey silt to silt that appears barren of plant macrofossil remains. This unit is unconformably overlain by 1.0 m of dark, bluish-grey, pebbly coarse sand with numerous small fragments of detrital wood (Moorhead Phase fluvial sediments). This fossiliferous unit is capped by 2.7 m of

well laminated, light grey, very fine sand with minor silt and numerous carbonate concretions (Emerson Phase).

Site E-165

Site E-165 is located on a cutbank of the LaVallee River (Elevation: 341 m asl), alongside Highway 613, approximately 4 km south of the town of Devlin. A greyish-brown silty clay unit, 35 cm thick, containing molluscs and finely disseminated charcoal (Moorhead Phase pond deposit) is underlain by 1.4 m of light buff-brown, faintly laminated, grit-free, sandy silt and silty very fine sand (lower Moorhead Phase). A thin horizon (2 to 3 cm) of well laminated, light brownish-red, grit-free clay overlies the organic-bearing unit (Lake Kamistikwia clay). The red clay is overlain by approximately 2 m of well laminated, light buff-grey and brown silt and very fine sand (Emerson Phase).

Site E-13

Site E-13 is located 19 km west-southwest of Fort Frances on the banks of the Rainy River (Elevation: 338 m asl), near the mouth of the LaVallee River. The organic-bearing horizon is 1.5 m thick and consists of a fining upward, channel-fill sequence of sandy gravel to silty very fine sand (Moorhead Phase). Faunal and floral remains are concentrated primarily on ripple foresets within the upper 0.8 m of the sequence. Insect, pollen, and plant macrofossil studies were performed on samples collected from this interval. Aside from a small, water worn log recovered

from the base of the unit, the lower 0.7 m is barren of macroscopic organic remains. Approximately 2 m of interstratified calcareous clay and silty clay diamicton of glaciolacustrine origin (Lockhart Phase) is truncated by and underlies the organic-bearing unit. Five metres of horizontally bedded, planar cross-bedded, ripple-laminated, horizontally laminated, and massive fine to very fine sand conformably overlies the organic-bearing unit (Emerson Phase transgressional sediments). Only the lower 0.2 m of this sand unit contains very fine plant detritus reworked from the underlying unit. Molluscs have been recovered from the same stratigraphic horizon at other exposures in close proximity to the sampling site. Cross-beds within the sand unit indicate paleocurrents to the south. The upper 3 m of the sequence is generally finer grained and consists of ripple-laminated to massive silty very fine sand. A thin cap, a few centimetres in thickness, of red silty clay completes the sedimentary sequence (Lake Kaministikwia clays).

Site E-1

Site E-1 is located in a roadside ditch (Elevation: 352 m asl), approximately 2 km north of the town of Crozier. The organic-bearing unit consists of 20 cm of silty very fine sand and sandy silt with thin interbeds of detrital peat underlain by 30 cm of well sorted, very fine sand with finely disseminated plant detritus (Emerson Phase nearshore

sediments). Plant macrofossils and pollen were recovered from the upper 20 cm of this unit. About 2.5 m of light buff-grey, horizontally bedded, pebbly, fine-medium sand, deposited as part of an Emerson Phase nearshore/beach complex, overlies the organic-bearing horizon.

CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

Conversion from SI to Imperial			Conversion from Imperial to SI		
<i>SI Unit</i>	<i>Multiplied by</i>	<i>Gives</i>	<i>Imperial Unit</i>	<i>Multiplied by</i>	<i>Gives</i>
LENGTH					
1 mm	0.039 37	inches	1 inch	25.4	mm
1 cm	0.393 70	inches	1 inch	2.54	cm
1 m	3.280 84	feet	1 foot	0.304 8	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	1.609 344	km
AREA					
1 cm ²	0.155 0	square inches	1 square inch	6.451 6	cm ²
1 m ²	10.763 9	square feet	1 square foot	0.092 903 04	m ²
1 km ²	0.386 10	square miles	1 square mile	2.589 988	km ²
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
VOLUME					
1 cm ³	0.061 02	cubic inches	1 cubic inch	16.387 064	cm ³
1 m ³	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m ³
1 m ³	1.308 0	cubic yards	1 cubic yard	0.764 555	m ³
CAPACITY					
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	4.546 090	L
MASS					
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	31.103 476 8	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	0.453 592 37	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	907.184 74	kg
1 t	1.102 311	tons (short)	1 ton (short)	0.907 184 74	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	1016.046 908 8	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	1.016 046 908 8	t
CONCENTRATION					
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	<i>Multiplied by</i>	
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.







