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GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

MEMOIR 350

GEOLOGY OF THE SOUTHEASTERN BARREN GROUNDS, PARTS OF THE DISTRICTS OF MACKENZIE AND KEEWATIN

(Operations Keewatin, Baker, Thelon)

G. M. Wright

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PLATE I. Caribou near Maguse River, July 1952. Note flat country and perfect visibility from aircraft.

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By
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ENERGY, MINES AND RESOURCES
CANADA

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PREFACE

The barren grounds of the Districts of Keewatin and Mackenzie, between Hudson Bay and Great Slave Lake, have always presented a challenge for field geological studies. Remoteness from bases, lack of internal settlements, facilities, communication and transportation networks, and short field seasons have combined to delay systematic study of the region.

In 1952, an experiment was undertaken using light helicopters in large self-contained parties for geological studies in southern District of Keewatin, northwest of Churchill, Manitoba. Operation Keewatin was so successful that it set a pattern that has been followed ever since. Keewatin and two more similar operations—Baker (1954) in central District of Keewatin and Thelon (1955) in eastern District of Mackenzie—form the basis of this report.

The light helicopters, supported by fixed-wing aircraft, were used to traverse systematically treeless terrain of low relief, and their use resulted in greatly increasing the efficiency of field geologists at very reasonable costs compared to older canoe methods.

This report presents the results of these three operations, which mapped on a reconnaissance scale approximately 185,000 square miles of previously unknown country. The geological studies have led to a more accurate assessment of the economic potentialities of the region, and have indicated many areas or problems where more detailed investigations are required. Some of these are currently being undertaken.

Y. O. FORTIER,
Director, Geological Survey of Canada

OTTAWA, August 31, 1964

MEMOIR 350 — Geologie des südöstlichen Ödlandes im Mackenzie-Distrikt und Keewatin-Distrikt (Nordwestterritorien)
(Operationen Keewatin, Baker, Thelon).
Von G. M. Wright

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Г. М. Райт

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GEOLOGY OF THE SOUTHEASTERN BARREN GROUNDS, PARTS OF THE DISTRICTS OF MACKENZIE AND KEEWATIN

Abstract

A region west of Hudson Bay covering 185,000 square miles of previously unmapped terrain was mapped geologically in a broad rather than a detailed manner, using light helicopters for wide-ranging reconnaissance.

With minor exceptions, all known rocks are Precambrian. Most of the area is included in the Churchill structural province, where a basement complex, mainly of granitoid gneisses, contains infolded Lower Proterozoic (Aphebian) sedimentary sequences, the Nonacho and Hurwitz Groups. Within this wide area, potassium-argon age determinations on granitic rocks and contained paragneisses indicate a general uniformity in age of 1,600 to 1,800 million years, and suggest regional metamorphism connected with the Hudsonian orogeny as the cause. Approximately 30,000 square miles of the central part of the map-area is occupied by a blanket of flat-lying sedimentary and igneous rocks of the Dubawnt Group, probably of Middle Proterozoic (Helikian) age. These sediments are believed to be continental in origin and to have been derived from the southeast.

In the northwest corner of the map-area are rocks of the Slave structural province, separated from those of the Churchill province by a major igneous and metamorphic discontinuity—the Thelon Front. Rocks of the Slave province include steeply dipping, metamorphosed, sedimentary and volcanic rocks of the Yellowknife Group intruded by massive granites of Archaean age. These are overlain, with marked angular unconformity, by moderately folded sediments of the Goulburn Group of, probably, Middle Proterozoic (Helikian) age.

Résumé

Une région à l'ouest de la baie d'Hudson, d'une superficie de 185,000 milles carrés et qui n'avait pas encore été cartographiée, vient de l'être du point de vue géologique mais de façon plutôt esquissée que détaillée. On a utilisé de petits hélicoptères pour effectuer de longs vols de reconnaissance.

A quelques exceptions près, toutes les roches connues sont du Précambrien. La majeure partie de la région est comprise dans la province structurale de Churchill où un complexe géologique de base, composé surtout de gneiss granitoïdes, comprend des séries sédimentaires (aphébiennes) plissées du Protérozoïque inférieur, les groupes de Nonacho et d'Hurwitz. Dans cette grande région, les datations au potassium-argon des roches granitiques et des paragneiss qu'elles renferment indiquent une certaine uniformité d'âge variant de 1,600 à 1,800 millions d'années et fait croire à un métamorphisme régional

relié à l'orogénèse hudsonnienne. Environ 30,000 milles de la partie centrale de la région sont occupés par une couche plane de roches sédimentaires et ignées du groupe de Dubawnt qui remontent probablement au Protérozoïque moyen (Hélikien). Les sédiments seraient d'origine continentale et proviendraient du sud-est.

Dans l'angle nord-ouest de la région, on trouve des roches de la province structurale de l'Esclave, séparées de celles de la province de Churchill par une importante discontinuité ignée et métamorphique appelée front Thelon. Les roches de la province de l'Esclave comprennent des roches volcaniques et sédimentaires du groupe de Yellowknife à pendage prononcé et métamorphisées dans lesquelles font intrusion des granits massifs de l'Archéen. Elles sont recouvertes, en discordance angulaire marquée, par des sédiments modérément plissés du groupe de Goulburn qui remontent probablement au Protérozoïque moyen (Hélikien).

Chapter I

INTRODUCTION

General Statement

This memoir gives an account of the geological reconnaissance of 185,000 square miles of the southern and central barren grounds of the Northwest Territories (Fig. 1). It deals primarily with the results of a series of airborne surveys carried out in 1952 (Operation Keewatin)[1], in 1954 (Operation Baker), and in 1955 (Operation Thelon), on which light helicopters were used extensively as the main instrument of surveying. Preliminary reports, with geological maps on the scale of 1 inch to 8 miles, on the areas covered by the separate operations have already been issued by Lord (1953c) and Wright (1955b, 1957). The operations and their overall results have been described by Lord (1953a, b), Wright (1955a), and in Bulletin 54 (1959) of the Geological Survey. Operational methods, procedures, and problems are discussed in Chapter II.

These surveys were undertaken to provide systematic primary geological studies for publication, at the scale of 1 inch to 8 miles, to outline the major features of both bedrock and surficial geology and to furnish a first assessment of the economic potentialities of the region. The nature of the method adopted (purely experimental initially) and the reconnaissance results desired precluded detailed investigations, but the work has outlined many areas and problems that merit detailed study and/or mapping.

Location and Access

The area discussed extends westward for about 500 miles from the west coast of Hudson Bay to Artillery Lake at longitude 108°, and northward for 400 miles from practical tree-line at latitude 60° to Pelly and Garry Lakes at latitude 66° (Figs. 1 and 2). The Daly Bay-Wager Bay area, and the heavily treed country west of Kasba Lake, however, were not covered in the field and are not treated herein.

The centre of the area mapped lies 375 miles northwest of railhead at Churchill, Manitoba, 350 miles northeast of Uranium City, Saskatchewan, and 400 miles east of Yellowknife, District of Mackenzie.

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[1] This was the first use of helicopters by the Geological Survey of Canada.

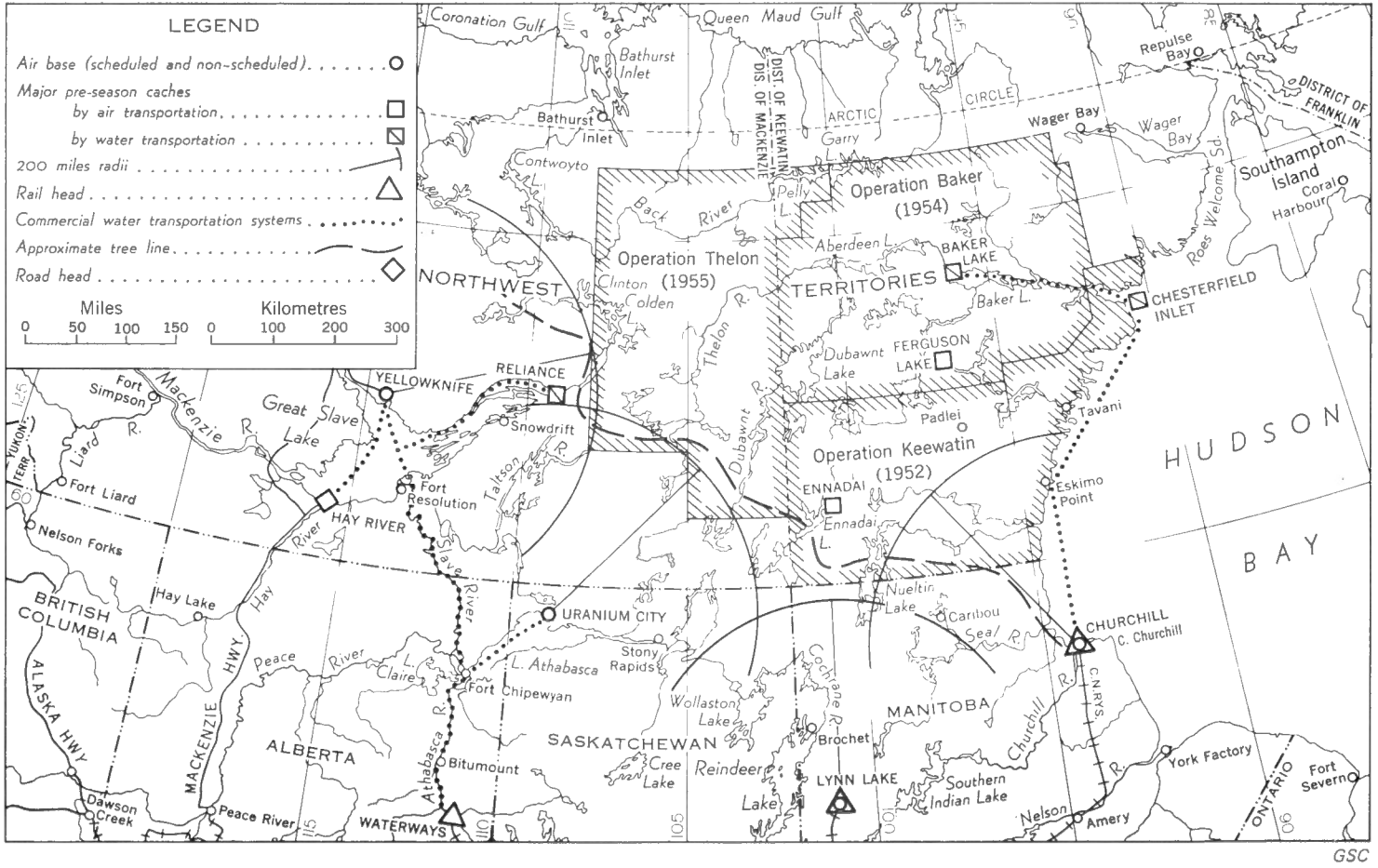

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FIGURE 1. Operational setting of barren grounds surveys for period 1952-55.

During the short shipping season water transportation is available from Churchill to points on Hudson Bay and up Chesterfield Inlet to Baker Lake. The Hudson's Bay Company operates scheduled services to these parts, and chartered ships from Montreal and elsewhere occasionally carry cargoes to selected points such as Rankin Inlet. Several places on Great Slave Lake, to the west of the map-area, are served by barges of the Northern Transportation Company; one barge per year visits Reliance, usually in late July.

For most practical purposes, the great areas removed from navigable waters are accessible only by air. Non-scheduled flights by bush-type aircraft, operating from bases such as Churchill, Uranium City, and Yellowknife, can reach most parts of the region (Fig. 1), but the scarcity of refuelling points, particularly in the western and northern parts, demands careful planning in advance. Abundant lakes over much of the barren grounds provide ready-made landing strips for ski- or wheel-equipped aircraft in winter and for float-equipped machines in summer. A gravel landing strip for multi-engined aircraft is maintained by the Department of Transport at Baker Lake, and less permanent airstrips have been constructed by private interests at Rankin Inlet and north of Pelly Lake (now abandoned).

Settlements and Population

Most of the settlements of the region are along or near the west shore of Hudson Bay or related navigable water routes; a few occur inland, but none exists between Dubawnt and Artillery Lakes. For the most part the settlements are centred about various government establishments or trading posts. The locations and main components of the populated localities in and adjacent to the region are shown in Figure 2.

The native population is small and in recent years has tended to converge on the settlements. Population shifts and a changing way of life for the Eskimo are currently taking place and are an inevitable consequence of the development of the country. The establishment of an operating mine at Rankin Inlet in the mid-1950's, for example, resulted in a considerable shift in the native population from the Chesterfield Inlet area, and also a change in the native way of life from trapping, hunting, and fishing to mine labour. The closing down of this mine in 1962, due to lack of ore, accentuates the problems inherent in such population shifts.

The Hudson's Bay Company post at Padlei has been closed down and the small Eskimo population transferred to Whale Cove, near Term Point, on Hudson Bay. A major shift in the Eskimos' way of life is also involved in this case.

Small bands of Eskimos were occasionally encountered away from the settlements in 1952 and 1954, but only three natives were seen in the entire area of 61,000 square miles of eastern District of Mackenzie mapped in 1955 (Fig. 1).

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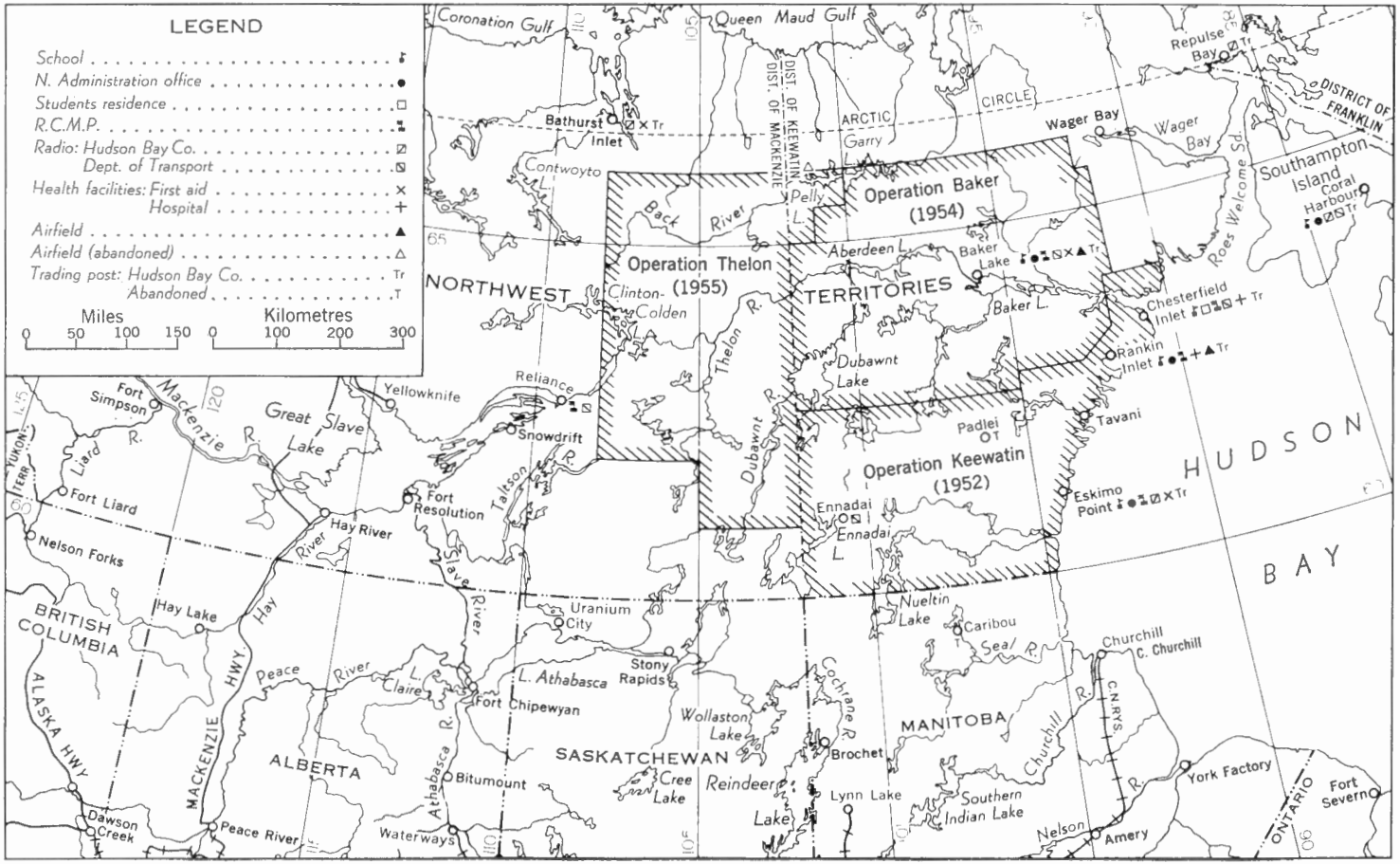

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FIGURE 2. Settlements and facilities in the operational and adjoining areas as of 1961.

Table I shows the approximate white and native populations of the various localities in and near the operational areas, as of 1951 and 1961.

Table I

White and Native Populations in and near the Operational Areas

Locality	1951	1961		
		Total	White	Eskimo[1]
Baker Lake	81	386	60	326
Bathurst Inlet[2]	7	23		
Caribou	*	*		
Chesterfield Inlet	287	146	52	94
Coral Harbour	73	117	18	99
Ennadai	*	3		
Eskimo Point	136	168	23	145
Reliance[2]	*	12		
Padlei	3	*		
Rankin Inlet	6	121	4	117
Repulse Bay	65	116	3	113
Stony Rapids[2]	351	107		

[1]The non-white population at Reliance and Stony Rapids is Indian, not Eskimo.
[2]Total population only available.
*Census not taken separately.

Terrain

The barren grounds are characterized by low altitude, low to moderate relief, relative but varying abundance of lakes, generally disorganized drainage except for the few large rivers, and wide variation in amount of exposed bedrock.

Probably no point within the map-area is more than 2,000 feet above sea-level, even allowing for local relief. The highest lakes are mainly in the southern and western parts, from which the large rivers drain to the east and north toward Hudson Bay and the Arctic Ocean.

Local relief is commonly low, in the order of 50 to 200 feet, but over extensive areas it is much less (Pl. I), and elsewhere may be as much as several hundred feet. The relief in many places obviously reflects bedrock control, but over extensive areas it is low or gently undulating due to the presence of a widespread but discontinuous mantle of glacial debris, much of which possesses its own characteristic topographic expression (drumlins, eskers, moraines, etc.). The maps of bedrock and surficial features (*in pocket*) indicate to a certain extent the terrain-types to be expected, and they should be consulted in conjunction with the generalized comments on topography that follow.

The Ennadai-Rankin Inlet greenstone belt includes rounded hills of greenstone (7)[1], low-lying areas underlain by sedimentary rocks (8, 10, 11), and by high, white, elongated or sinuous ridges of resistant Hurwitz quartzite (9); a

[1] Numbers in parentheses refer to map-units on the accompanying geological map.

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somewhat similar terrain occurs in part between Baker and Garry Lakes. To the southeast of the Ennadai-Rankin belt outcrop becomes less abundant to non-existent, the relief low, and the drainage almost completely disorganized locally by abundant glacial debris, in part reworked by the waters of a formerly expanded Hudson Bay and covered with clay deposits (*see* Chapter III).

Areas underlain by rocks of the Dubawnt Group (18-22) are, with some notable exceptions, widespread grasslands of low or gently rolling relief, with scattered outcrops rising a few feet above the surface. A few exceptions may be noted. At the east end of Baker Lake, Dubawnt sedimentary rocks (19) are tilted and form fairly rugged islands. Northwest of Marjorie Lake, north-dipping, crossbedded sandstones (19) underlie a prominent south-facing, steep slope more than 400 feet high. Between Steel Lake and Thelon River, rolling hills of Dubawnt sandstone rise to more than 500 feet above the river. In complete contrast is an area south of Beaverhill Lake, where a conspicuous mantle of wind-blown sand covers the flat-lying sedimentary rocks.

The granitic and gneissic terrane (4, 12, 13, 14) that occupies so much of the map-area is too varied to describe in detail. Much of it is of moderate relief with good outcrops, but again a few special cases may be mentioned. The more massive granitic rocks (4, 14) appear to form more hummocky and bolder outcrop areas. Where Dubawnt River enters the map-area from the south to approximately Barlow Lake there is little actual outcrop, and the terrain is in part an intricate jumble of hummocks and hollows in coarse, rocky, glacial rubble. Between Clinton-Colden and Moraine Lakes and south to Sifton Lake are extensive rock-barrens, developed mainly in granitic gneisses (13) and schist and gneiss (12). This area is, in large part, of very low relief with abundant outcrops, and the regional trend of bedrock structural and erosional features gives rise to many close-spaced, north-northeasterly trending lineaments (mainly narrow lakes), which from the air give the country a most impressive grain (Pl. II). The more massive granites (4) south of Beechey Lake form prominent outcrop areas, which are cut in a few places by long, canyon-like lineaments, probably representing faults. The granitic (13) and gneissic (12) rocks along Chesterfield Inlet form bold outcrops of moderate relief, cut by many rectilinear lineaments, and long, irregular bays.

In the extreme northwestern part of the map-area, Yellowknife volcanic rocks (1, 2) mainly form bold outcrops, whereas the sedimentary rocks (3) underlie low ground, the surface of which is commonly covered with frost-shattered plates of the schistose bedrock. Also in this region, the younger sedimentary rocks of the Goulburn group (15, 16), which overlie the upturned edges of the Yellowknife sedimentary rocks, form bare, rolling hills that rise to a maximum of almost 1,000 feet above the bottom of the Bathurst Trench, the lineament of lower Western River (Pl. III). This long, straight trench is probably the most spectacular topographic feature in the entire map-area.