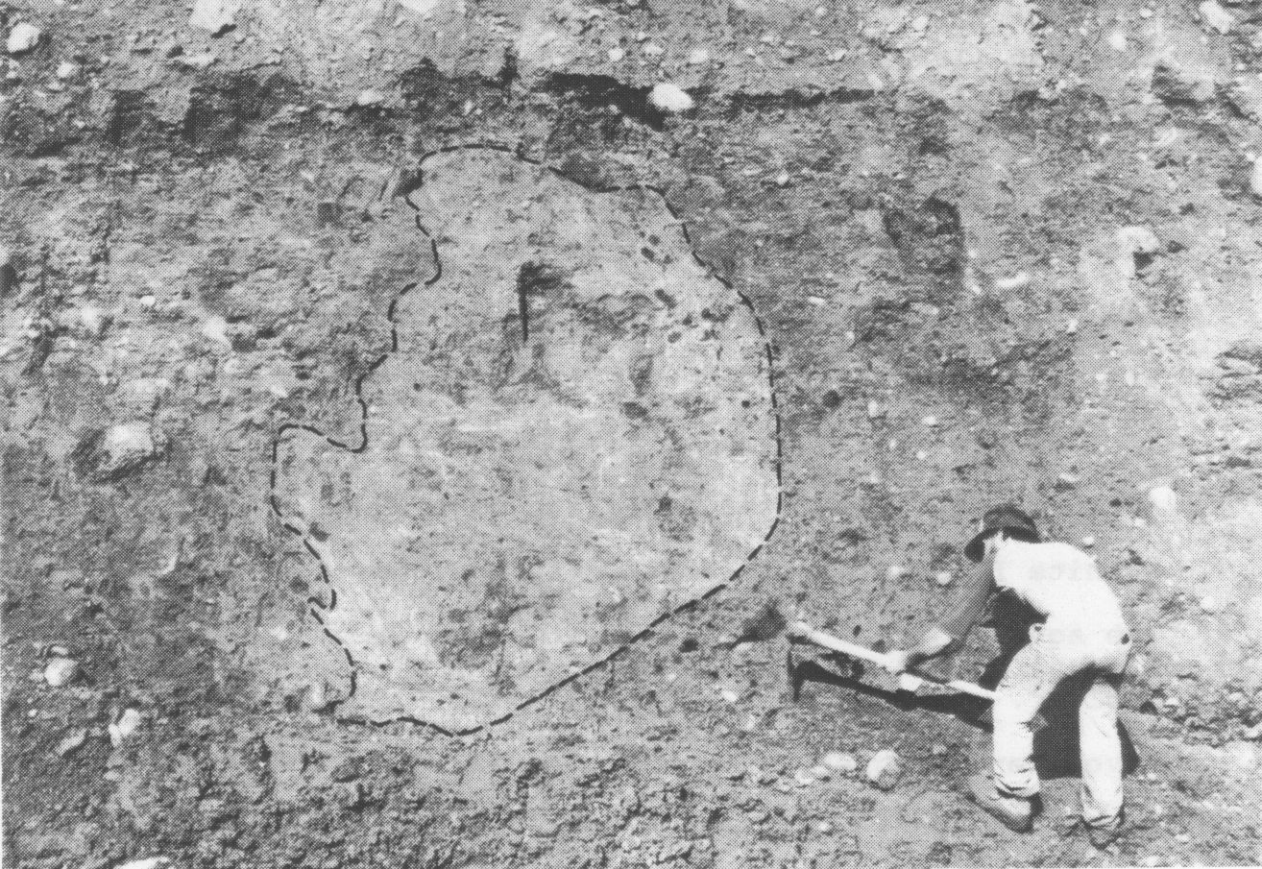












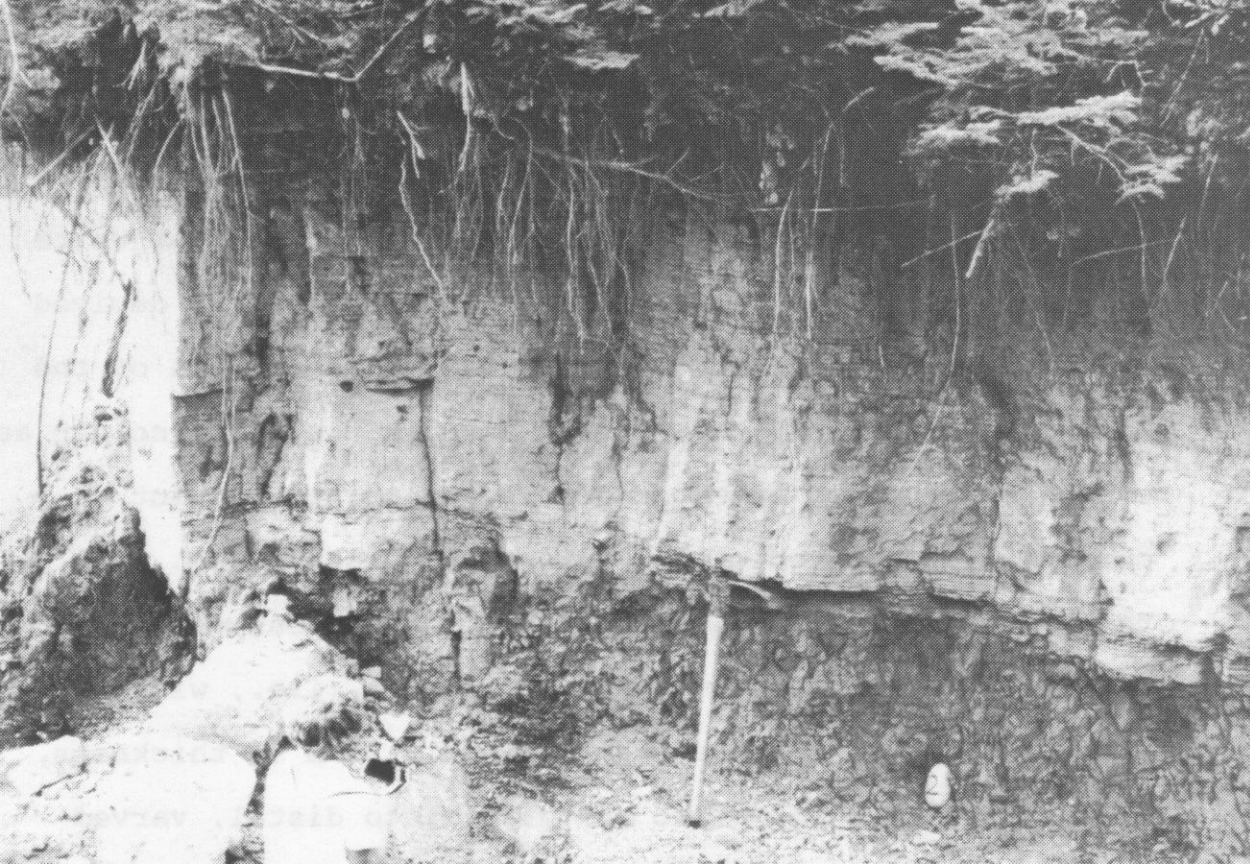
















MARGINAL NOTES

INTRODUCTION

Quaternary Geology mapping of the Rainy River area (Rainy River level, NTS 52 D/9) was completed during the Summer of 1986. The project is part of a multi-year program designed to establish a framework of Quaternary geology for future mineral exploration and aggregate-resource evaluation.

The authors were ably assisted in the field by A. Lisovsky, J. Ross and P. Cleve. Field methods involved digging test pits, hand mapping and probing and extensive available natural and man-made exposures as well as bedrock outcrops. Field work was supplemented by the interpretation of 1:15,000 scale 11 inch to 1.4 mile air photographs.

Good access to the map area is provided by a grid network of roads. Primary access is by Highways 11, 600, 621, 619 and 617 supplemented by interconnecting low-level roads, and secondary forest-access roads. The Rainy River and Lake of the Woods provide easy water access to the river basin of the map area.

Previous work on soils and surficial geology in the area includes reconnaissance surveys by Johnson (1941), Hill and Morawick (1944), and Zoltai (1961, 1963). Recently, Heller and Hill (1980) produced a geological map of the study area. The region and Northern Associates Limited (1984) undertook a general inventory of the peatlands in the Rainy River area.

The authors thank the staff of the Ontario Ministry of Natural Resources and Mines and the Ontario Geological Survey, in particular, in Fort Frances for their help and cooperation during the 1986 field season.

BEDROCK GEOLOGY

Limited outcrop within large parts of the map area has resulted in a simplified conception of the bedrock geology. The geology of the southern half of the area has been inferred largely from widely scattered outcrops in the northern half of the study area and has contributed to a better understanding of the bedrock geology.

Bedrock geology maps for the northern part of the map area are available at a scale of 1:63,360 or 1 inch to 1 mile (Blackburn, 1971). The bedrock geology of the southern part of the map area was originally documented in a compilation series at a scale of 1:25,440 or 1 inch to 0.4 miles (Heller and Fryxell, 1967) and more recently revised by Blackburn (1979).

The map area can be subdivided into two parts: a southern half formed predominantly from igneous rocks of the Western Superior Subprovince, and a northern half formed by the Sabaskong Batholith. The Sabaskong Batholith occupies the northern half and is primarily composed of felsic to intermediate intrusive rocks. Of economic interest is the impure western extension of the Quebec fault through the southern part of the map area.

QUATERNARY GEOLOGY

Two major ice-flow directions have been documented in the map area: a south-southwesterly direction of flow from the west and east-northeasterly trending ice flow. Thicknesses of glacial and non-glacial deposits are variable throughout the map area and contrasting terrain types can be defined. The northern part of the map area is characterized by a thick drift sheet, whereas the southern part contains sporadic outcrop with overburden commonly in excess of 20 m.

The Quaternary sediments observed in the map area were deposited during Late Wisconsinan and Holocene times. They are the product of two major glacial advances: the first originating from the Labradorian ice centre and the second originating from the Keweenaw ice centre. Large proglacial lakes formed the advancing and retreating ice masses within the study area and the sediments reflect the environment of deposition, whether of lacustrine sands, silts, and clays occur; the topographic lows throughout the map area and can be related to late glacial water-level fluctuations in the Lake Agassiz basin. Most peat growth was restricted to isolated basins following drainage of Lake Agassiz and, though pluvialization spread outward to adjacent low-lying areas, this peat growth required in waterlogged organic deposits averaging 1 to 3 m in thickness occurring in a central easterly trending belt.