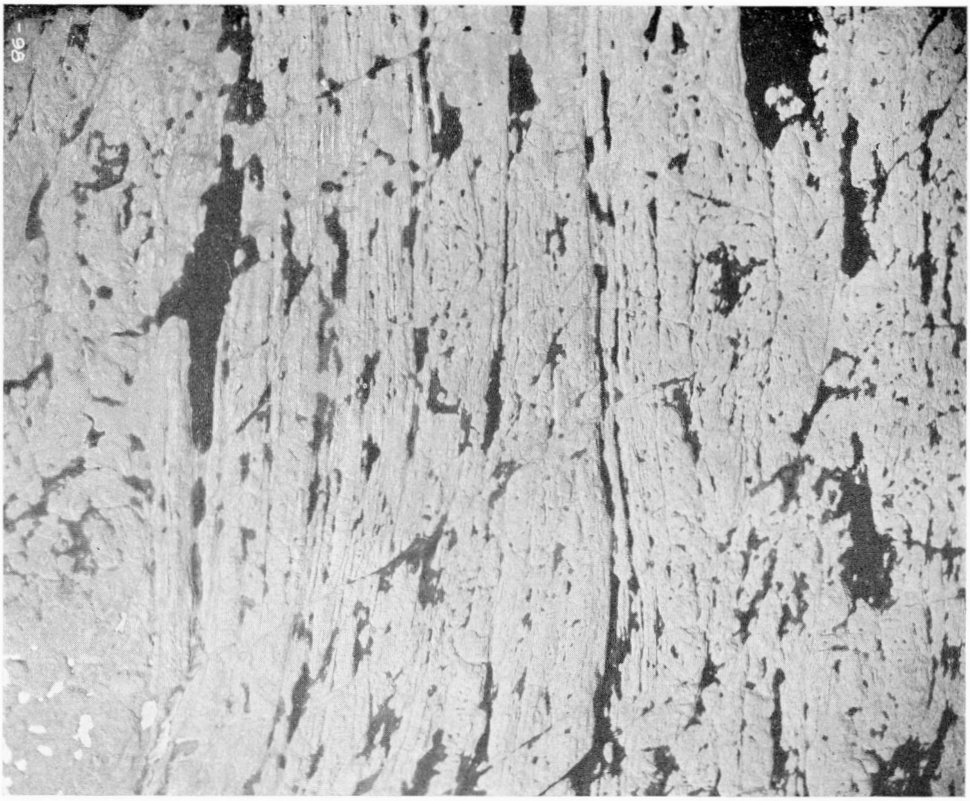

PLATE II. Rock-barrens northeast of Sifton Lake. Steeply dipping, well-foliated granitoid gneisses impart a distinctive 'grain' to the countryside.

Drainage and Canoe Routes

Except for a few large, well-defined rivers and some main tributaries, the drainage within the region mapped is poorly organized. The overall drainage is from the south and west to the north and east, with regional heights-of-land between the major river systems, the Back, the Hanbury-Thelon, the Dubawnt, and the Kazan.

The Back River, rising near Aylmer Lake (elevation about 1,200 feet, just west of the map-area), drains north to Beechey Lake, and thence east to and beyond Pelly and Garry Lakes, and finally turns north to empty into Chantrey Inlet on the Arctic coast. This river constitutes an acceptable peripheral canoe route (Back, 1836), but in several places it is interrupted by rapids.

The Hanbury-Thelon system (Tyrrell, J. W., 1902) crosses the entire map-area from just north of Artillery Lake to Hudson Bay at Chesterfield Inlet. In 1955, it was used by a canoe-equipped Topographical Survey party establishing elevations across the central barren grounds. Upper Thelon River, which joins the Hanbury and Thelon Rivers near Dickson Canyon, drains part of the southwest

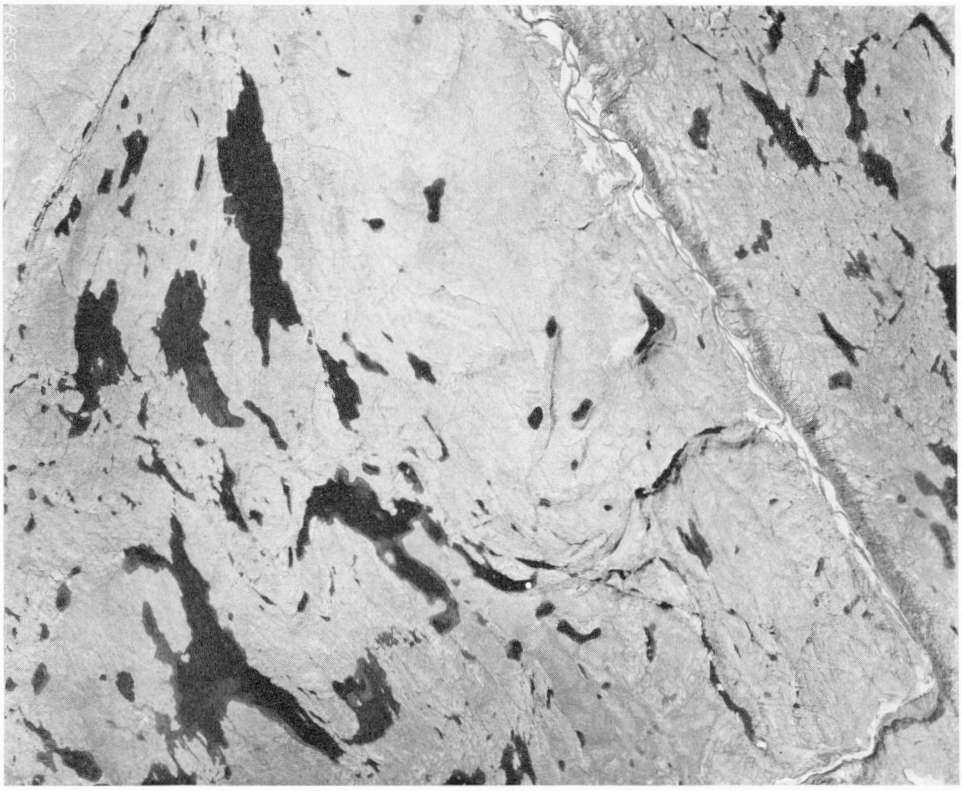

PLATE III. Pronounced canyon along major fault (Bathurst Trench). Compare details with geological map (*in pocket*).

corner of the map-area. Lower Thelon River system is navigable by small ships from Chesterfield Inlet to Baker Lake, and, if the rapids between Baker and Schultz Lakes could be overcome, would be navigable by shallow-draught small boats and barges to the west end of Beverly Lake, in the centre of the barren grounds. On the whole, the Hanbury-Thelon system is a good, continuous canoe route, some 500 miles long.

Dubawnt River enters the southwestern part of the map-area west of Ennadai Lake, and runs north-northeasterly in a rather confused waterway to the very large Dubawnt Lake (elevation 774 feet). From Dubawnt Lake it emerges as a well-defined stream with some large lakes (Grant, Wharton, and Marjorie), and joins the Thelon system at Beverly Lake. The Dubawnt River (Tyrrell, J. B., 1898) is a good canoe route, but again with many rapids.

The Kazan River runs in an irregular, northeasterly direction from Ennadai Lake (elevation 1,070 feet), through several large lake expansions, until it empties into Baker Lake near the mid-point of the south shore. This river also has many rapids, but provides the fourth major through canoe route in the region (Tyrrell, J. B., 1898).

Several lesser streams could be used as canoe routes of a local character. Among these are the Quoitch, draining from the north into Chesterfield Inlet near Baker Lake; the Ellice, in the northwest corner of the map-area; the Clarke, draining from the southeast to join the Upper Thelon near Dickson Canyon; and several rivers (Thlewiaza, Tha-Anne, McConnell, Maguse, Ferguson and Wilson), which drain easterly or southeasterly into Hudson Bay. Elsewhere, streams are generally small, in part intermittent, and are not good canoe routes.

The distribution of lakes can be seen on the map. Generally there is an abundance of them large and deep enough to float a pontoon-equipped aircraft, but locally, as in the flat grasslands west of Dubawnt Lake and in the granitic terrain near the border of the map-area northeast of Baker Lake, good landing lakes are scarce. Many of the larger lakes throughout the region provide canoe routes of limited extent.

In many parts of the map-area, rock outcrops are not abundant along lake shores or river banks.

Forest Cover

The barren grounds, as their name implies, are for the most part devoid of trees. North of tree-line, except for isolated patches retained or developed due to local conditions, trees larger than low bushes are not found.

The so-called tree-line is a sinuous zone in which the trees decrease in concentration and size toward the north or northeast. It extends northwesterly from the coast of Hudson Bay a few miles north of Churchill, through Ennadai Lake, to near the south end of Artillery Lake (Fig. 1). A large bulge in the line loops northward to include Nueltin Lake and the Padlei district. Small trees also occur in groups near Kamilukuak Lake. The valley of Thelon River, particularly from Grassy Island to near Beverly Lake, is densely wooded in a narrow belt along the river.

The trees are mainly spruce, with some tamarack in places. They are of no commercial value, except that they could be used locally for constructing cabins and for firewood.

Wildlife

In the region, wildlife varies considerably in type and number and, to a certain extent, from year to year. Only the more important species are considered here; mainly those that contribute to the economy of the region, or that can be used for food.

Of the mammals, caribou are by far the most numerous and important. In the past they formed the basis of life for the Eskimos, especially the inland groups, as they provided the main source of food, clothing, and summer shelter. With the opening up of the Canadian north and the changes thus introduced into the Eskimo way of life, the importance of the caribou is diminishing. So too is the caribou population (Banfield, 1954). Scattered caribou were seen at different

times in most major parts of the map-area. But, despite the many hundreds of hours of low flying carried out, medium to large herds, so commonly referred to in the older literature, were seen on only four occasions: near Maguse River in July, 1952 (Pl. I); north of Aberdeen Lake in July, 1954; crossing the Thelon River near longitude 105° in July, 1955; and in the general region of Beechey Lake in August, 1955.

Musk-oxen, the largest animals seen, are relatively restricted in occurrence and numbers. None was observed east of longitude 101° or south of latitude 63° 30′. In 1954, 33 musk-oxen were seen between Beverly Lake and longitude 102°, all but five south of Thelon River. In 1955, 176 were counted in or near the valley of Thelon River between longitude 102° and Dickson Canyon, and 104 in the Clinton-Colden Lake and Back River areas. The largest herd comprised 42 animals. A few of these observations may be duplications, but a probable minimum figure for the number of musk-oxen within the map-area is 250, with a possible maximum of about 400. Musk-oxen are rigidly protected by law. The Thelon Game Sanctuary (Clarke, 1940), originally established as a protected range for musk-oxen, lies in the west-central part of the map-area. Its revised (1956) boundaries are shown on the accompanying geological map. Prospecting and staking are forbidden within the Sanctuary.

The white fox is the main commercially-important fur-bearing animal in the barren grounds. It was, and for the inland Eskimos still is, the main source of income for the natives. However, it does not provide a firm economic base, due to the wide yearly variation in the fox population and in the value of the pelts. The barren-ground wolf, usually white to buff in colour, was seen in all parts of the map-area, but only once in what could be called a pack (9 animals). A few wolverines were encountered near the edge of bush in the southwestern part of the map-area.

The large, buff, barren-ground grizzly bear was observed on only two occasions, near Beverly Lake and north of Back River. The common black bear was found in thin bush in southern Keewatin.

In general, the lakes and rivers of the region abound in fish, which provide a major source of food for the Eskimos. Lake trout are most common, but grayling are also found, and Arctic char, from the streams flowing into Hudson Bay, are highly prized.

Arctic ptarmigan were seen in many parts of the area, and ducks and geese were seasonally plentiful, especially along the coast of Hudson Bay, and in the Thelon River system in late summer.

Climate

The barren grounds are characterized by short, cool summers and long, cold winters; the spring and autumn seasons are short. The short periods between winter and summer (break-up) and between summer and winter (freeze-up) are difficult times for air operations. (The problems of the break-up period are

discussed in some detail in Chapter II.) Moderate to high winds are common, due in some measure, probably, to the broad, flat, uninterrupted 'sweeps' offered to moving air masses. Total precipitation ranges from less than 6 inches at Baker Lake to almost 14 inches at Churchill, Manitoba. This precipitation is approximately half snow and half rain.

Meteorological stations in this region are few and widely separated, and it is doubtful if the records at such stations truly represent the intervening areas. Few records have been maintained long enough to provide true means. Table II gives selected data from available stations in or immediately adjoining the map-area, with a view to indicating general, rather than specific, conditions.

Weather conditions, as directly affecting air operations in the barren grounds, were generally good. However, some specific exceptions may be noted. At Carr Lake in July, 1952, persistent high winds from the north stopped all helicopter and most fixed-wing flying for more than a week; very few days were lost for this reason at any other time. Sea-fog along the Arctic coast and along the coast of Hudson Bay in late summer effectively interrupted flying, and this problem is probably more persistent. Temperatures of 85°F or above reduced the efficiency of the Hiller helicopters for two or three days in June, 1952, but cool operating conditions were generally the rule. Rain, mist, and low clouds were annoying at times, and occasioned some risky flying, but probably no more so than in other parts of the country.

Other Geological Work in and Adjoining the Map-Area

Little geological work was done in this region by the Geological Survey previous to 1952. In 1893, J. B. Tyrrell (1896, 1898) carried out an epic canoe traverse through the central barren grounds via the Dubawnt and Thelon Rivers systems, and then down the west coast of Hudson Bay to Churchill. Shortly after (1898), he undertook a similar track survey using the Kazan and Ferguson Rivers. Much later, L. J. Weeks (1930, 1932, 1933) carried out geological investigations on and near the west coast of Hudson Bay between Rankin Inlet and Maguse River.

Geological mapping and investigations have been done around the northern, western, and southern perimeters of the map-area, beginning some years before 1920. Starting at the northeast margin of the area and proceeding anti-clockwise are reports and/or maps by Heywood (1961), O'Neill (1924), Fraser (1964), Lord and Barnes (1954), Folinsbee (1952), Wright (1952), Henderson (1939), Taylor (1959c), Taylor (1959a), Taylor (1959b), Taylor (1957, 1963), Tremblay (1960), Fraser (1962), and Davison (1963). None of these was detailed studies.

Acknowledgments

On behalf of all those who served on the barren-grounds operations, the author wishes to acknowledge the great debt owed to the many organizations and

Table II

Meteorological Data

Station	Monthly averages of daily mean temperature								Average monthly total precipitation (equivalent inches)								Percentage of time with clear sky (≤ 2/10 covered)								Average wind speed (miles per hour)							
	April	May	June	July	August	September	October	November	April	May	June	July	August	September	October	November	April	May	June	July	August	September	October	November	April	May	June	July	August	September	October	November
Churchill 43 ft above MSL	12	30	42	55	53	43	29	7	0.7	0.6	1.4	2.5	2.4	1.9	1.5	0.8	38	30	28	24	19	14	17	25	14	13	12	11	13	16	17	17
Chesterfield Inlet 13 ft above MSL	1	21	37	48	47	37	22	0	0.7	0.6	1.0	1.7	1.5	1.4	1.3	1.1	44	24	19	23	24	13	12	29	14	14	12	8	13	15	17	15
Baker Lake 30 ft above MSL	2	23	36	49	50	36	17	−3	0.3	0.2	0.7	0.9	1.1	0.8	0.5	0.3	46	26	14	19	25	15	15	30								
Reliance 539 ft above MSL	18	36	45	54	56	45	26	9	0.3	0.5	0.8	0.8	1.3	1.0	1.1	1.1																
Ennadai Lake 1065 ft above MSL	11	29	42	52	53	39	21	7	0.3	0.5	0.8	1.4	0.9	1.4	1.0	0.5																

Data from: Climatic Summaries from Selected Meteorological Stations in Canada, Vol. I and addendum, Vol. II; Dept. of Transport, Meteorological Division, Toronto.

individuals who contributed, directly or indirectly, to their success. The list includes: the Department of National Defence, through its facilities and staff at Fort Churchill in 1952, 1954, and 1955, and through the Royal Canadian Corps of Signals at Ennadai Lake in 1952 and Reliance in 1954 and 1955; the Hudson's Bay Company through its transportation facilities, and its posts and personnel within the region, particularly Mr. A. Lunan at Baker Lake and Mr. J. A. Ford at Chesterfield Inlet; the Department of Transport, for its ever-ready willingness to provide vital communications links, accommodation, and other support, especially at Baker Lake in 1954 and 1955 and at Ennadai Lake in 1955; the Royal Canadian Mounted Police at several of its posts, particularly Reliance in 1954 and 1955; the Canadian Nickel Company Limited for assistance in communications, and other support in 1952 and 1954; Spartan Air Services Limited, through the facilities of its Pelly Lake base in 1955; and Imperial Oil Limited, who supplied the gasoline and lubricants for all three operations. Mr. Gus D'Aoust at Reliance helped in the establishment of the main gasoline cache in 1954 and supervised its use in 1955.

Many other individuals, too numerous to mention, in the government service, in private industry, or as private citizens, contributed of their time and knowledge. The aircraft companies and their aircrew, whose efficiency made the success of the operations possible, are acknowledged in Table III, along with other personnel of the field parties.

Chapter II

OPERATIONS

Introduction

Between 1936 and 1955, the Geological Survey of Canada completed about 85,000 square miles of mapping, for publication mainly on the scale of one inch to four miles, in the Precambrian parts of the Northwest Territories mainland. The mapping was concentrated along the western border of the Canadian Shield. mainly between Great Slave and Great Bear Lakes. These surveys used conventional canoe-foot traversing methods, and were supplied and supported at intervals during the field seasons by bush aircraft (such as the Norseman) operating on floats from bases at Yellowknife and Fort Smith. In this type of work, geological data of necessity are concentrated along the better canoe routes, and gaps occur in the coverage where canoe routes are scarce or time is short. Further, due to the limited range of loaded bush aircraft and to the necessity of repositioning the canoe teams of a survey party within the area to be mapped in conjunction with fortnightly supply trips, the maximum feasible range for this type of survey is about 200 miles from the aircraft bases (Fig. 1).

The advent of commercially available light helicopters in the late 1940's led to a reappraisal of the problem of geological mapping in the more remote areas of the Shield, particularly between Hudson Bay and Great Slave Lake. This country seemed most suitable for mapping by helicopter because of its low relief and almost complete lack of trees. It was decided to mount an experimental, self-contained operation, with two light helicopters and one Norseman (Pl. IV), in the southeastern part of this region near Churchill, Manitoba, and to follow it with others, farther afield, if the method proved successful.

The three helicopter reconnaissance surveys carried out in the southern and central barren grounds, Operation Keewatin, 1952 (Lord, 1953a, b, c), Operation Baker, 1954 (Wright, 1955a, b), and Operation Thelon, 1955 (Wright, 1957), have mapped 185,000 square miles in three field seasons (Fig. 1). The centre of the area mapped is 400 miles from the nearest railhead. There are no roads and, except for half a dozen very small communities (Fig. 2), no internal facilities. Previous to 1952, no systematic geological mapping had been done anywhere in the operational areas.

PLATE IV. Complete survey base-camp, with aircraft. Note low relief, treeless terrain. The essential 'working parts' of such a camp could be moved 100 miles in one day with one Norseman.

Organization

Personnel and Duties

The parties consisted of 16 people (17 on Keewatin); their distribution and general duties are set out in Table III. All duties relating to administration, operations, equipment, and messing were shared amongst the geologists, in addition to their geological and flying duties, so that purely administrative personnel were eliminated. This system permitted the party chief, a geologist, to participate fully in geological studies and compilation, in addition to exercising overall control of the operation.

Adaptability and cooperation of personnel are important factors in the overall efficiency of survey parties of this type. In particular, understanding and appreciation, by geologists and pilots alike, of each other's problems and requirements is a prerequisite to success.

Dr. Lord and the writer wish to take this opportunity to thank all those persons listed in Table III for their important contributions to the team efforts.

Special Equipment

The parties were equipped with tenting designed to withstand the high winds of the barren grounds. Strengthened wall-tents (8′ x 10′ and 10′ x 12′) with telescopic aluminum poles served as cook, dining, operations, office and stores

Table III

Personnel and Duties on Operations Keewatin, Baker, and Thelon

Assignment	Keewatin (1952)	Baker (1954)	Thelon (1955)	Remarks
Geologist	C. S. Lord	G. M. Wright	G. M. Wright	Party chief
"	G. M. Wright	C. H. Smith	J. W. Hoadley	Deputy chief–operations
"	H. A. Quinn	J. A. Fraser	J. A. Fraser	Equipment
"	K. E. Eade	R. C. Shields	K. E. Eade	Messing
"	H. A. Lee	J. G. Fyles	B. G. Craig	Surficial deposits
Topographical engineer	T. J. Rusk			Barometric elevations
Radio operator	L. Shea	H. Knapp	H. Knapp	
Helicopter pilot	G. Turner			Kenting Aviation
" "	J. Godsy			" "
" "		J. G. Theilmann	N. J. Armstrong	Spartan Air Services
" "		N. J. Armstrong	P. A. Peterson	" " "
" "			J. F. C. Morrison	" " "
Helicopter engineer	R. Bright			Kenting Aviation
" "	H. McGeach			" "
" "		L. Camphaug	T. Murray	Spartan Air Services
" "		M. Takacs	K. Thomas	" " "
" "			P. Istance	" " "
Norseman pilot	G. Lamb			Lamb Airways
" "		G. Ingebrigtson	D. Croal	Arctic Wings
" "		C. A. Weber	C. A. Weber	" "
Norseman engineer	R. Urch			Kenting Aviation
" "		N. Scutt	C. Chipman	Arctic Wings
Cook	J. O. Eddie	J. O. Eddie	J. O. Eddie	
Labourer (cookee)	J. Abrams	M. Schweder	A. Crockford	
Labourer	C. Schweder	C. Schweder	L. Fraser	
Expediter at Churchill	F. O. Martin	F. O. Martin	F. O. Martin	Sigurdson and Martin

tents. Enlarged 'Mount Logan' tents (7′ x 8′6″; 2′6″ wall), strengthened, and provided with suitable flies, proved very satisfactory for sleeping two men. Lightweight aluminum tent pegs were tried out, but were not strong enough to penetrate permafrost; iron pegs or rocks were used thereafter. Good fly-bars are necessary for all tents.

Reliable radio equipment with competent operators contributed greatly to the efficiency and safety of air operations, and to the maintenance of routine administrative control. The base-camp radio equipment maintained contact on a dependable, daily basis with outside points (e.g., Churchill, via Ennadai), and with the Norseman aircraft. Considerable difficulty was encountered, however, in developing a good communications system with low-flying helicopters; this problem never was solved to the satisfaction of all concerned.