TILL

Noncalcareous till

The oldest recognizable drift sheet is attributed to the Labradorian lobe of the Laurentide ice sheet (referred to as the Rainy Lobe) in northern Minnesota. Deposits of this till are calcareous, dense silty sand till have been observed on the steep slope of rock knolls in the extreme northeast corner of the map area. Thicker deposits of loose, stoney, stratified till and siltstone and calcareous till are present in the study area. These deposits are represented by Map Unit 3 in the study area. Felsic clasts are prominent in the matrix of the till. The till is silty and semicalcareous in the loose faces (i.e. between 81 and 86% of the pebbles are felsic and mafic intrusive rocks). This till extends outward in the subsurface as confirmed by borings from northern Minnesota. Only noncalcareous ice-contact deposits associated with the till sheet however, have been encountered beneath younger calcareous sediments in southern parts of the map area.

Calcareous till

The surface till encountered throughout most of the map area (Map Unit 4) was deposited by Keweenaw ice flowing from the west. This ice is referred to as the St. Louis Sublobe in northern Minnesota. The older limit of this drift sheet follows a north-south line in the extreme northeast corner of the map area. The Lockett Phase of Lake Agassiz, a contact level formed by the mass incorporation of lacustrine sediments resulted in the deposition of a fine-grained, calcareous, massive, gray and pebbly, silty till. The matrix varies from a sandy silt to the west to a silty clay and clayey silt to the east. Clayey, glauconitic sediments deposited progressively were incorporated into the till and are often preserved in a disordered state. This till typically exhibits a blocky fracture pattern and erodes in river cuts, ditches, and pits to form steep faces with vertical columnar joints.

A debris-rich, floating ice sheet at the edge of the melting ice front deposited interstitially only, glauconitic siltstones and subsurface flow tills. Dropstones are common in the laminated deposits. Flow till deposits seldom exceed 1 m in thickness but characteristically are about 0.3 to 0.5 m in thickness.

Peat bogs occur in the calcareous till. The peat bogs suggest a distal origin. Percentages of local and semicalcareous till (i.e. felsic, mafic and mafic felsic intrusive rocks) are 47 to 69% with a mean of 24%. The till sheet contains 47 to 60% calcareous and Silurian dolomite and Devonian limestone, with smaller amounts of Ordovician and Jurassic shales, siltstones, and sandstones and igneous rocks. These distal lithologies average 67% of the total pebble lithologies and originate from the Laurentian basin to the west. A transport distance of up to 500 km is suggested by some of these lithologies, with the presence of lignite providing a useful marker.

GLACIOLUVIAL ICE-CONTACT STRATIFIED DRIFT AND OUTWASH

Surface deposits of glacioluvial ice-contact stratified drift (Map Unit 5) and outwash (Map Unit 6) are of limited extent within the map area, being associated only with the older Labradorian ice retreat in the southern part of the map area. These deposits are locally overlain by the calcareous till. Deposits range from bouldery, poorly sorted, ice-contact stratified drift to well sorted and stratified, ice-contact stratified sand and gravel. Examples of the ice-contact stratified drift occur approximately 4 km northwest of the mouth of the Rainy River and in the south of Long Sault Rapids on the Rainy River. Buried outwash sands and gravels are present in a borrow pit along Highway 11 about 4 km west of Stratton.

Extensive deposits of noncalcareous sands and gravels have been encountered in a central borrow pit within the map area. Initially, the calcareous till was later removed by erosive processes of Lake Agassiz. These deposits are situated 2 km southwest and 2 km east of McGinnis Creek near the mouth of the Rainy River, 4 km southwest of Highway 621 and on Highway 617 in the Hamlet of North Branch.

LACUSTRINE DEPOSITS

Lacustrine deposits of sand, silt and clay (Map Unit 7) occur in the area with the laminated silt and clay being the most dominant. These deposits are consistently found below an elevation of 350 m a.s.l. and occupy the extensive lowlands along the western, northwestern and southern parts of the map area. These silts and clays were deposited during the Emerson Phase of Lake Agassiz (Campbell level), a transgressive event. These lacustrine sediments seldom exceed 2 to 3 m in thickness. The lower contact of the unit is usually sandy silt and in some cases, caps an erosional surface or unconformity which formed during the low-water Moorhead Phase of Lake Agassiz. Mollusk and vertebrate remains are commonly encountered both on the unconformable surface and within the lacustrine sediments.

BEACH AND NEARSHORE DEPOSITS

Beach and nearshore deposits of calcareous sand and gravel (Map Unit 8) associated with the Emerson and Lockett Phases of Lake Agassiz are found throughout the map area at and below the 350 m contour line. These sands and gravels are only around 2 m in thickness and were formed by a reworking of the calcareous-drift till. They are usually underlain by either glauconitic or lacustrine clay, calcareous silt, or bedrock. Beach ridges, bars, and spits, as well as erosional features such as wave-cut notches, boulder aprons, and windrowed drift mark the positions of the Agassiz beach deposits within the map area. Facies-related artifacts are occasionally found along the Campbell level shorelines within the map area and lake terraces below the shorelines.

OLDEN ALLUVIAL DEPOSITS

Faint remnants of fluvial channels, with comparative flow to the modern Rainy River appear on the aerial photographs and can be recognized in the field. Calcareous silt and gravel, medred by lacustrine silt and clay, fill in the shallow channel depressions. The channels probably formed prior to the transgression associated with the Emerson Phase and were partially infilled with lacustrine sediments. These channels are mapped on the map by terrace symbols. These deposits are mapped as older alluvium (Map Unit 9) where they outcrop and in some cases, caps an erosional surface of marginal-quality aggregate. The most significant deposits of older alluvium are located in the vicinity of the Village of Pinewood along the Rainy River, and 4 km west of the Long Sault Rapids on the Rainy River.

RECENT ALLUVIAL, BEACH, AND AEGIOLINE DEPOSITS

Accumulations of recent alluvium consisting of organic-rich sand, silt, or clay (Map Unit 10) are found predominantly along the floodplains of larger rivers. The Pinewood, Kwanakawosis, and Sault Ste. Marie are the major reaches along which deposits of recent alluvium are accumulating.

Longshore beach and bar processes and aeolian activity operate along the eastern coast of Lake of the Woods. Large quantities of fine sand occurring at the mouth of the Rainy River are being transported by longshore drift northward forming the Sable Islands, and Windy Point. Subsequently, the surface of these deposits have and are being modified by wind-swept, windward action resulting in the development of large dune systems, wind-aided action at the southern end of the Sable Islands.

PEAT AND SWAMP DEPOSITS

Extensive deposits of peat (Map Unit 11) averaging 2 to 3 m in thickness, occur in a central borrow pit within the map area. Small deposits occur in isolated topographic lows over the remaining area. Peat growth was initiated in isolated basins following drainage of Lake Agassiz and, later, spread into adjacent low-lying areas resulting in waterlogged deposits. Sphagnum moss is an important component of these peatlands, thereby augmenting the commercial value of this resource.

APPLIED QUATERNARY GEOLOGY

The field work to date has revealed two important factors to be considered for mineral exploration. Firstly, it is the lower, locally derived, noncalcareous till sheet which is the desirable resource medium as opposed to the calcareous till sheet which is found on surface throughout much of the map area. Secondly, thick deposits of Quaternary sediments conceal much of the underlying bedrock and the calcareous till sheet. Thus, deep overburden drilling is needed for mineral exploration purposes. Conventional surface exploration techniques are appropriate in areas outside of the carboniferous till zone (i.e. nonlacustrine cover).

Buried aggregate deposits of noncalcareous glacioluvial sediments are encountered beneath deposits of calcareous till and glacioluvial silt and clay, generally in the southern and eastern part of the map area. These deposits have a general east-west trend which may be related to ice-marginal positions of the Labradorian ice mass. There is potential for further discoveries of buried aggregate along these ice marginal lines. Deposits of calcareous beach and nearshore sands and gravels are consistently smaller than the buried deposits, limiting their use as a primary aggregate source.