Due to the lack of firewood in the region, all cooking and heating was done by gasoline stoves.[1] In general, these would not operate properly on aviation gasoline, and thus introduced an extra supply problem.

[1] In subsequent operations, propane gas stoves have been used.

Two-man, collapsible, rubber assault boats were used in 1954 and 1955, mainly to cope with break-up conditions (Pl. VI), when 'leads' up to a hundred or more feet wide separated shore from firm ice. These boats were very valuable during this period.

Pre-Season Caching

Major caches of gasoline, oil, and staple foods, averaging about 100 tons, were established in advance of each field season close to or within the area to be mapped (*see* Fig. 1). For Operation Keewatin (1952), this caching was carried out in the spring of 1952, mainly by Bristol Freighter, from Churchill to Ennadai and Ferguson Lakes, and to a lesser extent to Chesterfield Inlet.

For Operation Baker (1954), the main cache of fuel was established in the summer of 1953 by boat (Hudson's Bay Company) at Baker Lake, with smaller caches at Chesterfield Inlet and Eskimo Point. In May, 1954, just before the start of field work, considerable food and equipment was flown into Baker Lake by Dakota (DC-3) and Norseman aircraft operating from Churchill.

Also in the summer of 1954, a major cache of gasoline and oil was established at Reliance by barge (Northern Transportation Company Limited) for use by Operation Thelon in 1955. In May, 1955, Dakota and Norseman aircraft, again operating from Churchill, moved substantial amounts of food and equipment into Reliance and Ennadai, and some gasoline from Reliance into the field area.

The use of water transportation, where feasible, proved much cheaper than air transportation, and although caching had to be carried out a year in advance, the establishment of caches by boat or barge proved to be much less worrisome than by aircraft. It is advisable to establish major caches in advance of operations only where they will be under supervision.

Survey Operations and Procedures

It is doubtful if a combination of terrain and geological conditions can be found anywhere in Canada more ideally suited to direct geological mapping by helicopter than that in the barren grounds of the Districts of Keewatin and Mackenzie, Northwest Territories.

Although terrain and other conditions do vary somewhat within the region considered herein and in the country south of the Arctic Ocean, the differences are of degree only. Thus, low to moderate relief, absence of trees, low altitude, cool operating conditions, and relative abundance of irregularly shaped lakes (important as campsites and as essential aids to detailed map-reading) combine to provide a nearly perfect operational framework. Furthermore, the geological conditions (mainly moderately to steeply dipping crystalline rocks with good outcrops over much of the region) are such that the prospect of geological mapping by continuous low-level observation, supplemented by occasional landings, seemed to be feasible.

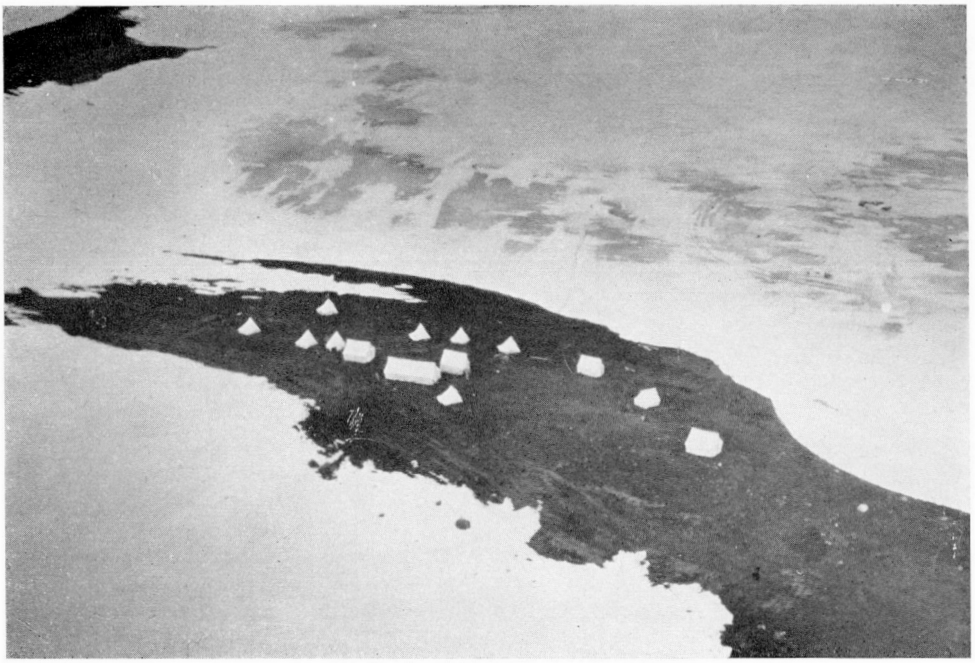

PLATE V. Aerial view of pre-break-up camp at Gibson Lake early in June, 1954. Ground is almost free of snow; ice is solid.

In general, the snow-free field season in this region may be taken as extending from the latter part of May to early September. The plan in all three operations was to start the survey while the lakes were still frozen (Pl. V), but much of the rock was already free of snow. The Norseman support aircraft operated on skis at this stage (Pl. VI), and returned to Churchill to change to floats over the break-up period. The surveys were thus able to use several weeks of good traversing weather in each season before canoe routes were open.

Break-Up

From an operational planning point of view, the time and duration of the break-up period is of prime importance, but little if any reliable data are available in advance, and past average values applied to any particular year mean little.

Some of the problems of using this snow-free to ice-free period are obvious (Pl. VI), but they are complicated by the fact that the major 'jump-off' points from which field operations are based (e.g., Churchill) may have a much earlier break-up and different duration than lakes in operational areas several hundred miles farther north. Furthermore, even lakes within a local area may have substantially different periods of break-up due to differences in size, depth, and shore conditions.

To a high degree, the problems of timing departure from main supply base to the field, and of moving camps near break-up time, must be 'played by ear', but a summary of the situations as met in field operations may be of interest.

In 1952, Camp 1 was occupied at Hurwitz Lake on May 10; in retrospect, it seems probable that this date could have been advanced by about one week.[1] The ice on Landing (Farnsworth) Lake at Churchill was unusable after May 15, and the deterioration of ice on Hurwitz Lake forced a move to Ennadai Lake starting May 16. This move was somewhat complicated by the crashing of the Norseman support aircraft (subsequently retrieved), but was completed on May 19 due to the quick response of the Royal Canadian Air Force Search and Rescue unit at Churchill. The ice at Ennadai, however, was still solid and did not break up sufficiently to allow float takeoffs until June 20. The enforced stay at Ennadai was thus 32 days, about half of which was actually used for helicopter mapping. The use of a heavy helicopter rather than a fixed-wing aircraft for support would eliminate this delay, but at a considerable increase in cost.

[1] K. E. Eade in 1962, however, could not begin field work until the first week in June, due to heavy snow in the Otter Lake area.

PLATE VI. Typical break-up conditions at Hurwitz Lake, May 17, 1952; ice melting around shores, but still suitable for ski-equipped Norseman. Small rubber boats helped to make the enforced break-up delay shorter and more manageable.

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In 1954, much snow fell in the first two weeks of May, and the establishment of Camp 1 at Gibson Lake was delayed until May 26. It was planned to spend break-up at Baker Lake, but conditions permitted occupying a second pre-break-up camp at Lunan Lake on June 8. The ice went out at Landing Lake, Churchill, on June 5, and the last pre-break-up supplies to Lunan Lake were delivered to the snow-covered airstrip at Rankin Inlet on June 10 by wheel-equipped Anson, operating from the airport at Churchill, and picked up by ski-equipped Norseman operating from ice-covered Lunan Lake. Bad ice on Lunan Lake dictated a move to Baker Lake by June 17. There the Thelon River, entering Baker Lake at the west end, exercises a local influence on ice conditions, and the party was able to move out of Baker Lake on floats by July 7, using a small stretch of open water between the mouth of Thelon River and the settlement of Baker Lake. Duration of break-up camp at Baker Lake was 19 days.

In 1955, snow conditions permitted starting field operations at Camp 1, near Nicol Lake, by May 22. The ice on this lake was bad by May 30, and Camp 2, ten miles east of the south end of Whitefish Lake, was occupied, just in time, on May 31. Landing Lake at Churchill, unusable by ski-equipped aircraft from June 2, was available for float operations by June 12, but the lake at Camp 2 was unusable by ski- or float-equipped aircraft from June 8 to June 17 when a float-equipped Norseman from Churchill landed in a stretch of clear water. It was hoped to move camp eastward, but an immediate, 300-mile, ice and campsite reconnaissance indicated that Whitefish Lake and most large enough lakes to the east and north were still mainly ice-covered. Thus on June 17, 1955, the use of float-equipped aircraft in this region was limited to widely scattered small lakes, isolated parts of larger lakes, or segments of rivers. Camp was moved 100 miles northward, starting June 18; break-up camp had lasted 18 days.

Purely local conditions can influence by up to several days the first use of float-equipped aircraft on a lake after break-up. For example, a favourable wind may move the floating ice-sheet away from the shore, leaving a usable stretch of ice-free water, or an unfavourable wind may push the ice up on the beach.

Freeze-up at no time influenced the field operations, as general bad weather or other factors dictated a halt to efficient field work by the beginning of September.

Traversing Systems

The light helicopters were used almost exclusively for systematic geological traversing. The crew consisted of one pilot and one geologist, navigation and detailed map-spotting being responsibilities of the geologist. The helicopters used float landing gear throughout, the airspeed and payload penalties over wheels or skids being accepted, as the safety factor involved in flying over an abundance of ice-cold water was decisive. The float-equipped machines landed readily on snow, ice, water, muskeg, or rock (Pl. VII).

At the start of Operation Keewatin in May, 1952, an attempt was made to fly a grid of rectangular traverses in the outline of a square around the base-camp.

PLATE VII. Helicopter lands directly on outcrop. The examination of such isolated outcrops requires minutes by helicopter, but hours and miles of unproductive effort on foot.

The limited range of the helicopters then employed (Hiller 360) imposed the necessity of pre-planning and pre-caching each such traverse or small group of traverses, and the method, although theoretically offering the best and most uniform coverage, was abandoned on operational grounds[1].

The basic method used thereafter was to fly a series of thin, triangular traverses, with a radius of 40 to 50 miles and with gaps of about 10 miles at their outer ends, from a centre-point near the base-camp and to 'square off' the resulting circle with four long traverses requiring gasoline caches (Fig. 3). This radial traverse system had the great advantage of simplicity and speed and it reduced the caching problem; its obvious disadvantage was the relative overconcentration of survey flight lines near the centre point.

Where complex geology was found while flying the standard radial traverse net, extra traverses of similar or irregular shape were flown on short notice, as needed. Groups of rectangular traverses were also used on occasion to meet special requirements.

On the completion of each camp 'square', the Norseman aircraft was used to move the survey base-camp to the next location, about 100 miles distant, and the whole process was repeated. Camp-moving days were not wasted geologically, as the helicopters ran survey traverses from one camp

[1] In 1957, Eade (1958), with longer-range aircraft and a more suitable arrangement of base-camps (Mid-Canada Line sites), revived and successfully used this system in New Quebec.

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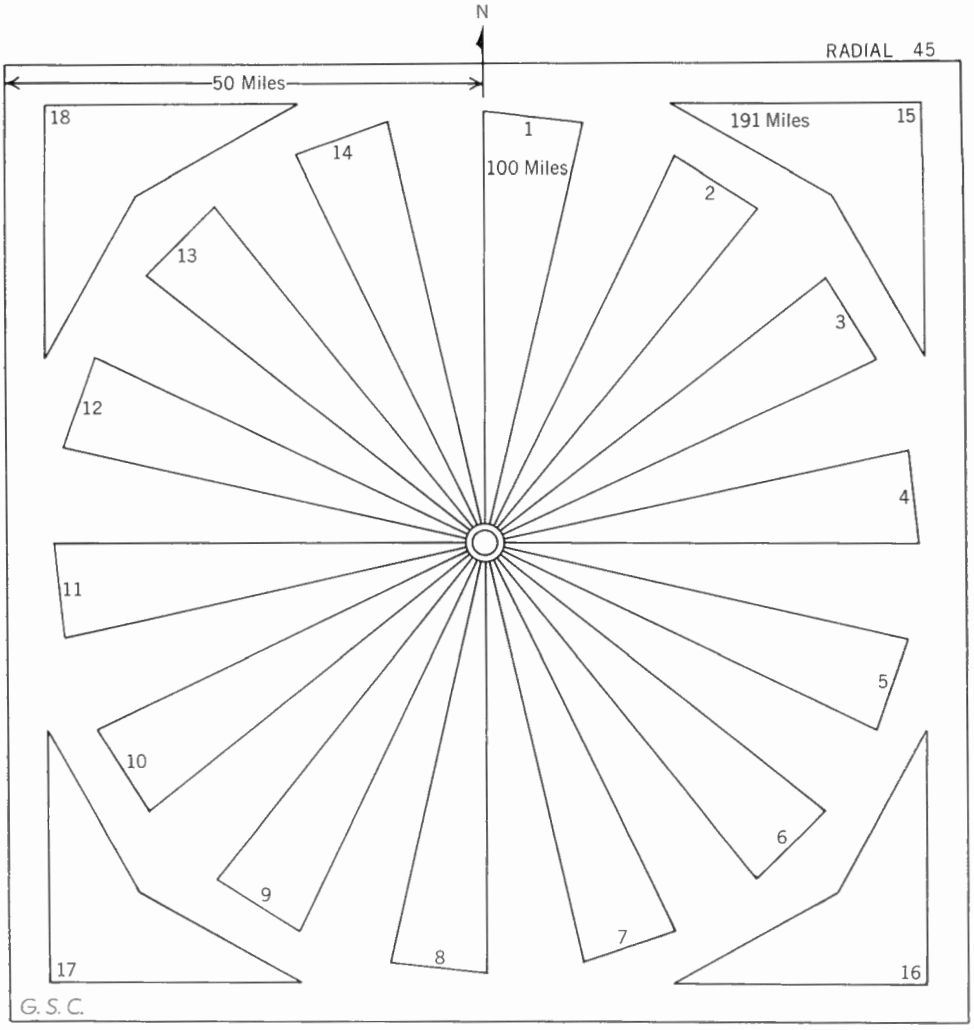

FIGURE 3. Basic radial traverse net as used in the barren grounds. Ideally, this would be surrounded by similar 'squares'.

to the next. Eight to ten base-camps were thus occupied in one season, a total of 27 for the three operations. In addition to moving camps, the Norseman supplied the necessary gasoline, oil, and food to current and future camps, and made many caching and a few exploratory flights. Supplies, mail, and spare parts were occasionally brought out from Churchill by the operation's Norseman, but more often this was done by using extra aircraft, to avoid the risk of serious operational delays if bad weather interrupted flying between Churchill and the field area.

During each radial traverse, observations were based on an average of 15 to 20 landings, perhaps twice as many low and slow passes (5 to 25 feet; 5 to 15

miles per hour), and on essentially continuous low flying (75 to 300 feet). The low relief and almost complete absence of trees over 95 per cent of the area mapped meant that the helicopters could fly continuously at low level with relative safety, and could land the geologists on or close to outcrops, thus ensuring maximum use of traversing time for geological purposes. Approximately 5,000 landings and 10,000 low passes were made in the three barren-ground operations.

The landings served to check aerial impressions, to permit sampling, and to allow the geologist to examine and measure various geological features unobservable or unmeasurable from the air. Low passes served to confirm or deny high-level identifications, often without landing; this was particularly true for most granitic rocks, many sedimentary rocks, and other rocks of coarse grain or with obviously definitive fabrics or structures (e.g., nodular schists, pillow lavas). High-level observations, although least valuable for specific determinations, were often most valuable from the point of view of reconnaissance mapping, provided that the rock-units concerned were easily recognizable. Thus, aerial observations were commonly more useful than ground observations for measuring overall trends in bedding and gneissosity (Pl. II). The three types of observations tended to support and complement one another.

The degree of reliability achieved by helicopter mapping was dependent on many factors, such as light conditions, wind and weather (as affecting aircraft usage in detail), complexity of geology, degree of contrast in rock types, length of traverse, and stamina of personnel. Perhaps the best conditions were bright overcast, light to moderate winds, and rock types of high contrast.

As a general rule, only one traverse per machine was made each flying day. Although light conditions, in so far as map-reading was concerned, would have permitted considerably more flying, the desirability of restricting geological observation from the air to those parts of the day (9 a.m. to 5 p.m. approximately) when light conditions were most favourable was a decisive factor. Other considerations affecting this decision were cost, personnel, size of party, and quality control of mapping.

Coverages and Costs

Table IV gives a summary of operational and cost data for the first three light helicopter surveys in the barren grounds. Although aircraft unserviceability did occur and was troublesome at times, the average availability of aircraft was good to excellent, and the unserviceability problem probably delayed the operations to a lesser extent than did break-up, wind and weather, and other conditions.

Considering the distances from aircraft and supply bases, and the shortness of the field season for canoes in the central barren grounds, it is unlikely that the cost of canoe reconnaissance mapping of comparable quality could be brought lower than the average of $2.63 per square mile of the three helicopter surveys considered; it probably would be substantially higher, in the order of $4 to $5 per square mile.

Table IV

Coverages and Costs of Helicopter Surveys

	Keewatin (1952)	Baker (1954)	Thelon (1955)	Totals and Averages
Area mapped (sq mi)	57,000	67,000	61,000	185,000
Favourable prospecting ground (sq mi)	14,100	6,100	5,500	25,700
Cost ($)	207,000	144,000	135,000	486,000[1]
Cost ($/sq mi)	3.63[2]	2.15	2.21	2.63
Days in field	113	98	92	303
Cost ($/day in field)	1,830	1,470	1,470	1,600
Helicopter hours	515	563	520	1,598
Helicopter cost ($)	92,073	73,222	54,147	219,442
Fixed-wing hours	626[3]	450	550	1,626
Fixed-wing cost ($)	82,952[3]	30,760[4]	38,907[4]	152,649
Total flying hours	1,141	1,013	1,070	3,224
Sq mi mapped per helicopter hour	111	119	117	116
Sq mi mapped per double helicopter day	814	837	813	826

[1]Excludes salaries of geologists and radio operators, cost of equipment and general overhead.

[2]The higher costs of Operation Keewatin were due almost entirely to the higher costs of renting helicopters in 1952, and of establishing pre-season gasoline caches by air freight.

[3]Approximate; includes use of Bristol Freighter in establishing gasoline caches.

[4]Includes some use of Dakota (DC-3) aircraft.

Two conclusions of general interest may be derived from Table IV. Firstly, if the cost of Operation Keewatin is adjusted to 1954-55 conditions in regard to the cost of renting aircraft and caching supplies, the total cost of this operation works out to $145,000.00. Thus, a rather surprising uniformity in field operating costs is indicated, despite considerable differences in geology, distance from bases, weather, and internal facilities.[1] Secondly, in operations of this nature, about one hour of fixed-wing flying is required to support one hour of helicopter flying.

Assessment of Helicopter Reconnaissance

The helicopter method of reconnaissance geological mapping, as applied under the almost ideal conditions in the barren grounds, appears to have justified the hopes of its initiators as to economy, speed, and efficiency.

If it is assumed that the average canoe reconnaissance survey would map 4,000 to 4,500 square miles in one field season in the barren grounds, it is clear that the combined coverage of 185,000 square miles for the three helicopter surveys is equivalent to at least 40 party-years of conventional methods. Five trained geologists were used on each of the helicopter parties. Had an attempt been made to cover the same ground in three field seasons using canoe reconnaissance parties, it would have required 45 to 60 trained geologists, and as many geological assistants, per year, in addition to a mass of equipment and heavy utilization of

[1] Subsequent operations—Coppermine, 1959 (Fraser, 1960), Back River, 1960 (Heywood, 1961), and Bathurst, 1962 (Fraser, 1964)—have been successfully carried out with similar cost structures.

fixed-wing aircraft. Under such conditions, uniformity in mapping and efficiency in administration would have been impossible.

The helicopter method has several distinct operational and technical advantages over canoe-foot traversing methods; some of the more important of these are:

1. A longer field season is attained by commencing field work before break-up, and working through the break-up period. In 1954, by the time waterways were partly open for canoe travel, Operation Baker had mapped 25,000 square miles.

2. Flexibility is much greater in helicopter operations, both in the individual traverse, where the geologists can make deviations in minutes rather than in hours, and also in the ability of the whole survey to change its degree of coverage quickly in order to meet changing geological complexity. Furthermore, the helicopter surveys are completely independent of canoe routes and refreshingly free of portages; unproductive field time is greatly reduced.

3. Only experienced geological personnel are used; the system requires no junior assistants.

4. The 'bird's eye' view from a slow-flying aircraft at low altitude gives an immense advantage to the geologists. In addition, widely separated areas and geology can be compared and contrasted before memories dim.

5. Uniformity in mapping is much easier to achieve, as any geological problems can be discussed daily by all the geologists concerned; such close control is impossible in canoe reconnaissance. The field work necessary to cover the whole region involved in these three helicopter surveys was carried out in an elapsed time of only 40 months, so that some of the same personnel were available to carry continuity of geological thought and operational treatment through the entire project (*see* Table III).

6. The preliminary results of geological study of this large, remote, and previously unmapped part of Canada were made available to the public in a few, rather than over 25 or more years.

Fundamentally, the most significant geological advantage of helicopter surveys is the opportunity presented to a few, selected observers to see the whole regional picture over a relatively short period of time. This process eliminates the expanse of years and the multiplicity of personnel, theoretical backgrounds, and methods normally associated with, and to some extent adding confusion to, the build-up of an integrated geological picture of any comparably large area.

Nevertheless, the helicopter method has a corresponding disadvantage in that the geologists are largely deprived of those opportunities for continuous close scrutiny of rocks natural to traverses on the ground. This leads to a relative dearth of information as to the details of petrography, metamorphism, structure, stratigraphy, and economic geology.

Thus, although the method as used adequately meets the needs of reconnaissance geological studies, operational procedures would need substantial revision if applied to detailed studies.

Chapter III

SURFICIAL GEOLOGY

Introduction

This chapter gives a brief account of the glacial geology of the map-area, and in conjunction with the map of surficial features (Map 1217A, *in pocket*), is intended to round out the descriptive geology of the region for the general reader. Those interested in more detailed and penetrating studies of this subject are referred to the writings of H. A. Lee, J. G. Fyles, and B. G. Craig, who were attached to the 'barrens' operations in 1952, 1954, and 1955, respectively, to concentrate on the problems of surficial geology. Much of the material in this chapter is derived from their published or unpublished data, and in minor part from other sources. The presentation here, however, is the responsibility of the author.

The map of surficial features shows many observed data and the major conclusions drawn from them. Not shown are the various deposits of ground moraine and erratic boulder concentrations, which form a thin mantle over much of the area but are almost completely absent from substantial areas of bedrock as, for example, along much of Chesterfield Inlet. Not shown also are the details of beach ridges, from which the extent of former glacial lakes and marine submergence are largely derived.

On the accompanying map, glacial and associated phenomena are divided into four main groups as follows:

1. Those features that may be attributed primarily to advancing ice (mainly regional, but in part purely local), including drumlins and associated forms (Pl. VIII), crag-and-tail features, and glacial striae.

2. Those features that may be due primarily to the last major period of ice-retreat (as well as minor fluctuations of the ice margin), including eskers (Pl. IX), minor moraines, and outwash aprons.

3. Generalized trend lines for glacial movement, ice-divide, and dislocation features (which are derived from the observations in the first two groups).

4. Locations of the maximum extent of glacial lakes and post-glacial marine submergence.

Admittedly, this arrangement is arbitrary, but the subdivision used should suffice for the practical needs of this chapter and the attendant map-construction.

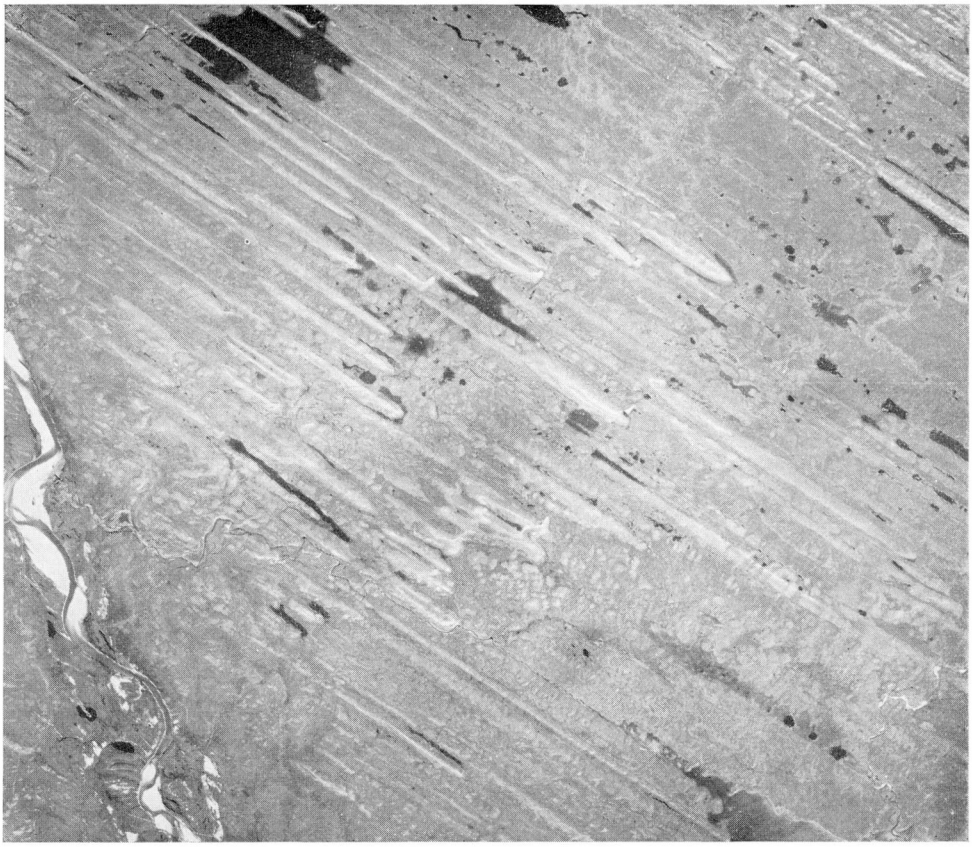

PLATE VIII. Drumlinoid ridges north of Dubawnt Lake. There is essentially no outcrop in the area covered by this photograph.

It is hoped that this map may be of some practical use in the preliminary planning of future transportation facilities. Obstacles to road and railway construction, for example, would include: the coarse, hummocky morainal deposits east of Kasba Lake and in the general area of Boyd Lake; unfavourable orientation of major drumlin concentrations; and, possibly, the narrow belt of flat, featureless, clay-covered material along the west coast of Hudson Bay. On the other hand, such construction would be facilitated by choosing routes that pass along or through areas of large eskers or prominent beach deposits—excellent sources of construction materials. Orientations of some glacial features such as major eskers and groups of drumlins are useful aids to low-level air navigation under adverse weather conditions.

Advancing Ice Features

Glacial striae and crag-and-tail forms give positive evidence of directions of ice-advance, which by and large are supported by orientations of drumlins and related forms (Pls. VIII and IX) also believed to have been produced during an

active phase of the ice-sheet. The drumlin family (Dean, 1953) includes both drumlins proper—composed of sandy till and shaped like inverted spoons, a few tens of feet high, hundreds of feet wide, and thousands of feet long—and drumlinoid ridges and flutings that are narrow and up to miles long. Although these forms occur singly in places, they are much more commonly found in fields of wide areal extent. The symbols on the map are thus designed to show the presence in relative abundance of the forms and their trends, rather than exact locations of individual features.

PLATE IX. Esker system and drumlins near tree-line southwest of Howard Lake, looking west from 15,000 feet.

Recessional Ice Features

Of main interest here are the eskers, predominantly of sand and gravel, that occur in many parts of the map-area. They vary from low, short, sinuous gravel ridges to high, wide, in part dendritic or anastomosing esker systems (Pl. IX) that have been traced, in some instances, for scores if not hundreds of miles. Associated with these in places, as in the region north of Aberdeen Lake, are broad areas of outwash sand deposits.

Eskers, although not genetically related to the features described in the previous section, are oriented everywhere in directions compatible with those of the active ice in any one place.

No large moraines are known in the area, but the location of several minor moraines is plotted. Lee (1959, pp. 12, 13) divided these into two types:

1. 'Ribbed' minor moraines are thought to be shear moraines and to have been formed (along with associated drumlinoid ridges) close to the ice-front by the last active ice in that area. These irregularly spaced ridges are up to 50 feet high and a few hundred feet long, and are of various forms; between them are coarse boulders as in the ridges themselves.

2. 'Straight-edged' minor moraines inland from Hudson Bay near Corbett Inlet are more linear and more regularly spaced than the ribbed variety. These may be annual deposits due to pauses in the retreat of the ice-margin, and if so, their spacing of from 400 to 1,100 feet gives a measure of the rate of retreat of the ice margin.

Two areas of gravel kames with pothole depressions and dry drainage channels, south of Hurwitz Lake and north of North Henik Lake respectively, are taken to mark the heads of outwash aprons that stretched southward and southeastward from former ice-fronts, and indicate that the ice retreated northward and northwestward from these positions (Lee, 1959, p. 14).

Keewatin Ice Divide

The spatial arrangements and orientations of striae, crag-and-tail forms, drumlins and associated features, esker systems, and outwash aprons delineate a broad, elongated zone extending from Hicks Lake through Baker Lake toward Wager Bay at the northeast corner of the area mapped. The glacial features appear to project from or back into this zone, but many of them are much less abundant within it.

This is the Keewatin Ice Divide, first suggested by Lee (*in* Lord, 1953b), and extended by Fyles (*in* Wright, 1955b). It is, essentially, that area into which the contracting ice-sheet shrank. It is defined by Lee, Craig, and Fyles (1957, p. 1760) as the zone occupied by the last glacial remnants of the Laurentide ice-sheet west of Hudson Bay.

Interlobal Discontinuity

Craig (*in* Wright, 1957) pointed out the divergence of separate, overall patterns of glacial movement across a line extending northwestward from Dubawnt Lake (*see* Map 1217A, *in pocket*). He further noted that the differences across this line are expressed not only in directions of movement, but also in the character and distribution of eskers and ice-flow features. Eskers south of the discontinuity are longer, more numerous, and more continuous than those to the north of it, and they seem to possess a more integrated arrangement. Drumlins also differ in that to

the south they are mainly individual, uniformly distributed forms, whereas to the northeast they are very closely packed and in part are elongated flutings; in the northwest part of the map-area drumlinoid forms are rare.

In discussing this arrangement, Craig stated (*in* Wright, 1957, p. 4), "Ice that entered the southeastern side of the map-area[1] moved westward and fanned out to the northwest and southwest. Ice that occupied the northern part of the map-area moved generally northwestward and fanned out to the north and southwest. In between the areas occupied by these two major ice-lobes the ice-flow features indicate some south-southwesterly movements that do not appear to have been directly associated with the retreat of the northern lobe." Apparently the northern lobe superposed its effects on those of the southern lobe in the area southeast of Dubawnt Lake.

The lobal discontinuity, its northwestward extension, and its significance and probable cause are treated by Craig and Fyles (1960, p. 7) in a wide-ranging discussion of Pleistocene geology in northern Canada.

Glacial Lakes and Marine Submergence

Raised beaches and allied phenomena are common in many parts of the map-area. From the region of Kasba Lake to Pelly and Garry Lakes, west of the Keewatin Ice Divide, these features have been taken to mark the positions of former proglacial lakes. The lakes came into existence as the ice-front retreated easterly while still damming escape of waters to lower ground to the east. Vertical successions of abandoned shorelines show that the lake levels gradually lowered as the ice-front retreated. The maximum extent of proglacial lakes is indicated in Map 1217A. Near Mosquito and Carey Lakes and east of Kasba and Ennadai Lakes elevations of abandoned shorelines range up to about 1,200 feet above present sea-level. West of Aberdeen Lake such elevations are between 700 and 800 feet above sea-level.

The relationships between the successive levels of these several large lakes and the retreat of the two major ice-lobes from the area (*see* preceding section) cannot have been simple. Craig (*in* Wright, 1957) stated, "The Thelon proglacial lake, which was formed when the drainage was blocked by the northern lobe, extended into part of the area crossed by the southern lobe." Presumably this is also true of the lake that occupied part of the Dubawnt basin, called Hyper-Dubawnt Lake by Tyrrell (1898, p. 190F).

A provocative feature of these former lake-basins is the apparent general absence of varved clays. This lack, if confirmed, may be due to an essential lack of clay materials in the source bedrock (granites, quartzites, and sandstones predominant over shales and limestones, etc.). Or, in part, it may be associated genetically with the absence of large moraines, if this absence implies that the ice-front failed to persist, with minor fluctuations, in appropriate positions for long enough periods to provide a sufficient, sustained source of fine sediments.

[1] Operation Thelon area, Figure 1.

As the ice gradually retreated westward and northwestward from Hudson Bay and finally disappeared along the Keewatin Ice Divide, the sea followed it and, as far inland as its maximum extent (*see* Map 1217A), reworked in some degree the various unconsolidated glacial deposits and forms. Thus wave-cut and terraced drumlins and eskers, many fine displays of beaches, bars, and spits, and areas of marine sediments and fossils were produced. Lee (1959, p. 17) gave the maximum former stand of the sea in the vicinity of Carr Lake as 560 feet above sea-level, and Fyles (*in* Wright, 1955b, p. 4) suggested 430 feet above sea-level near Baker Lake. Lee (1960, p. 1611) named this sea the Tyrrell Sea, and suggested that it reached its maximum extent 7,000 to 8,000 years ago.

Subsequent uplift of the land due to unloading of the mass of glacial ice has progressively lowered the level of the sea relative to the land, with a corresponding eastward movement of strand lines. This process has continued, but at a much reduced rate, almost to the present.

Chapter IV

GENERAL GEOLOGY

Introduction

The map-area is divisible geologically into two main parts, unequal in size and profoundly different in rock types, structure, and age. These are parts of the Slave and Churchill structural provinces, mainly of Archaean and Lower Proterozoic (Aphebian)[1] ages respectively. Younger, primarily sedimentary sequences, probably of Middle Proterozoic (Helikian) age, are found in both. Various basic intrusive rocks, of several ages within the Precambrian, occur as dykes, sills, and plugs. Only two occurrences of fossiliferous Palaeozoic sediments are known, both of small size.

The rocks of the Slave province underlie approximately 8,000 square miles in the northwestern corner of the map-area. There, steeply dipping metamorphosed sedimentary and volcanic rocks of the Yellowknife Group are intruded by massive granitic rocks of Archaean age. Moderately folded orthoquartzites and some argillaceous and calcareous rocks of the Goulburn Group, probably of Middle Proterozoic (Helikian) age, overlie Yellowknife sediments with profound unconformity.

The rocks of the Slave province are separated from those of the Churchill province to the east along the Thelon Front, an arcuate zone, convex eastward, that extends from Artillery Lake to Western River.

East and southeast of the Thelon Front to Hudson Bay, some 180,000 square miles of the map-area are underlain primarily by a basement complex, mainly of steeply dipping gneissic and impure granitic rocks within which are enclosed bodies of paragneisses and basic volcanic rocks, ranging in size from small to very large. This metamorphic and intrusive complex, according to potassium-argon ages on micas, appears to be in the order of 1,600-1,800 million years old, and may thus be assigned to the Lower Proterozoic (Aphebian). Within this complex are two sequences of moderately folded sedimentary rocks, the Nonacho Group in the southwest and the Hurwitz Group in much of the eastern half of the map-area. The ages of these two groups are not definitely established as yet, but they also are probably Lower Proterozoic (Aphebian). Superimposed on all these rocks, either observably or by strong implication, are extensive, flat-lying sandstones and coarser clastic rocks, igneous (probably mainly extrusive) rocks, and minor

[1] Names in parentheses are those of subdivisions of the Proterozoic proposed by Stockwell in Geological Survey of Canada Paper 64-17, Part II.

carbonate rocks of the Dubawnt Group. The age of this group is not accurately known—its constituent parts may cover a considerable span in time—but it appears to be about Middle Proterozoic (Helikian).

This reconnaissance study has already indicated many key areas or subjects on which more detailed and comprehensive work is required. Three such studies have been started: the Beechey Lake area (Tremblay, L. P., in preparation), especially as regards the internal makeup of the Goulburn Group (15, 16), and the structural and age relations of the granitic rocks across the Bathurst Trench; the Kognak River area (Eade, 1964, 1966), the type region of the Hurwitz Group (8-11), with the hope of unravelling the structure and stratigraphy of these rocks and their relationships to greenstones and granites; and an areal study of the stratigraphy and sedimentation of the Dubawnt Group (18-22) (Donaldson, 1964, 1966), and a parallel petrological study of the associated igneous rocks (20).

It is not intended in the present report to anticipate the results of these specialized studies, which may modify, perhaps drastically, the present treatment of map-units.

The order of discussion herein follows the map-legend and table of formations rather closely. The older sediments and volcanic rocks of the eastern and western parts of the map-area are separated in this treatment, as they are by vast distances on the ground. The gneisses and gneissic granites are ubiquitous and highly varied; their very complexity compels treatment as oversimplified units. The extensive areas of massive granites appear to be more common, or more apparent, in the western half of the region. The younger strata do not present such major problems as the correlation of older greenstones several hundred miles apart.

With the minor exceptions noted above, all consolidated rocks in the region are believed to be Precambrian in age, some Archaean, some Proterozoic. Ages of granitic rocks present peculiar difficulties, and complicate the drawing-up of a rigid legend. The present legend and table of formations are based on both field evidence and, in part, potassium-argon age determinations. Some major problems involving the impact of potassium-argon age determinations on geology in the map-area are discussed in the following chapter, partly because some of them involve more than one of the rock-units described in the present chapter and partly because the treatment is speculative.

For descriptive details and discussions of some geological features in southern District of Keewatin the author has drawn liberally from the report of C. S. Lord (1953).

Sedimentary and Volcanic Rocks

Yellowknife Group (1-3)

The name Yellowknife was introduced by Henderson (1938) in a geological report on the Beaulieu River map-area, north of Great Slave Lake. The group comprised a thick sequence of sedimentary and volcanic rocks of Archaean age. In subsequent years similar rocks have been mapped for long distances to the north

Table of Formations and Correlation Chart

Region			Sedimentary, Volcanic, Granitic, and (in part) Basic Intrusive Rocks				Gneisses Of sedimentary and igneous origin. Derivation, but not necessarily time of formation, is implied horizontally.	Basic Intrusive Rocks (in part) In many cases ages are not known with any exactitude; possibilities are implied horizontally, and may be minimum ages.
			West of 105 Degrees		East of 105 Degrees			
Era	Period	Epoch	Formation	Character	Formation	Character		
Cenozoic	Quaternary	Pleistocene and Recent		Stream deposits: mainly sand Glacial lake deposits: sand, silt, clay Glacial deposits: drift, sand, gravel		Stream deposits: mainly sand Glacial sea and lake deposits: sand, silt, clay Glacial deposits: drift, sand, gravel		
Palaeozoic	Silurian or Devonian					Limestone rubble (25)		
	Ordovician					Limestone (24)		
Proterozoic	Upper Proterozoic (Hadrynian)			Diabase and gabbro dykes and sills (23a)		Diabase and gabbro dykes and sills (23a) and allied dyke rocks (23b)		
			Known or assumed intrusive contacts		Known or assumed intrusive contacts			
	Middle Proterozoic (Helikian)				Dubawnt Group	Limestones (22) Conglomerate (21) Igneous rocks, in large part porphyritic, occur as flows, sills, and minor dykes (20) Sandstone, pebble sandstone, conglomerate; shale and argillite (19) Conglomerate; some sandstone (18)		Basic syenite, diorite, gabbro (F)
			Regional unconformity					
	Middle Proterozoic (Helikian)		Goulburn Group	Hornblende diorite and gabbro (17)				Diorite and gabbro (B) Anorthosite (C) Biotite-hornblende diorite (D) Ultrabasic rocks (E)
				Intrusive contact				
				Quartzite, cobble quartzite, conglomerate (16) Quartzite, argillite and slate, limestone (15)				
			Known or probable major unconformity					

Proterozoic	Lower Proterozoic (Aphebian)	Granitic rocks (intrusive and/or meta-somatic complex)	Mainly impure and gneissic granitic to dioritic rocks; massive varieties; granitic mylonites; some gneisses, schists, granulites (13, 14) (Age indicated is probably metamorphic; may be older in part)	Granitic Rocks (intrusive and/or meta-somatic complex)	Mainly impure and gneissic granitic to dioritic rocks; massive varieties; granitic mylonites; some gneisses, schists, granulites (13, 14) (Age indicated is probably metamorphic; may be older in part)	Undifferentiated stratiform granite gneiss, granulite, migmatite	
		Relations varied; in part uncertain		Relations varied; in part uncertain			
		Great Slave Group	Dolomite (may be younger) (6)	Hurwitz Group	Greywacke, impure quartzite, slate, conglomerate, dolomite and limestone, schist (10) Mainly white quartzite; some impure quartzite, pebble conglomerate; minor iron formation (9)		Diorite and gabbro (A)
		Nonacho Group	Quartzite, greywacke, conglomerate, schist (5)		Greywacke, conglomerate, slate; some schist (8)	Minor gneiss, schist, migmatite (12)	
				Conformable contact in part			
Archaean		Granitic Intrusions	Massive, unfoliated granitic rocks, generally free of inclusions (4)				
		Intrusive contact					
		Yellowknife Group	Impure quartzite, greywacke, slate; derived quartz-mica schist (3) Porphyritic felsite, rhyolite, agglomerate (2) Intermediate and basic volcanic rocks and metamorphic derivatives (greenstones) (1)	'Greenstones' of Keewatin District	Intermediate and basic volcanic rocks and metamorphic derivatives (greenstones); undifferentiated sedimentary rocks; undifferentiated basic intrusive rocks (7) (in part may be younger—possibly within Hurwitz Group)	Gneiss, schist, amphibolite, granulite, and migmatite, derived from sedimentary and volcanic rocks (12)	

Two major sequences are shown vertically. In general, no definite correlation is implied, but units are positioned horizontally as being possible, or in some cases probable, equivalents on the basis of lithology, relative position in sequences, degree of alteration and deformation, relation to intrusive rocks, and K-Ar dates. Map-unit numbers for geological map and legend are shown in parentheses.

(Lord, 1942) and east (*see* Geol. Surv. Can., Map 1055A), and their Archaean age has been confirmed by potassium-argon age determinations (Stockwell, 1961, p. 115).

Within the map-area, rocks of the Yellowknife Group are found only in the northwest corner, north of Artillery Lake. There the group includes intermediate to basic volcanic rocks (1) and derivatives thereof, acidic volcanic rocks (2), and slightly to strongly metamorphosed sedimentary rocks (3). So far as is known, the three units are conformable. In part, these rocks are eastward extensions of Yellowknife rocks in the Walmsley Lake (Folinsbee, 1952) and Aylmer Lake (Lord and Barnes, 1954) areas. Little definite information was obtained within the map-area as to the stratigraphic sequence of the units, and the succession appears similar to that previously established to the west.

Intermediate to Basic Volcanic Rocks (Greenstones (1))

The greenstones probably are derived largely from dacitic and andesitic lavas, and minor undifferentiated sedimentary rocks. They are not abundant, but occur near and northeast of Clinton-Colden Lake, and at Regan Lake. In these localities they are associated with sedimentary rocks (3), which appear to overlie them in places. The lavas generally form relatively massive outcrops in rugged, hummocky terrain of considerably higher relief than that of the sedimentary rocks.

The greenstones are mainly light to dark green, fine-grained rocks that weather various shades of brown and green. They are massive, schistose, or foliated; many are amygdaloidal and some show pillow structures. Breccia and agglomerate are present in a few places. Probably the most common rock-type is a fine-grained, green amphibole schist, not uncommonly garnetiferous. Some irregular veins of milky quartz have been observed in the greenstones.

A small area of greenstone (1a) and associated gneisses, not known to be of Yellowknife age, lies east of Whitefish Lake, and, in places, highly altered greenstones are included with the gneisses (12) in the general area west of Ennadai Lake.