The peat resources of the area have been studied by the Ontario Geological Survey (Northern Associates Limited, 1984). A small-scale peat deposit for horticultural peat presently exists in the vicinity of Blackwell, which occurs 13 km east of Stratton. There is potential for the expansion of the local peat industry for peat by-products and fuel, and for horticulture and forestry.

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Ministry of Northern Development and Mines
Ontario
Mines and Minerals Division
Ontario Geological Survey
MAP P.3065
Geological Series-Preliminary Map

QUATERNARY GEOLOGY
RAINY RIVER AREA
DISTRICT OF RAINY RIVER

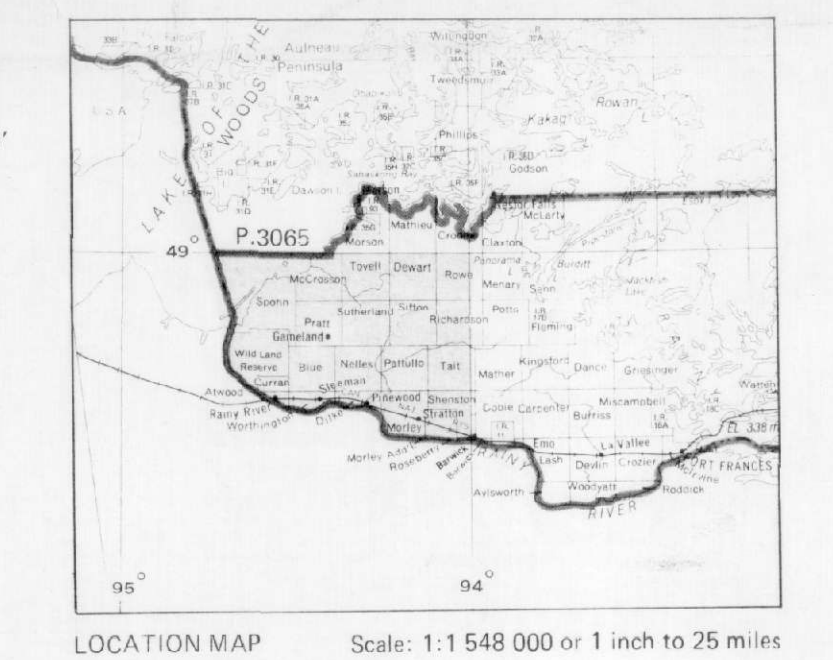
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Imperial: 1000
N.T.S. References: 52 D/9, 10, 15, 16
OGM-GSC Aeromagnetic Maps: 11742, 11793, 11820, 11850
OGS Compilation Map: 3443

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LEGEND

PHANEROZOIC
QUATERNARY
RECENT

11	Swamp and organic deposits: peat and muck
10	Modern alluvial, aeolian, and beach deposits: mainly fine sand, silt, clay, organics
9	Older alluvial deposits: mainly gravely to pebbly fine and medium sand
8	Beach, bar, and nearshore deposits
8a	Mainly sand
8b	Mainly gravel
7	Lacustrine deposits
7a	Very fine, fine, and medium sand
7b	Massive to laminated silt and clay
6	Glacioluvial outwash sand and gravel
6a	Mainly fine to medium sand
6b	Mainly sandy gravel and gravel
5	Glacioluvial ice-contact stratified drift: boulders, gravel, and sand
5a	Noncalcareous deposits originating from the Labradorian lobe
5b	Calcareous deposits originating from the Keweenaw lobe
4	Calcareous till: sandy silt to silty clay contains distally derived lithologies
4a	Subsurface to contact, massive, sandy silt to silty clay till
4b	Physically laminated glauconitic silt and clay, gritty, pebbly, silty flow till, and stratified, strongly laminated sandstone
3	Noncalcareous till: stoney, silty sand till contains local lithologies
2	Bedrock-drift complex: thin drift with numerous outcrops
2a	Mainly till cover
2b	Mainly stratified veneer
1	Bedrock knolls, ridges with very thin discontinuous drift cover



SYMBOLS

- Glacial strike, direction known
- Glacial strike, direction unknown
- Fluvial terrace
- Wave-cut notch or scarp
- Beach ridge or bar
- Small bedrock outcrop (not shown for units 1 or 2)
- Geological boundary (approximate)
- Geological boundary (assumed)
- Sand and gravel pit

SOURCES OF INFORMATION

Basemaps derived from Maps 52 D/9 (Pinewood), 52 D/10 (Rainy River), and 52 D/15 (Sable Islands) of the National Topographic System.

Aerial photography by the Ontario Ministry of Natural Resources. Contour interval 50 feet.

Magnetic declination approximately 5°4'E in 1986. Metric conversion factor 1 foot = 0.3048 m.

CREDITS

Geology by A.F. Bagg, F.A. Gray, and assistants, 1986.

Every possible effort has been made to ensure the accuracy of the information presented on this map. However, the Ontario Ministry of Natural Resources does not assume any liability for errors that may occur. Users may wish to verify critical data from other sources. Sources include both the references listed here and information on file at the Resident Geologist's Office and the Mining Geologist's Office nearest the map area.

This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary of the Economic and Development Cooperation Agreement (EDCA) signed by the governments of Canada and Ontario.

Issued 1987

Information on this publication may be quoted if credit is given. It is recommended that reference to this map be made in the following form:

Bagg, A.F. and Gray, P.A.
1987. Quaternary Geology of the Rainy River Area, District of Rainy River. Ontario Geological Survey, Map P.3065, Geological Series-Preliminary Map, scale 1:50,000. Geological Survey, 1986.

MARGINAL NOTES

INTRODUCTION

Quaternary mapping of the Emo map area (NTS 52 C/12) and the western portion of the Fort Frances map area (NTS 52 C/11) was completed during the summer of 1987. This mapping project is part of the multi-year Canada-Ontario Mineral Development Agreement program and was designed to establish a framework of Quaternary geology for mineral exploration in this area. The project was also directed at identifying areas with possible economically extractable aggregate reserves.

The authors were ably assisted in the field by J.L. McKay and J.M. Heston. Field methods consisted of digging test pits, staking out and probing, and examining available litho-made and natural exposures, as well as bedrock outcrops. Field work was supplemented by the interpretation of 1:50,000 scale 1 inch to 1.6 miles aerial photographs.

Good access to the map area is provided by a grid network of roads. Primary access is by Highways 11, 71, 613, 611 and 612. This is supplemented by interconnecting township, concession and forestry access roads. Rainy River and Rainy Lake provide easy water access to other parts of the map area.

Several investigations related to Quaternary geology have been undertaken within the map area. Earlier studies include a surficial geology and soil study within the Rainy River District (Johnston, 1915) and a reconnaissance soil survey undertaken by Hills and Morwick (1944). More recent reports related to surficial geology, terrain and aggregate resource evaluations, include those of Zolli (1961, 1962), Reed (1980) and the Ontario Geological Survey (1983). Mapping of the surficial deposits of the adjacent Rainy River area to the west was completed during the summer of 1986 and is now available as Ontario Geological Survey Preliminary Map 6043 and Grey 1987. Detailed soil studies of the area were recently conducted by the Ontario Institute of Pedology (1984). Peatland evaluation and resource investigations have been completed by Graham and Tibbatts (1965) and more recently by Northland Associates (1984). A soil survey was undertaken by the Minnesota Geological Survey in the Breckville-Indus area of Minnesota and in the vicinity of Emo during the summer of 1985. The purpose of this study was to test geochemical responses of soil, till and stream sediments in areas of known mineralization (Opkangas, Meinke and Johnson, 1977). The geological conditions in Minnesota, where most of this work was undertaken, is very similar to conditions across the Rainy River near Emo.

The authors thank the staffs of the Ontario Ministry of Natural Resources and the Ontario Ministry of Northern Development and Mines in Fort Frances for their assistance and co-operation during the 1987 field season.

BEDROCK GEOLOGY

A thick blanket of coverburden over much of the Emo area has resulted in sparse outcrop and hence a simplified interpretation of the bedrock geology. Present understanding of the geology has been inferred primarily from widely scattered outcrops, exploration drill-hole data and geological interpretations. The bedrock geology of the extreme northeastern corner of the map area, where over 85 percent of the total surface area consists of bare bedrock, is much better understood. Areas of continuous bedrock outcrop are represented by Unit 1. Smaller, isolated outcrops in areas of thick drift are shown by unit 2.

Bedrock geology mapping of the western half of the Emo area was undertaken at a scale of 1:50,000 (1 inch to 1 mile) by Fletcher and Hill (1954) and of the eastern half at a similar scale by Davies (1973).

The Emo area contains rocks of both the Quelon and Wabigoon Subprovinces of the Superior Province. The east-trending Seine River Fault traverses the extreme southern part of the map area and separates the rocks of the two provinces. The Quelon metasediments to the south of the fault consist primarily of sandstones, siltstones, argillites and derived shales. The Wabigoon Subprovince, north of the fault, can be subdivided into two distinct domains. In the western portion of the map area, the rocks consist of a suite of supracrustal rocks related to the Keweenaw intrusion. Within these major groupings, a lower unit of massive and pillowed flows is conformably overlain by a sequence of interbedded, talus-tailed debris flows, intermediate pyroclastic rocks, graywackes and reworked tuffs. These supracrustal rocks have been intruded by the Debe and Lash-Carpenter intrusions, which consist of gabbro, norite and diorite. In the eastern portion of the map area, the rocks consist primarily of felsic to intermediate intrusions of the Rainy Lake Batholith and the Devlin-Burton intrusion. Lesser amounts of classic metasedimentary rocks are present in the southeastern part of the map area.

Supracrustal rocks lying along the geographically interpreted position of the Seine River Fault have complex relationships. Supracrustal rocks in the northwest corner of the map area have a similar potential. The Debe and Lash-Carpenter intrusions were investigated for their base metal potential in the 1950s (Fletcher and Hill, 1954). These intrusions also have potential for platinum group element mineralization.

QUATERNARY GEOLOGY

Two terrain types have been identified based on drift thickness. The extreme northeastern corner of the map area contains up to 85 percent outcrop, whereas the remainder of the map area contains sporadic outcrop with coverburden thicknesses commonly in excess of 30 m, and maximum documented thicknesses of 60 m.

The Quaternary sediments observed in the map area were deposited during Late Wisconsinan and Holocene times. The glacial deposits are the products of two major advances that affected the study area. An early advance from the northwest, originating from the Labradorian ice centre, is crossed by a later advance from the west, originating from the Keweenaw ice centre. Large proglacial lakes formed the advancing and receding ice masses within the map area, the resulting sediment fans reflect this depositional environment. Late glacial water level fluctuations occurred in the Lake Agassiz basin in response to the opening and closing of a dammed outlet in the vicinity of Lake Nipigon to the northeast. A veneer of glaciolacustrine sands, silts and clays occupy topographic lows and can be related to these water level fluctuations. In early Holocene time, following the drainage of Lake Agassiz, peat bogs were initiated in low lying areas and, through paludification, spread outward into adjacent low lying areas. Peatland initiation is an important aspect of the surficial deposits of the Emo area.

BEDROCK DRIFT UNIT

Areas containing thin, discontinuous drift, with sporadic outcrop, are designated as Unit 1. Areas containing thick, continuous drift, with sporadic outcrop, are designated as Unit 2. The thickness of the drift is variable in thickness and tends to be concentrated in bedrock troughs or depressions transverse to ice flow. Only one surface exposure was discovered where this older till is present beneath younger sediments of the recent advance. This anomalous occurrence was documented in a high way exposure on the north side of Highway 11, 1.5 km east of the Rainy River Golf Club. In this case, northeast-trending striae from the older advance are preserved on the bedrock surface. Generally, till of this early advance is buried beneath the recent advance, and over much of the remaining map area. This is confirmed by borehole information.