Acidic Volcanic Rocks (2)

The acidic volcanic rocks of the Yellowknife Group include porphyritic (quartz and/or feldspar) felsite, rhyolite, and agglomerate. They underlie a considerable area of relatively high and rugged outcrops southwest of Regan Lake, on the western border of the map-area.

For the most part, these rocks are massive and featureless in outcrops—so much so that even from a low altitude the outcrops in many places appear granitic. The rocks are mainly white, greenish grey, or pale green on fresh surfaces, and weather white to pale grey. Most of them are highly silicic, aphanitic to fine-grained, hard and brittle, and break with conchoidal fracture; a few are schistose. Many contain small, scattered phenocrysts of rounded quartz and/or euhedral feldspar. Agglomerate, containing fragments of the porphyritic acidic rocks, was

seen in several places. Many of these rocks, particularly those associated with agglomerates, are probably rhyolitic lavas, but the more massive, porphyritic types may be intrusive in part.

Sedimentary Rocks and Derived Schists (3)

The sedimentary rocks and derived nodular schists are the most abundant rocks of the Yellowknife Group. They underlie several localities near Clinton-Colden Lake, and much of the northwestern part of the map-area.

Some of these sedimentary rocks are relatively unaltered; others have been highly metamorphosed. The former are mainly impure, fine-grained quartzites, greywackes, and minor slates. Colours vary from light grey or greenish grey in the quartzites, to dark grey in the greywackes, and to black in the slates. The quartzites contain grains of quartz and feldspar in fine-grained matrices, and they grade into greywackes with decrease in quartz content. Many of these rocks are relatively thin bedded, but some beds of quartzite are up to several feet thick.

The sedimentary strata dip from about 40 degrees to vertical. Tops of beds are generally not determinable, but in a few places the beds are known to be overturned. Many of these rocks, particularly the highly metamorphosed types, are schistose. The schistosity commonly appears to be parallel with bedding, but in some places schistosity and bedding diverge by as much as 80 degrees. No detailed structural information is available, but it seems likely that the strata are isoclinally folded and no estimate of their true thickness can be made at present.

Small areas of massive and structureless rocks (3a), which show a fine-grained clastic texture under the microscope, are present in the extreme northwest corner of the map-area. In outcrops they are characterized by a light yellow-brown weathered surface and by a lack of the prominent loose, slabby surface so commonly displayed by many exposures of Yellowknife sediments. These rocks are mainly impure quartzites containing varying but subordinate amounts of feldspar, chlorite, sericite, and brown biotite.

The sedimentary rocks (3) southwest of Regan Lake are intertongued with acidic volcanic rocks (2), and on the northeast shores of Clinton-Colden Lake they lie along the flanks of ridges of greenstone (1). The contacts between the sedimentary rocks (3) of the Yellowknife Group and granitic rocks (13, 4) are varied. In places, zones of gneissic rocks (12) or mixed intrusive and metamorphic rocks (12b) are present, but northeast of Malley Rapids, the intrusion of massive granite (4) into Yellowknife strata has produced a 'wrap-around' structure with relatively sharp contacts.

Many of the sedimentary rocks of the Yellowknife Group have been strongly metamorphosed with the production of much medium-grained quartz-mica schist (in part coarsely nodular) and some phyllites. The main nodule-forming minerals are euhedral pink andalusite and greasy brown staurolite, and a blue-grey micaceous aggregate (pinite?) that appears to have formed from andalusite, and

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possibly cordierite. Cordierite has been identified in only a few thin sections; its relative scarcity may be due to the ease with which it alters to pinite.

In general, the effects of metamorphism seem to be much more marked towards the south, particularly around Clinton-Colden Lake, where many of the rocks are coarsely nodular quartz-mica schists that show no remnants of clastic textures under the microscope. To the north—near Beechey Lake, for example—although scattered outcrops contain metacrysts of andalusite and staurolite, the sedimentary rocks appear to be much less altered, and their clastic nature is still quite discernible in many cases. However, at the scale of mapping employed, it was found impossible to map distinctive zones of metamorphism such as those demonstrated elsewhere in metasediments of the Yellowknife Group (Tremblay *et al.*, 1953).

Nonacho Group (5)

Extending northeast from Tent Lake to near the northwest bay of Whitefish Lake is a narrow, hook-shaped band of folded sedimentary rocks (5). These probably represent the northeasterly extension of the Nonacho Group, as mapped originally by Henderson (1939) and subsequently extended by Wright (1952) in the region southwest of Tent Lake.

Within the map-area these rocks include quartzite and arkosic quartzite, schistose greywacke and phyllite, and pebbly quartzite and conglomerate. Most of the rocks are sheared, in some places strongly so, and contain much sericitic mica. Dips are steep to vertical, but the tops of beds are not generally determinable. The rocks appear to form a southwesterly plunging syncline.

Nonacho sediments occur within gneissic granitic rocks (13). In some places the contacts are sharp, but in others, zones of 'lit-par-lit' mixed gneisses (12b) are present at and near them. The sedimentary strata are also known to pass concordantly across the strike into pink, fine-grained, well-foliated to stratiform, feldspathic gneisses of doubtful origin that have been mapped with the gneissic granites, although they may represent at least in part mylonitized arkosic sediments.

None of the Nonacho rocks is highly metamorphosed. In many localities their clastic texture is quite evident both in outcrops and under the microscope. To a certain extent they resemble the less metamorphosed parts of the Yellowknife sediments (3) to the north, or rocks of the Sosan Formation (Wright, 1952) in the East Arm of Great Slave Lake.

Pebbles of granite are present in the conglomerate of this group, proving that at least some of the granite of the region is older than the Nonacho rocks. The apparent deep infolding of Nonacho strata into granitic gneisses (13) and the development of mixed gneisses between the sedimentary and granitic rocks, however, at least suggests a younger age for the latter. This dual relationship of Nonacho sediments to granitic rocks has long been an object of interest and argument (Henderson, 1948; Burwash and Baadsgaard, 1962). Stockwell (1963b, p. 128) considered the Nonacho rocks to be Lower Proterozoic (Aphebian).

Great Slave Group (6)

Crystal Island and nearby small islands in Artillery Lake are underlain by buff-weathering dolomite, much brecciated in part. One sample weathers pale buff and is light grey on fresh surfaces. It contains about five per cent tiny rounded grains of quartz and some of feldspar in a fine-grained dolomitic matrix. Quartz stringers containing clusters of small, clear quartz crystals have been reported in these rocks by J. W. Tyrrell (1902, p. 18).

These carbonate rocks presumably represent the northeasterly extension (and termination) of the dolomitic limestones of the Pethei Formation in the East Arm of Great Slave Lake (Stockwell, 1936; Wright, 1952) and, if so, they may be of Lower Proterozoic (Aphebian) age. They could, however, be a distinct, younger unit, even equivalent to the Dubawnt carbonate rocks (22). This possibility receives some support from their apparent relationship to nearby granitic rocks, which they seem to overlie.

Greenstones and Allied Rocks (7) in District of Keewatin

The oldest rocks recognized in the eastern parts of the map-area are altered, intermediate to basic, volcanic rocks (greenstones) with derived amphibole schist and gneiss, and associated undifferentiated sedimentary rocks, and probably undifferentiated basic intrusive rocks. The main occurrences of such rocks are in southern District of Keewatin, particularly in the wide, northeasterly-trending belt between Ennadai Lake and Rankin Inlet. Lesser, but important, greenstone areas are found south and northwest of Baker Lake, and small bodies of such rocks are not uncommon within areas of granitic gneisses (13).

In discussing these volcanic and associated rocks in southern Keewatin, Lord (1953c, pp. 2, 3) stated, "The greenstones derived from the andesitic lavas are dark green to nearly black on fresh and weathered surfaces, whereas those formed from the dacitic members are green to greyish green rocks that commonly weather buff, pink, or grey, and here and there display a little visible quartz in the groundmass or in amygdules. The greenstone body at Rankin Inlet comprises intercalated, pillowed to massive greenstones, undoubtedly derived from lavas; massive, medium-grained, dioritic greenstones; and thin-bedded, light grey, quartz-sericite schists, possibly derived from tuffs. The texture and form of the dioritic greenstones suggest that they might be intrusive sill-like bodies, but here and there near their borders they contain a few amygdules as much as 5 inches in length and may, therefore, be of extrusive origin."

The east-trending greenstone belt north of MacQuoid Lake consists of fine- to medium-grained hornblende-rich rocks that are probably mainly of volcanic origin, but that may be to some extent altered basic intrusive rocks. They are well foliated in places and contain many quartz veins. The wide, northeasterly-trending greenstone belt that crosses lower Thelon River is composed mainly of altered, schistose to massive, volcanic rocks near Half Way Hills, and to the north, pale green to buff weathering, fissile schists, some of which, under the microscope, are

seen to be chloritic greywackes, or possibly tuffs. Several small areas northwest of Tehek Lake are underlain by dark green, relatively massive, chlorite- and/or hornblende-bearing rocks.

The greenstones are commonly fine-grained and schistose to massive; some exhibit pillow structures but most do not. In thin sections, many greenstones are seen to be highly altered aggregates of feldspar, amphibole, chlorite, epidote, zoisite, quartz, and other secondary minerals, but some are massive, medium-grained, hornblende-rich rocks of somewhat higher metamorphic grade.

These rocks are commonly foliated, with steep to vertical dips. They have been intruded by granitic rocks (13), and have been altered in places to hornblende schists and gneisses.

The main occurrences of the greenstone assemblage (7) seem related, at least geographically, to the rocks of the Hurwitz Group (8-11). Lord (1953c, p. 3) noted that "Much of the greenstone assemblage is clearly older than the Early Proterozoic strata[1]. However, in a few places, such as near South Henik and Quartzite Lakes and Rankin Inlet, inconclusive evidence suggests that some greenstones may overlie the Early Proterozoic quartzites . . . ." In central Keewatin, the greenstones are commonly associated with a similar, prominent, white quartzite (9) of the Hurwitz Group. In Half Way Hills, greenstones conformably underlie the quartzite, although in places they are interlayered along the contact. At MacQuoid and Yathkyed Lakes, the greenstones are not associated with the white quartzite, and there they may be older, although lithologically indistinguishable.

In summary, it would appear that many of the greenstones are at least slightly older than much of the Hurwitz sedimentary sequence, and may in fact be much older (Archaean). On the other hand, it is possible that an unknown portion of the greenstone assemblage is properly a major constituent of the Hurwitz Group, in age partly bracketing the quartzite (9) to which, in many places, it shows close affinities, both geographically and structurally.

Hurwitz Group

The name Hurwitz Group was applied by Wright (1955) to the prominent white quartzite (9) and associated greywacke, conglomerate, impure quartzite, sedimentary schist, and carbonate rocks first mapped on a regional scale in southern Keewatin, between Ennadai Lake and Rankin Inlet, by Lord (1953c, map-units 4-7). Wright, in naming the group, extended its application, mainly on the basis of pronounced similarities in rock types in places with directly comparable stratigraphic sequences, to several areas northwest of Baker Lake, and to scattered smaller areas northwest of Beverly Lake and north of Dubawnt Lake in central Keewatin, and finally (1957) to one isolated ridge-forming outcrop in eastern District of Mackenzie. It is of interest to note the relative abundance of the white quartzite in District of Keewatin, and its almost complete absence from

[1] Hurwitz Group of the present report.

Dubawnt Lake west to the Yellowknife area. In the present discussion, this white quartzite (9) is considered to be the main unit within the Hurwitz Group.

The type *region* (rather than *section*) for the Hurwitz Group, where its overall nature was first studied and where its rocks are most completely exposed, may be taken as that area in southern District of Keewatin which includes Watterson, Hurwitz, and the Henik Lakes.

Hurwitz Sediments (8) Below the Quartzite (9)

In southern Keewatin, Lord (1953, p. 3) discussed a sedimentary unit (8) that underlies the white quartzite. This lower unit[1] of the Hurwitz Group was not recognized as such in central Keewatin, but may comprise part of map-unit 11, undifferentiated Hurwitz rocks. In describing these rocks, Lord stated, "The Early Proterozoic greywackes (4)[2] are fine- to medium-grained rocks that weather grey, greenish grey, or buff. The coarsest phases display readily visible grains of quartz and white feldspar. Much of the rock is slightly schistose and apparently without readily definable bedding. Here and there, however, the greywackes display sharply defined, thin beds, a few of which grade from coarse at the bottom to fine at the top. Conglomerate is particularly abundant between Hurwitz and Fitzpatrick Lakes, where it is apparently intercalated with greywacke as lenses, discontinuous beds, and groups of beds separated by a little greywacke. It consists of rounded pebbles and cobbles of grey to pink, medium-grained, granitic rocks, fine-grained white quartzite, greenish volcanic rocks, jasper, and quartz, in this relative order of abundance, in a matrix of fine- to medium-grained micaceous greywacke. The largest cobbles exceed 10 inches in diameter and, together with the pebbles and smaller cobbles, locally comprise 30 per cent or more of the rock; however, their abundance, relative to the matrix, varies widely from place to place. The greywackes and conglomerates have, in part, been altered to medium-grained biotite schists, some of which still contain scattered, recognizable granitic pebbles. The bedding is steeply inclined. These strata were not found in contact with the Archaean rocks (1, 2)[3], but the composition of the conglomerate suggests an intervening period of uplift and erosion and, therefore, an unconformable contact."

White Quartzite

White quartzite is the most distinctive rock-unit in the Hurwitz Group. It is unique, both in being essentially pure white and being composed of pure quartz. Notable, too, is its pronounced tendency to stand up as relatively high, and in some cases sinuous, ridges essentially parallel with its strike. It is, literally, the backbone of the group. In the main, the quartzite is massive or thin- to thick-bedded, pure white or less commonly pink, sugary to nearly glassy, fine- to

[1] From detailed work in 1962 and 1963, Eade tentatively concluded that sediments (8) older than quartzite (9) are actually unconformably below it and constitute part of the greenstone assemblage (7) previously described.

[2] Map-unit 8 of the present report.

[3] Greenstones (7) and granites (13) of the present report.

medium-grained, and is composed almost entirely of quartz. In some places, as near South Henik Lake, pale purplish quartzites occur near the base of the unit, and pinkish grits are known in several places. There are some bands of pebble conglomerate up to 25 feet thick, with pebbles up to 5 inches in diameter of jasper, quartz, and dense siliceous rocks. Locally, as east of Whitehills Lake, the quartzite is schistose and carries considerable white mica and potassium feldspar. From the air it is difficult to distinguish it from light-coloured granitic rocks (13).

Useful ripple-marks and crossbedding are fairly abundant in this rock in southern District of Keewatin, but were not observed elsewhere. The quartzite beds have moderate to steep dips and, in places, are probably overturned. In aggregate thickness the quartzite strata may range from a few tens of feet to several thousand feet as, for example, near the Henik Lakes and Half Way Hills, but the greater apparent thicknesses may represent unrecognized isoclinal folding.

The distinctive colour, composition, and topographic expression of the Hurwitz quartzite over a north-south distance of several hundred miles, and its generally closely comparable geological associations, suggest that it may be of approximately the same age throughout this region. If there is a reasonably reliable unit for tentative regional correlation in the eastern barren grounds, this would appear to be it.

The relationships of the Hurwitz quartzite (9) to greenstones (7) have been discussed in the preceding section; mainly the quartzite appears to be younger. The quartzite appears to have conflicting age relationships with the gneissic granites (13) of the region. At Watterson Lake and elsewhere, it directly overlies granite, although actual contacts are obscured. The remarkably pure quartz sand that gave rise to the quartzite seems to require the existence of extensive older granite to provide an ultimate source, and the presence of granitic cobbles in conglomerate (8) underlying the quartzite proves that some granite, at least, is older than the quartzite. However, in central Keewatin granite locally intrudes the quartzite, and the presence here and there of considerable potassium feldspar and white mica, plus the fact that some of the overlying sediments have been converted to schist and hornfels, suggests a post-Hurwitz granite. In the Rankin Inlet area, mica schist (10) immediately overlying quartzite (9) is cut by granitic dykes. This problem is inextricably bound to that of the origin and age of the granitic rocks (*see* Chaper V).

Hurwitz Sediments (10) Above the Quartzite (9)

The younger rocks (10) of the Hurwitz Group include: fine-grained, thin-bedded, grey to green greywacke; massive to bedded, pink or grey feldspathic quartzite; some dark slate; conglomerate; buff-weathering dolomite with prominently ribbed weathered surfaces; lesser fine-grained quartz-mica schist and spotted, micaceous hornfels; and a very minor amount of crystalline limestone. These rocks are generally much lower lying and less well exposed than is the quartzite (9), with which they seem conformable although few actual contacts were seen. Conglomerate structurally overlies quartzite south of Half Way Hills,

and in several places along the central part of the major quartzite belt northwest of Tehek Lake south-dipping quartzite is conformably overlain by buff dolomite (10) and this in turn by greywacke. This sequence appears identical with that at Watterson Lake in southern Keewatin. Similar sequences of moderately inclined sediments of this unit occupy other quartzite-rimmed basins between Watterson and South Henik Lakes.

Undifferentiated Hurwitz Sediments (11)

In some places, undifferentiated Hurwitz-type sedimentary rocks (11) cannot be reliably placed in relation to the quartzite (9), even though locally they contain small bodies of quartzite. A considerable area underlain by these sediments lies east of Half Way Hills and north of Baker Lake. Much of the forest-covered terrain between Kasba and Nueltin Lakes also is underlain by such rocks, including, in places, conglomerate (8), white quartzite (9), and dolomite (10).

Origin and Age of the Hurwitz Group

In discussing the origin of Hurwitz rocks in southern Keewatin, Lord (1953, p. 4)[1] stated, "The relations between the quartzite (5) and greywacke and conglomerate (4) on the one hand, and quartzite with some of the granitic rocks (2) and greenstone (1) on the other, seem to require, at the close of Archaean time, a hilly surface carved from the complex of greenstone and granitic rocks. The greywacke and conglomerate were deposited in the lower parts of the basins and valleys of this surface, and deposition of the quartzite-forming sediments followed immediately. Thus, in a few places, these were deposited without significant break on the oldest Early Proterozoic strata (4), whereas elsewhere they encroached on the higher parts of the Archaean surface and, therefore, rest unconformably on greenstone or granitic rocks."

K. E. Eade (1964) considered that the older Hurwitz sediments are separated from the quartzite by an angular unconformity, although this is not evident everywhere. However, this does not necessarily invalidate Lord's outline of sedimentary deposition. Moreover, the presence of this unconformity within the Hurwitz Group removes the necessity of explaining rapid changes in environment of sedimentation sufficient to cause alternations from unsorted and coarse clastic sediments (8) to pure quartz sand (9) and then the reverse (10) without a major break.

In central Keewatin, although the rock types, and in places their sequences, are similar, the tendency for the white quartzite to be a sinuous structural marker within a larger group of sediments, as in the type region, no longer holds. At Whitehills Lake it forms massive ridges, mainly of quartzite, and in the main body north of Schultz Lake a very large mass of white quartzite is overlain by dolomite and greywacke, but apparently has no underlying sediments and, we might add, no

[1] Lord's units 5, 4, 2, 1 in this paragraph are map-units 9, 8, 13, 7 of the present report.

known greenstones. Isolated lenses of Hurwitz-type quartzite occur in granitic gneisses northeast of Tehek Lake, and a few are known in northern Keewatin outside the map-area (Heywood, 1961, map-unit 3). The sheer volume of detrital quartz required to form masses of what are probably multi-cycle quartzites appears to be much greater in central than in southern Keewatin.

Hurwitz rocks are presumably much older than those of the Dubawnt Group (18-22), which on a regional scale appear to overlie them, and which in places contain cobbles of Hurwitz quartzite in their conglomerates. The Hurwitz rocks are not highly metamorphosed. On the basis of composition, structure, metamorphism, and relations to some dated granitic rocks (*see* Chapter V), the Hurwitz Group may be approximately equivalent to the Nonacho (5) and Great Slave (6) Groups of Lower Proterozoic (Aphebian) age (Stockwell, 1963b) in eastern District of Mackenzie. The rocks of the Hurwitz Group are cut by diabase dykes (23a), presumably of Middle or Upper Proterozoic (Helikian or Hadrynian) age.

Disappearance of the Hurwitz

Geological reconnaissance in the areas west of Kasba Lake (Taylor, 1957, 1963), south of it (Tremblay, 1960), and southeast of it (Fraser, 1962) indicates the probability that Hurwitz rocks disappear by granitization into gneissic terrain along their regional trend to the southwest of their type area. Thus, Taylor's[1] unit 7, Tremblay's unit 1, and Fraser's units 1, 2, and 3 all appear to be likely equivalents of the Hurwitz sediments. Tremblay[1] and Fraser[1] both believe these sediments have been reconstituted into schists, gneisses, and granitized rocks. An interesting possibility arises in this connection: that the Hurwitz sediments, granitized to the southwest, loop back to the east and northeast and finally through the Munro Lake area (Davison, 1963), to reappear as thoroughly metamorphosed gneisses (12) in the area east of Nueltin Lake.

Relations of the Hurwitz sediments, if the units specified above are included, to granitic rocks of the region are in turn obscure, puzzling, and contradictory. In the type region of southern Keewatin, Lord (1953, pp. 6, 7) postulated two granites of pre- and post-Hurwitz age respectively, but lithologically indistinguishable. In many places the white quartzite appears to overlie granites, and associated conglomerates contain boulders of granitic rocks. Eade[1] in 1964 found evidence of contact metamorphism of Hurwitz sediments north of Bernier Lake. Tremblay considers that Hurwitz-type sediments have been granitized, and Fraser that they have been intruded by granite. Potassium-argon age determinations (*see* Chapter V) on granitoid rocks add to the present uncertainty by strongly suggesting that some of the so-called Proterozoic granitic rocks of the region are derived from Archaean rocks by metamorphism, whereas others are probably of igneous origin.

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[1] Personal communications

Goulburn Group (15, 16)

The Goulburn Quartzite of the Bathurst Inlet region was originally described by O'Neill (1924) as a sequence, more than 4,000 feet thick, of pink and grey quartzites with many conglomeratic layers.