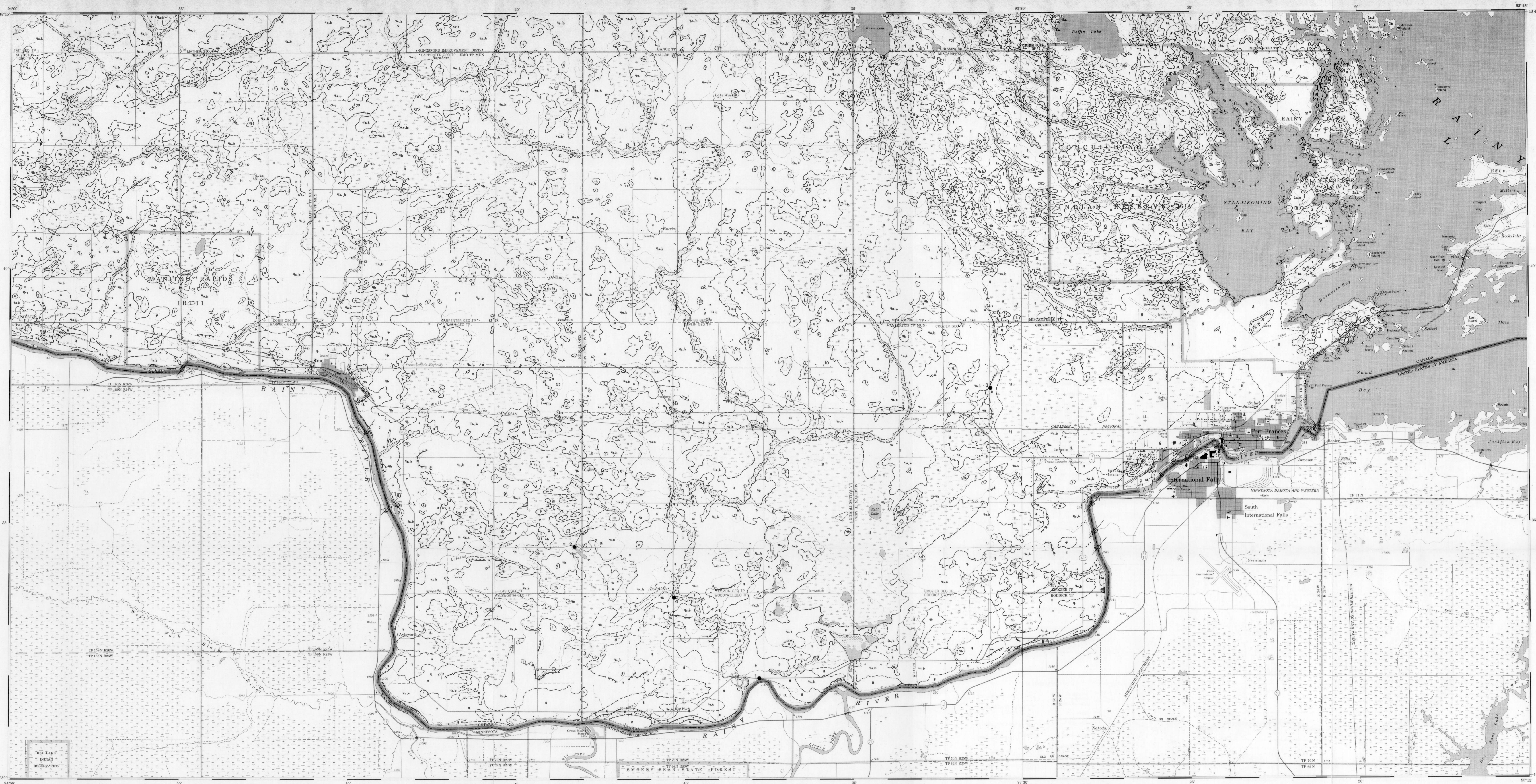
TILL

The oldest till sheet documented in the Emo area is attributed to an ice advance originating from the northeast (Labradorian sector of the Laurentide ice sheet). Till of this age is exposed on the surface only in the extreme northeastern corner of the map area (unit 3). The thickness of the till is variable in thickness and tends to be concentrated in bedrock troughs or depressions transverse to ice flow. Only one surface exposure was discovered where this older till is present beneath younger sediments of the recent advance. This anomalous occurrence was documented in a high way exposure on the north side of Highway 11, 1.5 km east of the Rainy River Golf Club. In this case, northeast-trending striae from the older advance are preserved on the bedrock surface. Generally, till of this early advance is buried beneath the recent advance, and over much of the remaining map area. This is confirmed by borehole information.

Exposure of this oldest till in the northeastern corner of the map area is poor. Till properties have been diagnosed primarily from thin, bedrock exposures. At these shallow depths, the till is extremely oxidized and weathered. It contains a high percentage of carbonate. Total carbonate values are usually in the range of 2 to 5 percent, however, values as high as 10 percent have been documented. Calcite to dolomite ratios are less than 1.0 and are extremely variable. Total carbonate values are generally variable and are best explained in terms of local facies variability of the till. The till is variable in thickness and tends to be concentrated in bedrock troughs or depressions transverse to ice flow. Only one surface exposure was discovered where this older till is present beneath younger sediments of the recent advance. This anomalous occurrence was documented in a high way exposure on the north side of Highway 11, 1.5 km east of the Rainy River Golf Club. In this case, northeast-trending striae from the older advance are preserved on the bedrock surface. Generally, till of this early advance is buried beneath the recent advance, and over much of the remaining map area. This is confirmed by borehole information.

Pre-Lockhart Phase glaciolacustrine sediments of Lake Agassiz are poor. Till properties have been diagnosed primarily from thin, bedrock exposures. At these shallow depths, the till is extremely oxidized and weathered. It contains a high percentage of carbonate. Total carbonate values are usually in the range of 2 to 5 percent, however, values as high as 10 percent have been documented. Calcite to dolomite ratios are less than 1.0 and are extremely variable. Total carbonate values are generally variable and are best explained in terms of local facies variability of the till. The till is variable in thickness and tends to be concentrated in bedrock troughs or depressions transverse to ice flow. Only one surface exposure was discovered where this older till is present beneath younger sediments of the recent advance. This anomalous occurrence was documented in a high way exposure on the north side of Highway 11, 1.5 km east of the Rainy River Golf Club. In this case, northeast-trending striae from the older advance are preserved on the bedrock surface. Generally, till of this early advance is buried beneath the recent advance, and over much of the remaining map area. This is confirmed by borehole information.

Continuously overlying this, in localized depressions, is a light brown, subventilating, gritty and pebbly, silt till which is in-



Ministry of Northern Development and Mines Ontario Geological Survey MAP P.3137 QUATERNARY GEOLOGY EMO AREA Scale 1:50 000 NTS Reference: 52 C/11, 12 Queen's Printer for Ontario, 1990 This map is published with the permission of V.G. Mine, Director, Ontario Geological Survey

CANADA ONTARIO The project is part of the five-year Canada-Ontario 1985 Mineral Development Agreement (CMDA), a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario. LOCATION MAP

- LEGEND Modern alluvium: fine sand, silt, clay and organics 11 Swamp and organic deposits: peat and muck 10 Older alluvium: Gravely to pebbly fine and medium sand 9 Beach, bar and nearshore deposits: sand and gravel 8a mainly sand 8b mainly gravel 8 Glaciolacustrine coarse-grained deposits: fine to very fine sand, minor silt and clay 7 Glaciolacustrine fine-grained deposits: silt and clay, minor sand 6 Glaciolacustrine outwash: sand and gravel 6a fine to medium sand 6b sandy gravel and gravel 5 Glaciolacustrine ice-contact stratified drift: sand, gravel and boulders 5a noncalcareous deposits originating from a Labradorian ice source 5b calcareous deposits originating from a Keweenaw ice source 4 Till: clay-poor to clayey silt to clayey silt till containing locally-derived rock types and high mass carbonate (Keweenaw-derived) 4a subcompact to compact, massive silty clay to clayey silt till 4b substratified, gritty, pebbly, silt till with interbedded glaciolacustrine silt and clay 3 Till: silty sand to sandy silt and low carbonate (Labradorian-derived) 2 Bedrock-drift complex: thin drift with numerous outcrops 2a mainly till cover 2b mainly stratified veneer 1 Bedrock with less than 1 m drift cover

SYMBOLS Geological boundary (approximate) Beach ridge or bar Small bedrock outcrop (best) Sand and gravel pit Glacial striae Ice-contact slope Crossing glacial striae (old) and broken symbol Rock quarry Landslide scar Wave-cut notch or bluff Dated fossil locality Redaction dates reported with a 2 sign are:

SOURCES OF INFORMATION Base maps derived from maps 52 C/12 (Emo) and 52 C/11 (Fort Frances) of the National Topographic System, contour interval 50 feet, scale 1:500 000. Aerial photography by the Ontario Ministry of Natural Resources, Toronto and National Air Photo Library, Ottawa. Magnetic declination approximately 5° 55' in 1978. Geology not tied to surveyed lines. CREDITS Geology by F. Bajc, T.N. White and assistants. 1987. Every possible effort has been made to ensure the accuracy of the information presented on this map; however, the Ontario Ministry of Northern Development and Mines does not assume any liability for errors that may occur. Users may wish to verify critical information. Issued 1980. Information on this publication may be quoted if credit is given. It is recommended that reference to this map be made in the following form: Bajc, A.F. and White, T.N. 1990. Quaternary Geology, Emo area, Ontario Geological Survey, Map P.3137, scale 1:500 000.

A thick blanket of coverburden over much of the Emo area has resulted in sparse outcrop and hence a simplified interpretation of the bedrock geology. Present understanding of the geology has been inferred primarily from widely scattered outcrops, exploration drill-hole data and geological interpretations. The bedrock geology of the extreme northeastern corner of the map area, where over 85 percent of the total surface area consists of bare bedrock, is much better understood. Areas of continuous bedrock outcrop are represented by Unit 1. Smaller, isolated outcrops in areas of thick drift are shown by unit 2.

The Quaternary sediments observed in the map area were deposited during Late Wisconsinan and Holocene times. The glacial deposits are the products of two major advances that affected the study area. An early advance from the northwest, originating from the Labradorian ice centre, is crossed by a later advance from the west, originating from the Keweenaw ice centre. Large proglacial lakes formed the advancing and receding ice masses within the map area, the resulting sediment fans reflect this depositional environment. Late glacial water level fluctuations occurred in the Lake Agassiz basin in response to the opening and closing of a dammed outlet in the vicinity of Lake Nipigon to the northeast. A veneer of glaciolacustrine sands, silts and clays occupy topographic lows and can be related to these water level fluctuations. In early Holocene time, following the drainage of Lake Agassiz, peat bogs were initiated in low lying areas and, through paludification, spread outward into adjacent low lying areas. Peatland initiation is an important aspect of the surficial deposits of the Emo area.