In the extreme northwest corner of the map-area a group of rocks, predominantly quartzites, is probably the southern extension of the Goulburn Quartzite. Aerial reconnaissance indicated that these rocks extend well north of latitude 66°, but actual continuity to the outcrop areas of the Goulburn Quartzite was not shown until 1962 when J. A. Fraser (1964) mapped the area to the north. The name Goulburn Group was tentatively assigned to these rocks by Wright (1957), and south of latitude 66° the group was divided for mapping purposes into a lower unit (15) of quartzites, slates, and dolomites, and an upper unit (16) of quartzite and conglomerate.

The rocks of the Goulburn Group form relatively rugged hills (almost mountains by barren-grounds standards) that overlook the granitic gneisses to the east of the Bathurst Trench and the metasedimentary lowlands to the south and west (Pl. III). The lower unit is probably hundreds of feet thick and the upper unit may be thousands of feet thick.

Lower Unit (15)

The lower unit of the Goulburn Group has at its base an impure, pebbly quartzite or conglomerate, overlain by a mixed succession of thin- to thick-bedded, grey to green quartzites and pebbly quartzites, green to red argillites and slates, and some dolomite and dolomite-quartzite rocks. On the east side of the western outcrop area of this unit, a postulated combined section may exceed 1,500 feet in thickness.

At the intersection of Western River and the Bathurst Trench a complex (15a) is outlined in which sills of diorite (17) are present in folded quartzite and dolomite of this unit.

Upper Unit (16)

The upper unit (16) of the Goulburn Group consists essentially of massive, pink to grey, medium-grained, sandy orthoquartzite, impure arkosic grit, and pebbly quartzite with many gradations to conglomerate. Aerial reconnaissance to the north of the map-area indicated the presence of at least one carbonate member in this unit. A common cobble-forming rock in the conglomerates is a pure white quartzite (Hurwitz?). The upper unit is much more extensively exposed than the lower unit. It forms rolling hills for many miles west of the Bathurst Trench (Pl. III).

Northeast of the east end of Beechey Lake, along the southward extension of the Bathurst Trench, is a narrow, folded belt of massive-bedded, pink quartzites (16a) with conglomeratic lenses. In the same area, one outcrop of conglomerate contains boulders of an older conglomerate. These rocks probably belong to the upper unit of the Goulburn Group, but it is possible that they are related to the Dubawnt sandstones (19) to the southeast.

Structural Relations and Age

The two units of the Goulburn Group, so far as is known, are conformable. They are moderately folded, and dips of strata range up to about 45 degrees. Pronounced canyons within the outcrop area probably represent faults, and the Bathurst Trench appears to be the locus of a major fault that has abruptly cut off the sedimentary strata on the east. The gently dipping beds of the lower unit were seen resting on the upturned edges of the Yellowknife sedimentary rocks (3) in several places, and it is presumed that the same markedly unconformable relationship applies to the vertically dipping granitic gneisses (13) of the region. No granitic rocks are known to intrude the Goulburn strata in the map-area, and the unconformity beneath the group apparently represents a major break in both sedimentation and igneous activity.

The age of the Goulburn rocks is not accurately known. They are obviously much younger than the Yellowknife strata (Archaean), and are probably somewhat older than the Middle(?) Proterozoic (Helikian?) or younger rocks of the Coppermine River Series (not present within the map-area) and the Dubawnt Group; at any rate, they are more disturbed than either of the latter. In the Bathurst Inlet area to the north, O'Neill (1924) considered the Goulburn Quartzite to be older than the rocks of the Coppermine River Series. The Goulburn rocks are less disturbed, and seem to be less metamorphosed than some, if not all, of the rocks of the Nonacho and Hurwitz Groups of Lower Proterozoic (Aphebian) age. In addition, unlike the rocks of these two groups, they appear to rest on, rather than to be folded into, the granitic gneisses (13) of the region. It must be admitted, however, that within the map-area Goulburn sediments are nowhere in reasonably close proximity to the Coppermine River, Dubawnt, Nonacho, or Hurwitz rocks. L. P. Tremblay[1] collected two specimens for potassium-argon age determination that bear on this problem. One is from a gabbro sill intruding lower Goulburn rocks, and one is from clastic mica from an argillite near the base of the group. These give ages of 1,215 and 2,380 million years, respectively, and provide upper and lower limits for the age of the lower unit of the Goulburn Group.

From this admittedly indirect evidence it appears probable that the Goulburn Group is approximately of early Middle Proterozoic (early Helikian) age.

[1] Personal communication; *see* Table VI, determinations 40 and 43.

Dubawnt Group (18-22)

The name Dubawnt Group was first proposed by Wright (1955) for the relatively flat-lying, unfossiliferous, vari-coloured sedimentary and associated igneous rocks that form an extensive, but discontinuous, unconformable 'blanket' over much of the central barren grounds north and northwest of a line from the east end of Baker Lake to Yathkyed and Kamilukuak Lakes. The group was later extended (Wright, 1957) to include large areas of clastic sediments and some carbonate rocks in the area southwest, west, and northwest of Dubawnt Lake.

Tyrrell (1896), who carried out an epic canoe reconnaissance through the central barren grounds in 1893, encountered some of the conglomerates, sandstones, and igneous rocks discussed in this section. The sedimentary rocks he called Athabasca sandstone and conglomerate, and he assigned them to the Cambrian. However, these rocks are separated by more than 200 miles from the type localities and major outcrop areas of the Athabasca Formation (Fahrig, 1961). Although the rocks in these widely separated areas may be of approximately the same age, and are physically similar in some respects, it was believed preferable to give a distinct name, Dubawnt Group, to the rocks herein described. The rocks of both the Athabasca Formation and the Dubawnt Group are believed to be Proterozoic rather than Cambrian in age. This opinion, however, is not unanimous (Gussow, 1959).

The rocks of the Dubawnt Group, as here defined, occur over an east-west distance of more than 300 miles, and a north-south distance of some 250 miles. It is possible that this group (super-group?) may be broken down into two or more distinct groups in the future; certainly, many sub-units of more local extent will be distinguished. No all-inclusive type section or even localized type area is presented here, because of the likelihood of major subdivision in the future.

These younger rocks are generally much fresher and much less indurated than the older volcanic and sedimentary rocks and dip at lower angles. In most cases they are readily distinguished by these characteristics. Nowhere are Dubawnt rocks known to be strongly folded; they are not known to contain fossils; and no evidence of other than minor and local low-grade metamorphism has been seen in them. Although, in general, post-consolidation alteration seems rare, these rocks in places are sheared or cut by quartz stringers. In a large area west of Thirty Mile Lake and north of Yathkyed Lake, porphyritic Dubawnt volcanic rocks (20), granitic gneisses (13), Dubawnt conglomerate (21) containing cobbles of these rocks, and Dubawnt porphyry dykes cutting granitic gneisses some distance from the Dubawnt-granite contact are all epidotized, in some instances heavily so. A similarly epidotized Dubawnt conglomerate is found on an island near the entrance to Outlet Bay of Dubawnt Lake.

The occurrences of Dubawnt rocks commonly consist of widely scattered, low, rounded, pancake- or mesa-like outcrops with drift-covered contacts against other rocks, so that external relationships or internal stratigraphic details are

known in few places. The areal extent of these flat-lying rocks clearly indicates that, with the exception of late dyke rocks (23a, b), minor Palaeozoic rocks (24, 25), and possibly, but not certainly, some granitic rocks (*see* p. 58) they are the youngest rocks in the region.

On the basis of reconnaissance studies, the Dubawnt Group has been divided into five units for mapping purposes, namely basal conglomerate (18), sandstones (19), volcanic and associated igneous rocks (20), upper conglomerates (21), and limestones (22).

Lower Dubawnt Conglomerate (18)

The oldest known unit in the Dubawnt Group is a basal conglomerate that is clearly recognizable only at and south of the east end of Baker Lake, and on the west side of Dubawnt Lake; a conglomerate described by Lord (1953, p. 5) near Angikuni Lake may be basal in part. No basal conglomerate was recognized along the entire western and northwestern limits of the Dubawnt outcrop area. These conglomerates are mainly reddish or brown in colour, and commonly carry well-rounded pebbles, cobbles, and boulders of granitic and other gneisses in gritty, arkosic matrices. Arkose, with few or no pebbles, also occurs as intercalated lenses within the conglomerates. At the east end of Baker Lake, the conglomerate dips west at 40°, and appears to rest with marked unconformity on the old, steeply dipping gneisses (12) of Chesterfield Inlet. West of Dubawnt Lake, the conglomerate grades upward into sandstone (19).

Dubawnt Sandstones (19)

An assemblage of rocks, consisting mainly of impure sandstones but with some arkoses, grits, and siltstones, apparently conformably overlies the older conglomerate (18) at the east end and to the south of Baker Lake. Other sandstones occur southwest of Baker Lake and cover a very large area west of Aberdeen and Dubawnt Lakes. The finer-grained siltstones, however, seem to be restricted largely to the east end of Baker Lake. The sandstones and associated rocks commonly occur as scattered, low-lying outcrops, separated by wide expanses of grassland, sand, or rubble, and they presumably represent remnants of a formerly extensive but relatively thin sheet of such rocks. In some places, however, as in one section of the Marjorie Hills, they form prominent, steep-sided cuestas; near Steel Lake, hills of crossbedded sandstone rise more than 500 feet above Thelon River. In these instances the sandstone is more than 400 feet thick, but its true thickness likely varies considerably from place to place.

The sandstones and associated sediments vary widely in colour, composition, and grain size, and in internal structures. In general, they have in common crossbedding and a porous and permeable texture with a corresponding low degree of induration, although there are notable exceptions to the latter. A preliminary study of the petrography of the Dubawnt sandstones confirms the general impression gained from the field work as to the overall characteristics of the rocks and

their approximate distribution within the unit. These conclusions, however, can be expressed only in the broadest terms, in that the sandstones may be divided tentatively into two main groups.

On the southeastern flank of the Dubawnt outcrop area—around and particularly southeast of Baker Lake, and southwest of Yathkyed Lake—the rocks are mainly red to brown, medium- to coarse-grained, immature and poorly sorted grits, arkoses, and impure feldspathic sandstones or subgreywackes. Some contain carbonate minerals in their matrices. On the islands at the east end of Baker Lake these rocks are found in association with mud-cracked and ripple-marked siltstones and argillites. These generally impure clastic rocks and the underlying coarse-grained conglomerate (18) are clearly related to the nearby major unconformity against the regional granitic rocks (13) and gneisses (12).

To the west and northwest, in the region from Sid Lake in the southwest to Aberdeen and Garry Lakes in the northeast, is a great sheet of mainly white to buff, highly porous, crossbedded, fine- to medium-grained, and largely equigranular orthoquartzites (quartz sandstones). Although variations in colour, texture, composition, and degree of induration do occur, a very common type comprises 80 to 90 per cent well-rounded quartz grains showing conspicuous quartz overgrowths, with a few per cent of very fine-grained chert and some clay in the matrix. In some specimens, the presence of considerable clay in an otherwise extremely well sorted and mature sandstone seems anomalous. Carbonate material (apparently dolomite) in the matrix of these sandstones is rare and, perhaps significantly, is known only from the area near Thelon River between the two outcrop areas of Dubawnt limestones (22). In a few places along Thelon River northwest of Lookout Point, thin-bedded, fine-grained sandstone and siltstone are interbedded with seams of shaly material. Pebble-rich layers are relatively common within the sandstones, and in some instances the sandstones as mapped contain enough pebbles and cobbles to be considered conglomerate. In such cases the distinction between pebbly sandstone (19) and conglomerate (21) is arbitrary.

Igneous Rocks (20) of the Dubawnt Group

The igneous rocks of the Dubawnt Group are widespread in the region from Baker Lake southwest to Kamilukuak Lake and north to Dubawnt and Beverly Lakes. A smaller area within the big bend of Thelon River is underlain by similar rocks. For the most part their thickness is unknown but, where they are thought to be extrusive, it is unlikely that the thickness of individual flows exceeds 100 or 200 feet. They commonly form low, rounded to mesa-like outcrops that in many cases are widely scattered in grassland of low relief.

These rocks are light to dark purple, shades of green, brown, or red, or almost black. They vary in grain size from nearly aphanitic to coarse. Many of them are strikingly porphyritic, with phenocrysts of one or more of biotite, pyroxene, minor olivine, feldspar, and quartz in an aphanitic to fine-grained groundmass. Most outcrops are relatively massive or display vertical or sub-

horizontal jointing, but some show amygdules, flow-layering, and, in one case, pillow structures. Thin sections of Dubawnt igneous rocks show much alteration, with abundant carbonate, iron oxide, and other secondary minerals commonly effectively masking the original composition.

A general study of the Dubawnt igneous rocks indicates the following main types: massive, fine- to medium-grained, sub-porphyritic, generally dark rocks carrying biotite and pyroxene as phenocrysts and in the groundmass; medium- to coarse-grained, porphyritic (feldspar and/or quartz), generally lighter-coloured types; and relatively coarse-grained, deep red, porphyritic (feldspar) rocks. The matrices vary from aphanitic to fine grained and may contain the same minerals that make up the phenocrysts. Often, however, the groundmass consists largely of a very fine-grained felt of potassium (?) feldspar microlites. In general terms, these rocks appear to be relatively basic in the east (Baker Lake) and southwest (Kamilukuak and Yathkyed Lakes) and more acidic in the central areas, particularly in the wide belt between Mallery Lake and Kazan River.

The non-porphyritic rocks of this unit include agglomerates, breccias and tuffs, and amygdaloidal volcanic rocks; pillow lavas are rare. Small, low outcrops that appear to be in part rhyolite tuff and breccia and in part highly weathered conglomerate overlie granite-gneiss (13) in several places on the southwest shore of Nicholson Lake. In the area west of Lookout Point on Thelon River the most common rock type is a massive, dull purplish brown, fine-grained rock that occasionally carries greenish chlorite-carbonate amygdules up to a few mm in diameter. The groundmass consists largely of plagioclase microlites, with some of potassium feldspar, muscovite, ferromagnesian minerals, and an indeterminate, brownish material in varying amounts. These rocks probably range in composition from trachytes to andesites. Northeast of Lookout Point a small area of massive porphyritic syenite is included in this unit.

The igneous rocks of the Dubawnt Group appear to have several modes of origin. They occur as red porphyry dykes cutting other Dubawnt and older rocks (Tyrrell, 1896, p. 77F). South of Baker Lake, where the Dubawnt igneous rocks are in part massive hill-formers, they are believed to be intrusive stocks or plugs, at least in part. In the same general area they have been found between layers of Dubawnt sedimentary rocks (19) and are probably sills. From Thirty Mile Lake to Tulemalu Lake, and elsewhere, porphyritic rocks occur over a very large area of widely scattered, low outcrops and are thought to be lava flows, as are the amygdaloidal and rare pillowed rocks.

Upper Dubawnt Conglomerate (21)

Conglomerates of the Dubawnt Group not definitely known to be basal, many of which contain pebbles and cobbles of Dubawnt sandstone (19) or porphyry (20) or structurally overlie the latter rocks, are grouped together as one map-unit (21). This map-unit, however, may include conglomerates of several different ages, and even some outcrops of basal conglomerate (18).

The upper conglomerate, together with pebble-sandstone and bands of intercalated sandstone, underlies large areas around Schultz Lake and south of Aberdeen Lake, and forms isolated outcrops north and east of Dubawnt Lake, northwest of Beverly Lake, and near the western and northwestern borders of the Dubawnt sandstone (19).

Although this conglomerate may contain pebbles and boulders of any older rock, it is most distinctive where it carries cobbles of pure white Hurwitz quartzite (9) or brick-red Dubawnt porphyry (20).

Limestones (22)

Carbonate rocks form only a minor part of the Dubawnt Group. Such rocks, containing no known fossils, form an area of widely scattered outcrops on high ground south of Thelon River between Hornby and Lookout Points. Their maximum known thickness is less than 100 feet. They are mainly dense, dark grey, fine-grained limestones or dolomitic limestones that occur in beds from a few inches to a foot or more thick. From the air, outcrops and disintegration rubble are distinguished by their buff-weathered surfaces. In places the limestone contains abundant concretions a few inches in diameter. Most specimens effervesce gently in acid. The rock has a fine-grained, equigranular fabric; some is oölitic and clastic. Six miles southwest of Lookout Point on Thelon River, limestone directly overlies volcanic rock (20), but elsewhere it is not in contact with either volcanic rocks or sandstone (19). However, its outcrops occur on high ground overlooking the latter rocks, and as all three units appear to be conformable and more or less flat lying, it is probable that the limestones are the youngest rocks of the Dubawnt Group.

In the same general area, but north of Thelon River, several small outcrops of carbonate rocks are present. They are mainly pink, arenaceous limestones with buff-weathered surfaces and sandy textures. In one outcrop they contain abundant crystalline quartz in thin bands or as vug fillings. These rocks are thinner-bedded, coarser in grain, and contain more abundant quartz grains than the carbonate rocks south of Thelon River. In one place they are capped by a few feet of sandstone (19), but otherwise they appear to overlie the sandstone.

Internal Relationships of the Dubawnt Group

At the east end of Baker Lake, conglomerate (18), containing abundant rounded boulders of granite (13), unconformably overlies older gneisses (12), and here and to the southwest sandstone (19) dips away from the conglomerate at low to moderate angles. Just west of Thirty Mile Lake, along Kazan River, porphyry (20) overlies sandstone (19) that dips north at 25°. The stratigraphic sequence in this region appears to be conglomerate, overlain by sandstone, overlain by porphyry. Lord (1953, p. 5) also suggested that the sedimentary rocks lie at or near the base of the Dubawnt assemblage in the Yathkyed Lake district.

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Fifteen miles northwest of Marjorie Lake, on the north shore of Dubawnt River, is a steep, south-facing hill of Dubawnt sandstone (19) whose strata dip north at 25°. To the north of this and separated from it by grassland is a line of low black hills of coarse-grained, dull brick-red feldspar porphyry (20). Farther north, dipping gently northward to Aberdeen Lake, is conglomerate (21) that contains cobbles of the distinctive red porphyry. There the succession from bottom to top appears to be sandstone (19), porphyry (20), and conglomerate (21). In other isolated instances conglomerate is known to overlie porphyry. In the Schultz Lake area conglomerate overlies sandstone, at least in part, although the two rock-types are also apparently interbedded in some places.

Of the carbonate rocks (22), the northern arenaceous limestone is probably near the top of the sandstone (19), and may represent a facies change within it, but the major body of carbonate rocks south of Thelon River appears to overlie the sandstone in structural conformity. It probably represents the youngest unit of the Dubawnt Group, but might possibly be considerably younger, even Palaeozoic in age.

Origin and Provenance of the Dubawnt Sediments

As a whole, the Dubawnt clastic sediments are coarse, impure, and immature along their southeastern flank. Basal conglomerates, grits, arkoses, and impure sandstones occur there. To the northwest, however, are abundant pure quartz sandstones of high mineralogical and textural maturity, which form a thin sheet of great areal extent marked by abundant crossbedding and include few arkoses and no basal conglomerates.

This arrangement seems to require a large source of granitic material to the southeast, the detritus from which was gradually but thoroughly reworked and winnowed during transportation to the northwest. It seems to indicate a combination of fluviatile conditions leading from the source area, gradually coalescing into broad littoral and then to shallow basin environments with a continually shifting shoreline producing essentially continental sedimentation. Pettijohn (1957, pp. 298-300) pointed to similar blanket sand deposits and suggested that a likely origin for such deposits is related to repeated washing and winnowing of sands under tectonically stable conditions at or near base-level. The limestones and arenaceous limestones (22) at and near the top of the sandstone sequence and geographically near the northwestern border of the Dubawnt area may imply a local deepening within the shallow Dubawnt basin, although D. J. McLaren[1] considers them to be 'high energy' limestones, implying considerable reworking in shallow water.

The Dubawnt sediments and their overall setting seem to be directly comparable in many ways to the Athabasca and Carswell Formations, of sandstone and limestone respectively, in the area south of Lake Athabasca. Fahrig (1961) considered these sandstones to be continental in origin and to have had their

[1] Personal communication

source in the southeast. Thus, similar orthoquartzite-carbonate sequences, of comparably great areal extent and with sources to the southeast, are side by side on a front of some 600 miles. It will be interesting to see if future detailed mapping discovers scattered remnants of these sandstones in the intervening area, as suggested by small outcrops of arkosic conglomerates near the north end of Snowbird Lake (Taylor, 1957, map-unit 8; 1963, map-unit 10).

Age of Dubawnt Group

The age of the Dubawnt sediments is not accurately known. Red porphyry dykes that are probably related to Dubawnt volcanic rocks (20) cut them. So also do dykes of diabase (23a) and other gabbroic rocks (23b) that, on regional grounds, are believed to be of late Precambrian age. Granitic rocks, however, are not known to intrude them, except locally perhaps. Contacts between rocks of the Dubawnt Group and other units are generally concealed, but the regional extent of the gently dipping, unmetamorphosed clastic sediments, plus the composition of some of their conglomerates, indicates beyond any reasonable doubt that the Dubawnt rocks overlie all other Precambrian rocks, other than dyke rocks, with profound unconformity. On this general evidence the Dubawnt rocks have been thought of as probably late Precambrian in age (Wright 1955b, 1957; Brown and Wright, 1957), although older or younger ages were obviously possible.

The association with Dubawnt sediments of porphyritic igneous rocks, many of which contain biotite, led to the hope that the age of the group could be fairly closely determined by potassium-argon methods, rather than loosely bracketed or in substantial doubt as is true of the Athabasca Formation (Fahrig, 1961; Gussow, 1959).

The first potassium-argon determination on these rocks (GSC 59-35)[1] gave an age of 1,515 million years on biotite from a pyroxene-biotite porphyry. This 'first word' on the age of the Dubawnt thus set its position back to Middle Proterozoic (Helikian) (Stockwell, 1961, p. 116). GSC 60-60, a narrow dyke of biotite-pyroxene lamprophyre cutting granite-gneiss and correlated with the Dubawnt Group on the basis of geological reasoning, gave an age of 1,720 million years; GSC 61-100, on biotite from a feldspar-pyroxene porphyry thought to be a flow-rock, gave an age of 1,770 million years. With the expectable error in determinations ignored for the moment, these results are too close to the mean (1,700 million years approximately) of the underlying granitic rocks (13) to be readily explainable. Finally, GSC 61-101, on biotite from a massive, dark purple rock gave an age of 2,240 million years. In the light of the regional granitic ages, this cannot be accepted without recourse to 'ad hoc' explanations for which no real evidence, let alone proof, is available. Because of these difficulties Stockwell (1963a, p. 127) omitted the Dubawnt from his histogram illustrating the three main orogenies of the Canadian Shield.

[1] For details of age determinations see Lowdon (1960, 1961), Lowdon *et al.* (1963), and Leech *et al.* (1963).

At the present state of studies in the barrens it is not possible to explain these discrepancies. A complete study of the internal make-up of the Dubawnt Group may yet indicate a wide range in age for its constituent parts, but will not explain such ages as 2,240 million years unless the rocks involved are actually older intrusions bearing superficial resemblance to some Dubawnt igneous rocks, or unless some process inducing mixed ages has been operative.

A recent determination (Table V, number 37) on biotite from a large diabase dyke that cuts Dubawnt sandstone (19) north of Thelon River gives an age of 1,360 million years. All Dubawnt rocks beneath the limestone (20) must, therefore, be older.

Thus, the problem of the age(s) of the Dubawnt Group seems insoluble at present, as good, fresh material is not readily available, and geological data are not yet exact. At best, we can give an approximate age within the range of Middle Proterozoic (Helikian).

Palaeozoic Rocks (24, 25)

Fossiliferous Palaeozoic rocks outcrop at two places and form rubble, presumably near its place of origin, at a third. It is at least possible that these may be remnants of formerly extensive sheets of Palaeozoic rocks. This possibility has been applied to the Canadian Shield in general by Liberty (1959), who concluded in part that "straits or wide arms must have extended across the Shield to connect with seas on its Arctic margin . . . ."

Ordovician Limestone (24)

In the area covered by this report, these rocks are known only from islands in Nicholson Lake (on Dubawnt River some 30 miles southwest of Dubawnt Lake), and along its west shore.

Pale, buff-weathering, fine-grained limestone (24) underlies a small island at the north end of Nicholson Lake. It is gently dipping, well-bedded, and contains scattered fossils. The outcrop and its fossils were first described by J. B. Tyrrell (1898, p. 54F). No other outcrops of the limestone were seen, but at two places on the west shore of the lake fossiliferous limestone rubble was found. The fossil assemblage is Ordovician in aspect, and in age it might be anywhere from middle Trenton to Richmond, inclusive.[1]

Limestone of Silurian or Devonian Age (25)

Twenty-five miles north of Aberdeen Lake are angular blocks of fossiliferous limestone. These blocks are not in place, and no bedrock was found. However, the softness of the rock and the angular nature of the blocks indicate that they cannot have moved far. The collection of fragmentary fossils contained in these erratics indicates that the rock may be tentatively assigned to the Silurian, or possibly Devonian.[1] In 1963, Donaldson (1964) found outcrops of similar limestone a few miles to the south.

[1] The fossil collection was examined by G. W. Sinclair of the Geological Survey of Canada.

Intrusive, Metamorphic and Migmatitic Rocks

Granites and Allied Rocks (4, 13, 14)

The most abundant rocks in the map-area are members of the granite family. They comprise a wide variety of types, both mineralogically and texturally, and frequently the interrelationships of the different types, their relations to sedimentary and volcanic rocks, and even their boundaries are only inexactly known.

For mapping purposes these rocks have been divided into three broad groups, based mainly on physical appearance and distribution, but which may have important genetic significance. The groups are: fresh appearing, very massive granites (4) north of Artillery Lake that contain few gneissic inclusions; a heterogeneous assemblage of largely gneissic and impure granitic rocks (13) that commonly contain irregular patches of undigested 'foreign' rocks; and relatively massive and clean granitic rocks (14) that occur within gneissic granitic terrain.

This subdivision of granitic rocks and their relative ages as shown in the legend is based on rapid reconnaissance studies of large areas modified by age determinations on micas using the potassium-argon method. In part, the field and laboratory data as to the relative ages of these rocks conflict, possibly because the massive granites (4) are igneous in origin and the gneissic granites (13) are metamorphic or metasomatic. This and allied problems are discussed in the next chapter.

Massive Granites (4) North of Artillery Lake

These granitic rocks (4) occur west of a line running approximately from the north end of Artillery Lake to the southeast end of Beechey Lake. The boundary between them and the gneissic granites (13), as shown on the geological map, is probably not exact in detail, but the marked change in rock-types, in part gradational over a few miles, is undoubted. Existence of this great change was confirmed by subsequent potassium-argon age determinations, in that the massive rocks west of the boundary contain micas that are several hundred million years older than those in the gneissic rocks to the east (Wright, 1960).

Most of these granitic rocks (4) are massive, free of inclusions, medium grained, equigranular, and unaltered. They range from white muscovite granites (4a), which in some places carry considerable green apatite, to pink or grey biotite granites and quartz monzonites (4b), and to red hornblende granodiorites or quartz diorites (4c). The first two types appear in part to be gradational to one another through binary (two-mica) granites, but it is not known whether the main rock-types represent essentially one intrusive mass, discrete intrusions from an extensive granitic terrain of approximately the same age, or completely separate and unrelated intrusions. The spread in potassium-argon ages (*see* below and Chapter V) tends to support the last possibility, but the compositions and occurrences of the rocks themselves favour one of the first two. No attempt has been made to draw contacts within this group, but a few locations where the different types were observed in the field are shown on the map.

These rocks commonly show relatively sharp contacts, in a few places with narrow 'mixed' zones, against rocks of the Yellowknife Group which they appear to intrude. Inclusions of gneisses (12) are not nearly so abundant as within the gneissic granites (13). Dykes of coarse white pegmatite, containing muscovite, and in places black tourmaline, are fairly common in or near the border zone of this large body of massive granites.

Potassium-argon age determinations show these rocks, or at least their contained mica, to be about 2,000 to 2,600 million years old (Table V, Chapter V; geological map) with a possible error of about ±125 million years. The three oldest ages (2,390, 2,550, 2,465 m.y.) are late Archaean, that of the Kenoran orogeny (Stockwell, 1961, 1963). Two younger ones (1,950 and 2,030 m.y.) are on comparable granitic rocks from similar geological settings. Their younger ages may be due to a mild reworking of Archaean granites during the Hudsonian orogeny at about 1,700 million years, giving a mixed age, intermediate between the Kenoran and Hudsonian ages.

Gneissic and Impure Granitic Rocks (13)

This is the largest group of granitic rocks—largest, perhaps, because of a lack of sufficient detailed information to permit appropriate subdivision. In these rocks predominant colours are shades of pink and grey; textures vary from fine-grained equigranular to coarse-grained porphyritic, gneissosity from faint or non-existent to stratiform, and content of impurities from nil to more than 50 per cent.

Microscopic examination of 164 specimens from this group revealed[1] 52 granites, 8 syenites, 33 quartz monzonites, 3 monzonites, 31 granodiorites, 11 quartz diorites and 3 diorites. In addition, 23 specimens were of highly sheared to mylonitized rocks whose original compositions could not be accurately determined. Most of these rocks contain biotite; some carry hornblende or both biotite and hornblende. The most common member would seem to be a quartz-rich rock carrying appreciable biotite, but no distinct systematic areal variations in composition are apparent from the presently available data.

Lord reported (1953, p. 6) that "Grey granitic gneiss is cut in innumerable places by dykes of massive, fine- to medium-grained, equigranular pink granite; and on the southwest shore of Chesterfield Inlet, a gabbroic intrusion, containing inclusions of the granitic gneiss, is cut by dykes of the pink granite." Pink granite cutting grey granite-gneiss was also noted in the western parts of the map-area.

Many of these granitic rocks are more or less gneissic, and some are mylonitized. The dominant trend of gneissosity over much of the area mapped, and especially in the eastern part, is northeast. Variations to north and northwest in the northwestern part of the map-area seem to be related to the boundary between the Slave and Churchill provinces (*see* Chapter V). Locally, trends in

[1] Classified according to I. C. Brown (1952).

gneissosity may vary over short distances. In some places these granitic rocks exhibit a well-developed, sub-horizontal jointing, which from a distance resembles coarse bedding.

Strongly gneissic to mylonitized rocks, apparently mainly of granitic composition, are sporadically distributed throughout the region, few, however, in any direct connection with known faulting. One notable exception should be pointed out. Along the south side of Campbell Lake a zone of mylonitized rocks about 4,000 feet wide and with a northeasterly trend is present in granitic terrain of low relief. This zone, and a similar one southeast of Ford Lake, appears to be the northeasterly continuation of the great McDonald Fault, which, along the south shore of the East Arm of Great Slave Lake, is expressed by a high and impressive scarp. No direct evidence has been found of any further extension of this fault beyond Campbell Lake, to join up with pronounced lineaments along the south shore of Wager Bay and north of Lunan Lake as suggested by Wilson *et al.* (1956, p. 557).

Although many areas of uncontaminated granites are included in map-unit 13, it is perhaps characteristic of the gneissic granitic rocks that they contain discrete or partly assimilated or injected bands of amphibolitic rocks or paragneisses. Between Chesterfield Inlet and Gibson Lake, for example, the granites are highly contaminated in this manner and grade into injection gneisses. In the Ferguson Lake area, a complex (13a) has been outlined of granites with greenstone, paragneiss, and basic intrusive rocks of several types. Probably about 40 per cent of this economically significant area (*see* Canadian Nickel Company Limited) consists of granitic rocks, but it was not feasible to outline the different rock-types separately on the present scale of mapping. A somewhat similar but smaller complex of igneous and metamorphic rocks lies southeast of the sharp bend in Kazan River west of Thirty Mile Lake. Many of the granitic rocks in the area northeast and north of Tehek Lake are highly impure. There, as elsewhere, some of them carry appreciable amounts of pyroxene and grade into paragneisses and associated rocks (12).

The stratiform varieties of the gneissic granites are mainly fine- to medium-grained, equigranular, well-banded gneisses consisting primarily of quartz, feldspar, and biotite. In several instances it seems probable that they have been formed locally by granitization of sedimentary rocks. Some of the gneisses bordering Nonacho strata (5) southwest of Whitefish Lake may well be of this origin. Elsewhere, similar rocks occur for long distances across the regional trend, and granitization, if involved in their production as seems highly probable, must have been active on a regional scale. An example is found in the wide expanse of well-banded granitic gneisses between Moraine and Cruikshank Lakes, north of Hanbury River (Pl. II).

In reconnaissance studies it was not possible to differentiate by age the granitic rocks of this group. However, in general terms it is believed that much of the gneissic granite (13) is younger than the main greenstone assemblage (7),

and older than Hurwitz quartzite (9); that an appreciable but unknown part is younger than the Hurwitz rocks; and that most, if not all, are older than the rocks of the Dubawnt Group (18-22), which in many places appear to overlie granites with marked unconformity. Potassium-argon age determinations on the contained micas of these rocks and their significance are discussed in Chapter V. In general, they record ages, probably largely metamorphic, in the range 1,600 to 1,800 million years.

Only in one area, that extending from Dubawnt Lake east to a line between Tulemalu and Tebesjuak Lakes, is there widespread evidence suggesting granitic rocks of Dubawnt or even post-Dubawnt age. In no single occurrence is this evidence complete and compelling, nor can any well-defined body of such rocks be outlined at present. The evidence may be direct. For example, aplite dykes cut basic porphyry dykes and flows (?), presumably of the Dubawnt Group, and in one such place the basic porphyry dyke in turn cuts an older gneissic granite. Or it may be indirect and perhaps more generally persuasive. For instance, strikingly porphyritic (feldspar, quartz) rocks with very fine-grained to aphanitic matrices occur close to very coarse-grained porphyritic granites. In many instances these rocks are very similar except for the coarseness of their matrices; in addition, they both carry prominent smoky quartz. These similarities suggest that the fine-grained porphyries may be intermediate connecting links between the more acid Dubawnt porphyries (20) of the region and the coarse-grained granites. The latter would then be Dubawnt or post-Dubawnt in age. In one place where pink, alaskitic granite contains large, zoned feldspar crystals and rounded, smoky quartz eyes, a very similar rock (but with a fine-grained to aphanitic matrix) forms dykes that cut a quartz-deficient Dubawnt porphyry.

If a distinct Dubawnt or post-Dubawnt granite exists, perhaps it would help to explain two other striking phenomena of this same general area, namely: the common presence of fluorite in the smoky quartz granites and, rarely, in Dubawnt porphyries; and the heavy epidotization locally throughout this region of all rock types. These would be deuteric effects from the younger granite.

Even in this region, however, many outcrops of Dubawnt porphyries have the form of flat and relatively thin remnants on top of the granitic rocks rather than of inclusions within them. Furthermore, potassium-argon age determinations have failed to give any firm indications of granites younger than the general range of 1,600-1,800 million years in this area. The answer to this problem may be, in part, that the Dubawnt porphyries (20) as here mapped and grouped include rocks of different origins and ages.

Massive Granites (14) in Gneissic Terrain

Many sizable bodies of essentially massive and clean granitic rocks (14) occur within the gneissic granites (13). These may be simply more massive phases of the gneissic granites, or they may be younger rocks intrusive into the latter. Conceivably, they might even be related to the massive and clean granites (4)

north of Artillery Lake, as remnants of an older terrain. The last two possibilities are not supported by the only potassium-argon age determination on such rocks within the map-area (south of Ennadai Lake). This determination (GSC 60-63; *see* Table V) gives an age of 1,800 million years which is close to the general age for the gneissic granites (1,600 to 1,800 m.y.). In general, no clear-cut contact relationships have been observed against the gneissic granites, although some gradational tendencies have been noted.

Nueltin Lake Granite (14a)

The most distinctive rock of this unit is here named, informally, the Nueltin Lake granite. It occurs as several large bodies in the area including Nueltin and Ennadai Lakes in southern Keewatin, and to the north and northwest. Referring to this rock, Lord (1953, p. 7) stated, "The biotite granite (8)[1] is a coarse-grained, commonly porphyritic but otherwise massive, red to pink rock that, on weathering, affords very large slabs and blocks. It contains 30 per cent bluish, honey-coloured, or milky quartz, 10 per cent biotite, abundant reddish potash feldspar as phenocrysts 2 inches or more in length, and a little cream-coloured plagioclase. It is nearly free of foreign inclusions; is cut by a few aplite dykes; and, west of Ennadai Lake, is bordered by an area of numerous pegmatite dykes. Its age relative to the granitic assemblage (2)[2] is not known, nor were the two intrusions found in contact." A prominent feature of the Nueltin Lake granite is a sub-horizontal jointing, which gives an appearance of coarse bedding.

This rock apparently extends southward for many miles outside the map-area. In the Munro Lake area of northern Manitoba, Davison (1963) reported a continuation of the mass of coarse-grained, porphyritic granite of Hearne Bay on Nueltin Lake. Fluorite is abundant in this rock. To the west in the Kasmere Lake area, Fraser's (1962) map-unit 7a, a very coarse-grained, porphyritic potash granite, underlies a large area, and his unit 7b, finer grained but with Carlsbad-twinned feldspar crystals up to ½ inch in length, contains fluorite. Fluorite has been noted in the Nueltin Lake granite or in its less coarse border facies north of Nueltin Lake and south of Ennadai Lake. The total area known to contain significant bodies of massive and coarse-grained to strikingly porphyritic potash granites with associated fluorite thus amounts to some 20,000 square miles astride the 60th parallel. In view of the common geological association of fluorite with minerals of beryllium and tin, and to a lesser extent molybdenum and tungsten, this area may have some economic significance.

The age of the Nueltin Lake granite is reported as 1,800 million years in the area south of Ennadai Lake (Table V, GSC 60-63). In the Kasmere Lake area to the south, coarse-grained porphyritic granite gives an age of 1,770 million years and fluorite-bearing granite 1,735 million years[3]. If these rocks are magmatic granites, this age would place their time of intrusion at about the end of Lower Proterozoic

[1] Map-unit 14a of the present report.
[2] Map-unit 13 of the present report.
[3] J. A. Fraser, personal communication.

(Aphebian) time—during the Hudsonian orogeny (Stockwell, 1961, 1963a). Potassium-argon age determinations (*see* above, and Table V) indicate that no great age difference is likely between these massive, porphyritic granites (14a) and the regional granitic gneisses (13), but the present limitations of the method permit no definite answer. On grounds of general geological reasoning the Nueltin Lake granite appears to be somewhat younger than the associated gneissic granites. Lord (1953, p. 7) suggested that it may be younger than the Hurwitz quartzite (9).

In texture and composition, and in apparent geological relationships to gneissic granites, the Nueltin Lake granite shows striking similarities to other massive, very coarse-grained and porphyritic potash granites (supposedly younger than surrounding gneissic granites) in the western Canadian Shield, as at Ghost Lake, Northwest Territories (Wright, 1954, map-unit 8), and Uhlman Lake, Manitoba (Wright, 1953, map-unit 6, in part).

Carey Lake Complex (14b)

A large body of massive, granitoid rocks extends northeastward from Carey Lake toward Dubawnt Lake. The southwestern third of this mass is an igneous complex comprising medium- to coarse-grained syenites, granites, diorites, and minor gabbroic rocks that form relatively high and mammillary outcrops. The remainder is mainly pink, coarse-grained, in part porphyritic granite. The distinctive rocks in the southwestern part of this mass suggest that the complex may be younger than the regional granitic gneisses (13).

Other Massive Granites (14)

Less is known of the many other areas of massive granitic rocks (14) in gneissic terrain, but few are as coarsely porphyritic as the Nueltin Lake type. The large body of such rocks outlined east of Moraine Lake seems to be characterized by smoky or bluish quartz. Across the southern part of this mass, gneissosity appears at its borders and it grades outward into granitic gneisses. Blue quartz also appears in these gneisses near the west edge of the mass. Under the microscope these apparently massive rocks are seen to be partly crushed. It seems probable, in this case, that the massive rocks are a textural variant of the gneissic granitic rocks (13) rather than an intrusion of significantly younger age.

Gneisses (12)

Sedimentary and Volcanic Gneisses (12, 12a)

Several types of gneissic rocks, not specifically assignable to rock-units previously discussed, are present in many parts of the map-area, commonly as irregularly shaped and relatively small bands or areas within gneissic granitic rocks. Most boundaries shown are arbitrary; some are gradational through mixed gneisses. Almost everywhere these gneisses are regularly banded and exhibit steep to vertical dips.

Some large areas are underlain by rocks of this unit. Between Rankin Inlet and Baker Lake, and particularly along the upper part of Chesterfield Inlet, are well-banded, garnetiferous paragneisses. Gneisses west of Ennadai Lake seem to have been derived from both sedimentary and volcanic rocks. The northeasterly trending band 30 miles north of Ennadai Lake includes much fine and regularly banded, garnetiferous acidic gneisses of doubtful origin. The presence of these gneisses, and of others between these areas, seems to imply a sedimentary sequence of pre-Hurwitz age, although some of them conceivably could be the more highly metamorphosed equivalents of Hurwitz sediments (8, 9, 10) (*see* Disappearance of the Hurwitz).

The elongate belt of gneisses between Sifton and Tourgis Lakes in the northwestern part of the map-area includes: completely recrystallized, more or less well-banded, pink to grey, quartz-feldspar-biotite gneisses of medium grain that commonly carry red garnets as accessories; dark grey gneisses with abundant light-coloured porphyroblasts of plagioclase; and some bands of amphibolite and even schistose greywacke. It is at least possible that this belt represents a large 'undigested' remnant of Yellowknife sediments (3) in gneissic granites (13), into which it grades in part through almost stratiform, impure granitic gneisses or mixed gneisses. To the north, near Back River, the gneisses (12) show some similarities to Yellowknife schists. Gneissic rocks (12a) within areas of Yellowknife schists are more obviously derived from them.

Less common rocks of this unit, whether mapped separately or not, include scattered occurrences of pyroxene and/or garnet-bearing granulites; coarse-grained, quartz-feldspar-biotite gneiss with kyanite, garnet, and staurolite (?) some 15 miles northwest of Ennadai; and minor skarn rocks in the Eileen Lake area, which indicate the former presence of impure limestones in the original sedimentary rocks of this region. In some places garnetiferous amphibolites occur alone and it was not generally determinable whether these were derived from limy sediments or from basic intrusive rocks.

Mixed Gneisses (12b)

A few small areas of mixed gneisses are outlined near the western border of the map-area. They consist mainly of granitic and metamorphic rocks in varying proportions, and they tend to grade into one or other of the end-members. Some are 'lit-par-lit' (injection?) gneisses; others are areas of granitic rocks with abundant discrete or partly assimilated inclusions of schist or gneiss. These migmatites are most obvious at or near contacts between sediments or gneisses and granitic rocks intrusive into them, but many such rocks are mapped with impure and gneissic granitic rocks (13), as it was impracticable in many cases to separate them on the scale of mapping employed.

Basic Intrusive Rocks (A-F 17, 23)

A large variety of basic intrusive rocks occurs in the map-area as dykes, sills, plugs, and irregularly shaped masses. The ages of the plug-like bodies (A-F) are

not known, and may encompass a considerable spread in time. But the sills and dykes of diorite (17) appear to be at least post-Goulburn, and the dykes of diabase (23a) and other intrusive rocks (23b) are probably post-Dubawnt in age.

In the sections that follow, the basic and associated intrusive rocks are grouped mainly to facilitate description, and, in general, no definite, genetic relationship or correlation is intended, although in several cases these are not unlikely.

Hornblendite and its altered varieties are not shown separately on the map, but have been noted in a few places. The Ferguson Lake complex (13a), for instance, includes irregular, sill-like bodies of medium- to coarse-grained hornblendite, the largest of which contains the main zones of sulphide mineralization (*see* Chapter VI). Eight miles north of the northwest tip of Clinton-Colden Lake a body of brown-weathering, coarse-grained, dark green meta-hornblendite apparently cuts the granite (4) of the region, but is itself cut by abundant granitic pegmatite.