Areas containing thin, discontinuous drift, with sporadic outcrop, are designated as Unit 1. Areas containing thick, continuous drift, with sporadic outcrop, are designated as Unit 2. The thickness of the drift is variable in thickness and tends to be concentrated in bedrock troughs or depressions transverse to ice flow. Only one surface exposure was discovered where this older till is present beneath younger sediments of the recent advance. This anomalous occurrence was documented in a high way exposure on the north side of Highway 11, 1.5 km east of the Rainy River Golf Club. In this case, northeast-trending striae from the older advance are preserved on the bedrock surface. Generally, till of this early advance is buried beneath the recent advance, and over much of the remaining map area. This is confirmed by borehole information.

Exposure of this oldest till in the northeastern corner of the map area is poor. Till properties have been diagnosed primarily from thin, bedrock exposures. At these shallow depths, the till is extremely oxidized and weathered. It contains a high percentage of carbonate. Total carbonate values are usually in the range of 2 to 5 percent, however, values as high as 10 percent have been documented. Calcite to dolomite ratios are less than 1.0 and are extremely variable. Total carbonate values are generally variable and are best explained in terms of local facies variability of the till. The till is variable in thickness and tends to be concentrated in bedrock troughs or depressions transverse to ice flow. Only one surface exposure was discovered where this older till is present beneath younger sediments of the recent advance. This anomalous occurrence was documented in a high way exposure on the north side of Highway 11, 1.5 km east of the Rainy River Golf Club. In this case, northeast-trending striae from the older advance are preserved on the bedrock surface. Generally, till of this early advance is buried beneath the recent advance, and over much of the remaining map area. This is confirmed by borehole information.

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MARGINAL NOTES

INTRODUCTION

Quaternary mapping of the Northwest Bay map area (NTS 52 C/13) and the southwestern corner of the Mainville Lake map area (NTS 52 C/14) was completed during the summer of 1987. The mapping project is part of the multi-year Canada-Ontario Mineral Development Agreement program and was designed to provide a framework of Quaternary geology for mineral exploration in this area. It was also an aim of the work to outline areas with economically extractable aggregate resources.

The authors were ably assisted in the field by J.L. McKay and J.M. Halstead. Field methods consisted of digging test pits, hand augering, probing and excavating available man-made and natural exposures as well as bedrock outcrops. Field work was supplemented by the interpretation of 1:15 000 scale (11 sheets) and 1:63 000 scale (1 sheet) 1 mile aerial photographs.

Good access in the map area is provided by a grid network of roads in the southwest corner, and intersecting forestry roads and water bodies in the central and northeastern portions of the map area. Primary road access is by highways 71, 500, 915 and 913. This is supplemented by secondary township and concession roads, as well as maintenance and construction roads in most of the remaining area. Primary water access is by Beadles Lake, Panorama Lake, Off Lake, Burditt Lake, Offertau Lake, Albert Lake, West Jordan Lake, Jackson Lake, Footprint Lake, Lake Despar and Rainy Lake.

Several investigations within the map area. Earlier studies include a surficial geology and soil study within the Rainy River District by Johnston (1915) and a reconnaissance soil survey undertaken by Hele and Morwick (1944). More recent reports related to surficial geology, engineering and terrain evaluation include those of Zolva (1961, 1962) and Reid (1966). Mapping of the surficial deposits has been completed for the adjacent Rainy River area to the west (Bajo and Gray, 1987) and the Emo area to the south (Bajo and White, 1989). Detailed surficial geology mapping was recently conducted by the Ontario Institute of Pedology (1984). Peatland evaluation and terrain inventories have been completed by Graham and Tibbets (1985) and more recently by Northern Associates (1986).

The authors thank the staff of the Ontario Ministry of Natural Resources and the Ontario Ministry of Northern Development and Mines in Fort Frances for their assistance and co-operation during the 1987 field season. The authors also thank the Naaschtewewin Band of Rainy Lake Indian Reserve 17A and 17B, as well as all private land owners in the map area for allowing access onto property.

BEDROCK GEOLOGY

A simplified understanding of the bedrock geology of the southwestern quadrant of the Northwest Bay area is provided by the known and discontinuous cover of Overburden. Present understanding of the geology here has been inferred primarily from widely scattered outcrops, geological interpretations and exploration boreholes. The bedrock geology of the remaining quadrants, where overburden thicknesses are limited, are only locally attainable. The thickness is much better understood. Areas of continuous bedrock outcrop are represented by unit 1. Smaller isolated outcrops in areas of thick drift are indicated by unit 2.

Bedrock mapping of the northern half of the map area was undertaken at a scale of 1:52 300 (1 sheet) by Blackwood (1976). Mapping of the southeastern and southwestern quadrants was undertaken at a similar scale by Davies (1979) and Fletcher and Ivins (1954), respectively.

The Northwest Bay map area contains rocks of the Wabigoon Supergroup of the Slave Province. The Slave Supergroup is divided into two contrasting domains. The western half of the map area contains a relatively thinning succession of metavolcanic rocks; an extension of the Kibikog River and Manitow lakes granitoid belts to the northwest. To the north, these supracrustal rocks consist of a lower, more mafic, mafic gneiss, commonly locally overlain by layered lavas with minor pyroclastics, overlain to the east by an upper sequence of mafic gneiss and mafic gneiss. The mafic gneiss and mafic gneiss are mafic to mafic-mafic rocks consisting of thin massive and pillowed lavas. A narrow unit of mafic metavolcanic rocks borders the belt on its extreme eastern flank.

The southwestern corner of the map area consists primarily of mafic metavolcanic rocks, siltstones, argillites and derived schists (Blackwood 1976, 1979).

The supracrustal belt has been intruded by, and is bordered to the northeast and east by, felsic to intermediate plutonic rocks of the Sabakong Batholith and the Rainy Lake Batholith Complex, respectively.

Supracrustal rocks lying along the Quetico and the Northwest Bay faults and on numerous north-south trending shear zones in the Off Lake, Burditt Lake area, have produced extensive mineralization. Gold and copper mineralization is the focus of exploration in the Off Lake-Burditt Lake greenstone belt (Blackwood 1976).

QUATERNARY GEOLOGY

Two contrasting terrain types have been identified in the map area based on drift thickness and surface geomorphology. The southwestern quadrant of the map area is typically a gently undulating till plain with sporadic bedrock outcrops (i.e., 5% till) of common with the area, masking the irregular bedrock topography. The remaining quadrants of the map area contain abundant outcrop (i.e., 75 to 80% of the total surface area) with the surface geomorphology controlled primarily by the rugged bedrock topography. Locally, peaks of drift may exceed several tens of metres in thickness, but such deposits are discontinuous.

The Quaternary sediments observed in the map area were deposited during Late Wisconsinan and Holocene times. The deposits are the products of two major glacial advances. The first was the Keweenaw ice advance, which is dated by a radiocarbon date to the west. Stratigraphic data support the latter advance to be minimal. This is attributed to a thin, lobate ice sheet that advanced into a rock of stratigraphic rock types at the base of the glacier. Evidence of this westerly advance is based primarily on the compositional nature of the sediments. Further to the northeast, in the vicinity of Off Lake, just beyond the limits of stratigraphically deposited western-derived till, stratified drifts and ice proximal glacial-lake sediments (western-derived till) are present. The latter till is composed of a variety of glaciolacustrine sand, silt and clay occupies topographic lows and can be traced to these basins.

An early Holocene time, following the drainage of Lake Agassiz, peat bogs developed, approximately 1 m, in level of approximately 10 m. The peat spread outward into adjacent low-lying areas. Basins situated in areas unaffected by glaciolacustrine processes of Lake Agassiz were available for the deposition of organic sedimentation immediately following deglaciation. Peatlands now constitute an important aspect of the surficial geology of the Northwest Bay map area.

BEDROCK-DRIFF UNIT

Large areas within this discontinuous drift, with sporadic outcrop (unit 2) have been identified in the Northwest Bay map area. This map unit is confined primarily to the northwest, northeast and southeast quadrants of the map area. It is predominantly composed of the basal sector of bedrock outcrop. Locally, the drift may exceed several tens of metres within this map unit, however, the physiographic expression of the mapped unit is largely controlled by the bedrock topography of the area. The unit is composed of a variety of till veneers are mapped as unit 2, whereas areas containing a veneer of fine-grained glaciolacustrine or glaciolacustrine drift are mapped as unit 2b.

TILL

Weathered Northwestern-derived Till
In this report of the surficial geology and soils of the Rainy River District, Johnston (1915) refers to an occurrence of local, calcareous drift in the northwest corner of the map area. This drift is composed of a variety of till veneers and gravel containing numerous ironstone pebbles rests on bedrock overlying by 10 to 3 m of a bouldery deposit that is generally fine to medium grained and is apparently associated with a low level of ice source.

A strongly detrital inclusion of leached, stone-poor silt till was found in a narrow, 2 m deep trench excavation, approximately 3.5 km southwest of Pinewood Lake. The till had abundant rounded, calcareous clasts, and was completely encased by a stony, silty sand till. The detrital matrix contained rounded, calcareous clasts. This exposure may represent the same stratigraphic sequence as that reported by Johnston (1915). The till was probably introduced as a boulder block into its circular shape and quickly reworked by passive methods to its present form. The weathered till is probably of northern or Early Wisconsinan age.

Northeastern-derived Till

The oldest, widely distributed till sheet (unit 1) documented in the Northwest Bay area is attributed to an ice advance originating from the northeast. This till is generally subangular in shape and have been strongly affected by glacial abrasion. Pebble counts reveal predominantly local rock types in the detrital matrix and local glaciolacustrine or glaciolacustrine sand and clay. This advance is exposed on the surface in the northern and eastern sectors of the map area. In these areas, the till is variable in



thickness and tends to be concentrated in bedrock troughs or depressions (Ivins and White 1989) as well as in northern Minnesota and southern Manitoba where it is referred to as the Rainy Lake Till and the Whitehill Formation, respectively (Wright 1972; Miller and Fenton 1986).

Zolva (1961) reported the occurrence of a noncalcareous, fine-grained till around Shaw Narrows and along the eastern shore of Lake of the Woods which he attributed to a readvance of the Laurentian glacial to the Rainy Lake-Lake of the Woods Moraine, a feature which traverses the northeastern corner of the map area. This till is stone-poor, noncalcareous and is always found in local depressions within the map area. It appears that the fine-grained till of this till is primarily composed of two northeastern-derived tills in juxtaposition within the map area. It appears that the fine-grained till of this till is primarily composed of two northeastern-derived tills in juxtaposition within the map area. It appears that the fine-grained till of this till is primarily composed of two northeastern-derived tills in juxtaposition within the map area.

Western-derived Till
The surface till encountered over most of the southwestern quadrant of the map area (unit 4) was deposited by ice flowing from the west and possibly the southwest (Keweenaw sector of the Laurentian ice sheet, also referred to as the St. Louis Sublobe of the Des Moines Lobe in northern Minnesota). The outer limit of this drift follows a north-south trend in the southwestern corner of the map area. The till is generally subangular in shape and have been strongly affected by glacial abrasion. Pebble counts reveal predominantly local rock types in the detrital matrix and local glaciolacustrine or glaciolacustrine sand and clay. This advance is exposed on the surface in the northern and eastern sectors of the map area. In these areas, the till is variable in

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Zolva (1961) reported the occurrence of a noncalcareous, fine-grained till around Shaw Narrows and along the eastern shore of Lake of the Woods which he attributed to a readvance of the Laurentian glacial to the Rainy Lake-Lake of the Woods Moraine, a feature which traverses the northeastern corner of the map area. This till is stone-poor, noncalcareous and is always found in local depressions within the map area. It appears that the fine-grained till of this till is primarily composed of two northeastern-derived tills in juxtaposition within the map area. It appears that the fine-grained till of this till is primarily composed of two northeastern-derived tills in juxtaposition within the map area.

Western-derived Till
The surface till encountered over most of the southwestern quadrant of the map area (unit 4) was deposited by ice flowing from the west and possibly the southwest (Keweenaw sector of the Laurentian ice sheet, also referred to as the St. Louis Sublobe of the Des Moines Lobe in northern Minnesota). The outer limit of this drift follows a north-south trend in the southwestern corner of the map area. The till is generally subangular in shape and have been strongly affected by glacial abrasion. Pebble counts reveal predominantly local rock types in the detrital matrix and local glaciolacustrine or glaciolacustrine sand and clay. This advance is exposed on the surface in the northern and eastern sectors of the map area. In these areas, the till is variable in

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Ministry of Northern Development and Mines
Ontario Geological Survey
Mines and Minerals Division
Ontario Geological Survey
MAP P.3138
QUATERNARY GEOLOGY
NORTHWEST BAY AREA
Scale 1:50 000
NTS Reference: 52 C/13, 14
Queen's Printer for Ontario, 1990.
This map is published with the permission of V.G. Maw, Director, Ontario Geological Survey.

CANADA
Ontario
This project is part of the five-year Canada-Ontario Mineral Development Agreement, a multi-year agreement to the Economic and Regional Development of Ontario, signed by the governments of Canada and Ontario.

LEGEND

12	Modern alluvium:	fine sand, silt, clay and organics
11	Swamp and organic deposits:	peat and muck
10	Older alluvium:	gravelly to pebbly fine and medium sand
9	Beach, bar and nearshore deposits:	sand and gravel
8a	mainly sand	
8b	mainly gravel	
8	Glaciolacustrine coarse-grained deposits:	fine to very fine sand, minor silt and clay
7	Glaciolacustrine fine-grained deposits:	silt and clay, minor sand
6	Glaciolacustrine:	sand and gravel
6a	fine to medium sand	
6b	sandy gravel	
5	Glaciolacustrine ice-contact stratified drift:	sand, gravel and boulders
5a	noncalcareous deposits originating from a Labrador ice source	
5b	calcareous deposits originating from a Keweenaw ice source	
4	Till:	clayey silt to clayey silt till containing locally isolated rock types and high matrix carbonate (Keweenaw-derived)
4a	subcompact to compact, massive silty silt to clayey silt	
4b	subsilty, gritty, pebbly silt till with interbedded glaciolacustrine silt and clay	
3	Till:	very fine sand to sandy silt till containing local and semi-local rock types and low matrix carbonate (Laurentian-derived)
2	Bedrock drift complex:	thin drift with numerous outcrops
2a	mainly till cover	
2b	mainly stratified veneer	
1	Bedrock with less than 1 m drift cover	

UNITS

1	Units were mapped to a depth of 1 m
2	Not present or present in small patches, see OGS map P.3137, Quaternary Geology of the Emo Area.

SYMBOLS

	Beach ridge or bar
	Moraine ridge
	Ice-contact slope
	Small bedrock outcrop
	Sand and gravel pit

SOURCES OF INFORMATION

Base maps derived from Maps 52 C/13 (Northwest Bay) and 52 C/14 (Mainville Lake) of the National Topographic System. Contour interval 50 metres.

Aerial photography by the Ontario Ministry of Natural Resources, Toronto and National Air Photo Library, Ottawa.

Magnetic declination approximately 5°54' in 1978.

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