Diorites and Gabbros of the Ennadai-Rankin Belt (A)

Lord (1953, pp. 7, 8), in discussing the basic intrusive rocks of southern Keewatin, divided them into three main types, one mainly associated with greenstones (7), and two closely associated with the white quartzite (9) and other sediments (8, 10) of the Hurwitz Group. He stated, "The most common variety of the basic intrusions (A)[1] is a massive, medium-grained diorite and gabbro, comprising about equal parts of altered amphibole and andesine or labradorite. In most instances it lies between granitic rocks (2) and greenstones (1), but two stock-like bodies west of Ennadai Lake appear to be surrounded by the greenstones. It was not found in contact with the greenstones nor with large granitic intrusions, but here and there it is cut by pegmatitic and granitic stringers and by diabase dykes. Although its texture and distribution with respect to the granitic rocks suggest an intrusive origin, its proximity to the greenstones suggests that it may, in part, comprise a thoroughly recrystallized phase of the latter. It is, in places, at least slightly older than the granitic intrusions (2), and therefore probably of Archaean age.

"Another variety of basic intrusions (A) is a black, massive, medium- to very coarse-grained meta-diorite or meta-grabbo. Fresh surfaces display numerous, ragged, black, amphibole crystals up to ½ inch in length in a fine-grained, dark grey to black, indeterminate matrix, which is not readily distinguishable from the amphibole crystals. The rock is cut by white quartz veins, some of which contain a little feldspar. Under the microscope it is seen to consist mainly of highly altered amphibole and plagioclase (oligoclase or andesine) in about equal proportions, and minor, black, metallic iron oxide, leucoxene, apatite, quartz, biotite, and other minerals. Most mapped occurrences of this rock lie close to Early Proterozoic quartzite (5), as northeast and east of Watterson Lake; at Griffin, Sealhole, and

[1] In these quotations, Lord's map-units A, 1, 2, 5, and 6 are respectively, map-units A, 7, 13, 9, and 10 of the present report.

Hurwitz Lakes; on the north and east shores of Otter Lake; and about 4 miles southwest of Montgomery Lake. In most of these places the basic rock appears to form sill-like bodies lying immediately above the quartzite (5) and below the greywacke, dolomite, and associated strata (6). It was not, however, found in contact with these or other rocks. Because of its common occurrence stratigraphically above the quartzite, it is of Early Proterozoic age or younger and the relatively high degree of alteration evident under the microscope renders a Late Proterozoic age improbable.

"A third variety of basic rock (A) outcrops as prominent rounded hills between parallel bands of quartzite (5) on Quartzite and northern Kaminak Lakes. It is a medium-grained, massive, dark green or grey-green meta-diorite cut by many seams of epidote. Under the microscope it is seen to be composed of a felt of green actinolitic amphibole and laths of plagioclase, with a little epidote, zoisite, and other minerals. It was not found in contact with other rocks, but its massive appearance and dioritic texture suggest an intrusive origin. Its age relative to the nearby Early Proterozoic quartzite (5) is not known, although at one place it appears to lie stratigraphically above the quartzite and may, therefore, be younger."

These basic rocks (A) may, in part, be equivalent to some of the dioritic and gabbroic rocks (B) described in the next section.

Diorites and Gabbros (B) in Granitic and Gneissic Terrains

Several types of basic intrusive rocks are grouped together in this unit. In the main, they occur as plug-like or irregularly shaped bodies of small to moderate size, sparsely distributed within granitic and gneissic terrains.

A common type in this group in central Keewatin is a fresh-appearing, massive, medium- to coarse-grained, mottled, greenish grey diorite or gabbro, consisting largely of intermediate to basic plagioclase and amphibole, or in some cases altered pyroxene. These mostly form rounded, rugged, plug-like bodies, but similar rocks are known to occur as dykes. The largest body of this rock, some 5 miles in diameter, lies just south of the east end of Baker Lake. It is a massive, light brown-weathering hornblende diorite. About 30 miles north of Cross Bay on Chesterfield Inlet is a prominent hill of massive, coarse-grained hornblende meta-gabbro, which in places shows well-developed coronas of fine-grained garnet around hornblende grains.

Small bodies of diorite and gabbro are present in, and appear to intrude, gneissic granites (13) in the western parts of the map-area. They are mainly dark green and medium grained. Many are considerably altered, and commonly contain abundant hornblende, in part at least derived from pyroxene. A few small dykes of meta-diorite or amphibolite were found cutting granitic rocks, but are not shown on the map.

Most of these basic intrusive rocks (B) are probably older than the rocks of the Dubawnt and Goulburn Groups, as none is known to occur within such rocks,

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and younger than some of the granites (4, 13, 14) and gneisses (12). However, the large body of gabbro and anorthositic gabbro astride Elk River near the southwest corner of the map-area is cut by dykes of both pink granite and pegmatite.

Anorthosite (C)

A large mass of anorthosite forms rugged outcrops along the north shore of the east end of Baker Lake. The anorthosite in the western part of this body is mainly a massive, light purplish grey rock of very coarse grain and consists largely of labradorite with some remnants of pyroxene and amphibole. A second rock-type in this body is light grey and medium grained and consists almost entirely of plagioclase. The anorthosite in places possesses a marked lineation, and the medium-grained type contains inclusions of schist. To the east, the anorthosite is well-banded and apparently has been strongly sheared, and there the position of its contacts with gneiss (12) and gneissic granites (13) is arbitrary. No signs of mineralization were observed in this anorthosite body.

Elsewhere in the map-area anorthositic rocks are rare. A small body of purplish anorthosite (C) occurs 25 miles northeast of Tulemalu Lake, but its true extent and geological relations are unknown. North of Hanbury River, some 10 miles southeast of Sifton Lake, is an outcrop of pale, greenish grey, almost massive anorthosite containing about 10 per cent combined hornblende, pyroxene, biotite, and magnetite. In the field this rock resembles a hornblende syenite. A similar rock forms a small outcrop about 15 miles to the north.

Biotite-Hornblende Diorite (D)

Massive biotite-hornblende diorite (D) underlies a large, hilly area about 40 miles north of Clinton-Colden Lake, at the western edge of the map-area. The rocks in this intrusive mass are grey to greenish grey, medium grained, and dense. They vary somewhat in composition, being lighter coloured and more acidic in the eastern part of the mass. The main constituents are andesine feldspar and hornblende, with up to 15 per cent biotite and, sometimes, minor quartz and potassium feldspar. The different rock-types probably represent variations within one intrusion rather than separate intrusions, as they have decided similarities both in composition and texture.

Ultrabasic and Allied Rocks (E)

True ultrabasic rocks are not common in the region, but a few have been noted and are briefly described below. The Ennadai-Rankin belt contains at least two bodies of ultrabasic rocks, and some indications of others. In discussing these, Lord (1953, p. 8) stated: "One outcrop of massive, medium- to coarse-grained, brown-surfaced peridotite occurs about 11 miles north of the southwest end of Ennadai Lake, and within the western part of a stock-like body of dioritic

rock (A) [1]. Under the microscope, this peridotite displays remnants of olivine and pyroxene, as well as serpentine, chlorite, and fine-grained magnetite. A sill of fine-grained, dull green, massive serpentinite, possibly derived from pyroxenite, contains the nickel-copper deposits being explored by Rankin Inlet Nickel Mines Limited on the north shore of Rankin Inlet. It is presumably younger than the adjacent greenstones (1) and intercalated schistose tuffs or sedimentary strata, but its age relative to the other rocks is not known. A little ultrabasic rock is reported to outcrop a few miles north of the west end of Griffin Lake. Soapstone erratics, reported by Eskimos to be common near the northwest end of Hicks Lake, may be derived from an unmapped ultrabasic intrusion."

Forty miles northwest of Tehek Lake, a body of basic intrusive rocks lies along the southern edge of a large mass of white quartzite (9). One sample from this body is dull brown weathering, greenish black, and aphanitic. A thin section cut from it reveals serpentine, amphibole, and secondary iron ore minerals. It is probably a serpentinized dunite. Other rocks within this mass are more dioritic in aspect.

Just south of the west end of Schultz Lake is a small outcrop of brown weathering, dark green rock comprising about 80 per cent serpentine, plus other secondary minerals.

Basic Syenites, Diorites, and Gabbros (F)

These rocks form small, plug-like bodies of rather distinctive compositions and textures. They give the impression, not as yet confirmed, of being intrusive equivalents of Dubawnt igneous rocks (20). They resemble some of the Dubawnt porphyries found south of Baker Lake, but are differently distributed in that they are found outside the confines of known Dubawnt rocks.

Near the north shore of Whitehills Lake, north of the west end of Baker Lake, outcrops of these rocks are found on three small islands. The two easterly occurrences are massive, medium-grained, hornblende-biotite syenite and finer grained, massive gabbro. The westerly island shows a grey, porphyritic (biotite) diorite with a fine- to medium-grained matrix, and also a dark biotite porphyry (lamprophyre?) with an almost aphanitic matrix. These rocks are not in contact with any other.

Age determinations by the potassium-argon method on the coarse and fine biotites from the last-named porphyry yielded 1,220 and 1,665 million years respectively (Table V). These results, astonishing if true, do not deny the possibility of a co-Dubawnt origin and age, but the older is obviously within the general range of ages of granitic rocks of the region.

North of Yathkyed Lake is a series of four small to medium-sized outcrops or outcrop areas consisting, in part, of rocks similar to the above. The two smaller areas are of hornblende diorite or gabbro, one of which appears to cut grey

[1] In this quotation, Lord's map-units A and 1 are, respectively, map-units A and 7 of the present report.

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granite-gneiss, but is itself cut by medium-grained, pink granite. The second largest consists of red-black, massive, medium-grained augite syeno-gabbro with a well-oriented fabric. The largest area is underlain by light grey-pink hornblende diorite, porphyritic hornblende syenite, and a coarse-grained, purple syenite or diorite with a pronounced trachytoid texture.

Hornblende Diorite (17)

West of the Bathurst Trench and its southern extension are dykes, sills, and larger masses consisting mainly of diorite (17). These are believed to be related, despite some differences in composition, texture, and geological expression.

Between Ellice and Western Rivers is a large area of intrusive rocks. The southern part of this area has scattered, rounded outcrops of massive, fine- to medium-grained, dark green hornblende diorite, and in the central part the diorite is apparently interfingered as narrow, sill-like bodies in sedimentary schists (3) of the Yellowknife Group. At the northern edge of this area are thick sills of dark green diorite and diabasic gabbro that outcrop in bluffs and show good columnar jointing. Just to the north, at the sharp bend in Western River, sills of the diorite are intimately intruded into the folded strata of the lower part of the Goulburn Group (15), and this intrusive-sedimentary assemblage has been mapped separately (15a).

To the west, north of Western River, two sills of basic igneous rocks (17) are present in rocks of the Goulburn Group (15, 16). The smaller eastern sill consists of brown-weathering, mottled red on dark green, massive, medium-grained hornblende diorite with a granitoid to sub-ophitic texture. A whole-rock, potassium-argon determination on this sill gave an age of 1,215 million years. (Table V, number 40). The western sill is similar but finer grained.

Younger Diorite, Diabase, and Allied Rocks (23a, b)

In general, this group of basic rocks comprises those that form dykes and some sills, and that are known or thought to be of relatively late Precambrian age. By no means are all known dykes plotted on the map, but an attempt has been made to show the larger ones, and the main trends.

Gabbro and Diabasic Gabbro (23a)

Dykes of diabase and gabbro are present in most parts of the map-area, but only in a few places, as near Gibson Lake and east of Clinton-Colden Lake, do they occur in swarms like those so commonly found in the Yellowknife region to the west of the map-area. Furthermore, these apparently late dyke-rocks appear to vary somewhat more in mineral content and in freshness than do those of similar geological occurrence in the Yellowknife district.

The dykes range up to several hundred feet in width, the largest examined being 325 feet wide. Due to their predominantly steep to vertical dips and their resistance to weathering, they tend to stand up as straight, linear features. The

dykes may be many miles in length, the longest known having been traced, over some gaps, for 150 miles, from north of Schultz Lake to east of Kaminuriak Lake. Trends vary, but northwest seems to be most prominent. In the Gibson Lake area several large dykes trend east. Many of the dykes are cut by faults of small displacement and predominantly of northeasterly or northwesterly strike.

These dyke-rocks are generally massive, brownish to reddish weathering, dark green to black, and consist essentially of labradorite and pyroxene, small amounts of magnetite and apatite, and in some cases quartz or a little olivine. Secondary amphibole, probably derived from alteration of pyroxene, is visible in some thin sections. Lord (1953, p. 8) reported that, "Some are cut by quartz veins and epidote seams and probably contain abundant secondary minerals, . . ."

None of the rocks appears to have been metamorphosed. In one place or another, representatives of this group (23a) have been seen to cut most rocks except Dubawnt limestone (22) and Palaeozoic rocks (24, 25). It therefore seems likely that the diabase dykes are mainly of late Precambrian age.

Intermediate to Basic Dyke-Rocks (23b)

Two large, vertically dipping dykes trend northwesterly from near Lookout Point on Thelon River through country of few outcrops but presumably underlain by Dubawnt sandstone (19). Both dykes are at least 200 feet wide, and along parts of their lengths they stand up like walls as much as 40 feet above the surrounding country. The rocks are mainly red-weathering, with a mottled red and green surface. They are dense, medium grained, and equigranular with sub-ophitic textures. The feldspar minerals are highly altered, but the samples appear to range from micropegmatite to albite andesite and gabbro. Pyroxene is generally absent, but much of the amphibole in these rocks may be derived from it. In the main, these dyke rocks (23b) seem substantially different in composition from the late diabasic gabbro (23a) of Yellowknife type, and it is possible that they are dyke-equivalents of the volcanic rocks (20) of the Dubawnt Group, in the same sense that the rocks of map-unit F may be their pluton-equivalents. A potassium-argon age determined on biotite from the south end of the eastern dyke gave one of 1,360 million years (Table V, number 37). The most northerly outcrop of the eastern dyke is anomalous. It is fresh gabbro, with about 40 per cent each of pyroxene and labradorite feldspar, and an ophitic texture: a typical late diabase. Because outcrops are not continuous, it is not known whether these are parts of two different dykes or of one dyke with marked compositional variations.

Chapter V

POTASSIUM-ARGON AGES APPLIED TO REGIONAL PROBLEMS

Discussed in this chapter are age patterns in the Churchill structural province and the nature of the boundary between the Churchill and Slave provinces—here called the Thelon Front. Solutions of other problems, some of lesser import, are aided but as yet not effected by potassium-argon dating, for example the question of the relative ages of the Nueltin Lake granite (14a) and the surrounding granitic gneiss (13) (*see* Nueltin Lake granite).

Geological reconnaissance within the map-area was completed in 1955, but the first age-determinations were not available until late in 1959. To the end of 1963, 44 ages from 43 samples within the map-area have been determined. These are plotted on the accompanying geological map and essential data from them are listed in Table V. Details of all but 8 of these determinations can be found in recent Geological Survey publications (Lowdon, 1960, 1961; Lowdon *et al.,* 1963; Leech *et al.,* 1963).

Analytical errors involved in these determinations range from approximately ±125 m.y. at 2,500 million years to ±100 m.y. at 1,500 million years. Most of the determinations are on biotite, a few are on muscovite, and one is from crushed whole rock. In all cases the age given refers presumably to the time since the minerals concerned last achieved the physical capacity to retain argon in their crystal lattices—thus the age can refer either to magmatic or metamorphic processes, or to combinations of the two. It is assumed that no argon escaped subsequently due to natural (e.g., chloritization) or man-made (e.g., grinding) processes. Such assumptions are not necessarily always true, nor is there any marked unanimity of opinion on this subject.

Age Patterns in the Churchill Province

Examination of the distribution of potassium-argon ages within the map-area shows that, with the exception of its northwestern segment, it is characterized by a preponderance, in granitic rocks and associated major inclusions, of ages within the relatively narrow range of 1,600 to 1,800 million years. Wright (1960) remarked on this arrangement and its apparent extension southward into Manitoba and northeastward into Baffin Island. Further determinations (Lowdon, 1961; Lowdon *et al.,* 1963) have amply confirmed this general pattern, and have also

Table V

Potassium-Argon Age Determinations

Number on Geological Map	GSC Number	Age (m.y.)	Mineral	Rock Type	Map Unit Number	Reference: GSC Paper
1	59–22	2465	Muscovite	Granite	4a	60–17
2	23	2390	Biotite	"	4	"
3	24	2550	Muscovite	"	4a	"
4	25	2100	Biotite	Nodular schist	3	"
5	26	1950	"	Granite	4b	"
6	27	2040	"	Gneissic granite	13	"
7	28	1670	"	Amphibolite	12	"
8	29	2070	"	Quartz monzonite	13	"
9	30	1605	"	Granite	13	"
10	31	1805	"	Granitic gneiss	13	"
11	32	1690	"	Gneissic granite	13	"
12	33	1655	"	Gneissic granite	13	"
13	34	1695	"	Granite	13	"
14	35	1515	"	Pyroxene-biotite porphyry	20	"
15	60–57	2000	"	Paragneiss	5	61–17
16	58	1680	"	Garnetiferous paragneiss	12	"
17	59	1630	Muscovite	Gneissic granodiorite	13	"
18	60	1720	Biotite	Lamprophyre	20	"
19	61	1925	"	Granitized gneiss	12	"
20	62	1590	"	Granitic gneiss	13	"
21	63	1800	"	Quartz monzonite	14	"
22	64	1685	"	Sillimanite paragneiss	12	"
23	61–84	1680	"	Paragneiss	12	62–17 (Part 1)
24	86	1880	"	Granodiorite	13	"
25*	98	1220	Biotite (coarse)	Augite-biotite lamprophyre	F	"
26*	99	1665	Biotite (fine)	Augite-biotite lamprophyre	F	"
27	100	1770	Biotite	Feldspar-pyroxene porphyry	20	"
28	101	2240	"	Dacite	20	"
29	102	1810	"	Garnetiferous biotite schist	12	"
30	103	1695	"	Paragneiss	13	"
31	104	2375	"	Granitic gneiss	13	"
32	105	1795	"	Quartz monzonite	13	"
33	106	1735	"	Gneissic granite	13	"
34	62–95	1810	"	Granitic gneiss	13	63–17 (Part 1)
35	96	1770	"	Paragneiss	12	"
36	97	1785	"	"	13	"
37+	FA203–62	1360	"	Gabbro (dyke)	23b	to be published
38+	TG5–62	2030	"	Granite	4b	"
39+	TG94–62	1920	"	Schist	12	"
40+	TG154–62	1215	Whole rock	Gabbro (sill)	17	"
41+	EA88–62	1685	Biotite	Gabbro	A	"
42+	EA429–62	1760	"	Granodiorite	13	"
43+†	TG65–63	2380	Muscovite	Argillite (detrital mica)	15(3)	"
44+	TG90–63	2490	Biotite	Nodular schist	3	"

*Coarse and fine biotites from same specimen determined separately.
+Will receive GSC sample numbers when published.
†Muscovite probably detrital from Yellowknife schists (3).

added large areas of northern Keewatin, northeastern Mackenzie, and northeastern Quebec-Labrador. The extension of Precambrian rocks of the Churchill province under Palaeozoic rocks to the west of the exposed Canadian Shield has been discussed by Burwash *et al.* (1962).

The problem arising from these data is how to explain this relatively short range in ages of micas, not only over such a tremendous area, but also over an area that has no apparent elongation, no single tectonic orientation, and no evident history of a single orogenic cycle. The 400-mile long Ennadai-Rankin sedimentary-volcanic assemblage may represent a major, folded eugeosynclinal zone, although present data in part support a considerable gap in age between the volcanic rocks and some of the overlying sediments. This does not necessarily alter the fundamental problem herein posed, as this greenstone belt is but a small segment of a very extensive terrain of, apparently, almost uniform age. Thus, although the eastern half of the map-area might be said to have a predominant northeasterly structural trend, this is not true of the western part, or of much of northern Manitoba. It is even less true of Baffin Island; in fact, the Baffin Island trend north of Hudson Strait is almost perpendicular to that of the eastern Keewatin trend. However, faulting or cross-folding on a regional scale may account for this arrangement.

Wright (1960, p. 48) has suggested that the sheer size of the area characterized by similar ages defies ready explanation, whether the process involved be magmatic or metamorphic. The latter, however, would seem to be a somewhat more appealing proposition to consider. Wetherill *et al.* (1962, p. 83), in speaking of age measurements of about 1,800 million years from the Finnish Precambrian, stated, "Thus minerals of this age are found over a very wide area, and interpretation of this tectonic period in terms of a narrow linear belt similar to the Appalachian will not be possible." More recently, Stockwell (1963a, p. 126) has remarked on the lack of extensive sedimentation between the Hudsonian and Grenville and the apparent absence of a recognizable orogenic cycle associated with the Grenville orogeny.

The picture presented above is perhaps deceptively simple; indeed, the presence of several ages in micas of about 2,000 million years complicates it considerably. Stockwell (1963a, p. 125) suggested that the Hudsonian orogeny (1,700 m.y.) that ends Lower Proterozoic (Aphebian) time produced gneisses and granites throughout most of the Churchill province and generally obscured earlier geological history. This leaves the possibility that much of the original material may well be as old as Archaean, which was terminated by the Kenoran orogeny at about 2,500 million years ago. Stockwell stated, "Certain parts of the Churchill province, however, appear to have escaped complete reworking so that some older dates survive. This is illustrated in a large, poorly defined region some 200 miles wide and 600 miles long that extends from Nonacho Lake (which lies southeast of Great Slave Lake) eastward toward Hudson Bay. In this region, a number of survival dates, varying erratically from 1,900 to 2,460 m.y. are found here and there among the more common ages of 1,700 ± 150 m.y. that characterize the Hudsonian orogeny. In this area of mixed

dates the effect of the Hudsonian was, apparently, more severe in some places than in others." Another, but less likely, possibility is that actual intrusive activity took place in the interval between 2,500 and 1,700 million years ago. Thus, a 2,000 million years age could be a true age on rocks unaffected by the Hudsonian orogeny, rather than an Archaean modified by it.

In spite of the complicating factors, however, it would appear from these examples that the involvement of areas of up to several hundred thousand square miles in orogenies not demonstrably related to the development of classic tectonic cycles is not uncommon. Or does the restriction of these examples to the Precambrian suggest that lack of detailed evidence is the main problem? This hardly seems likely, as the problems dealt with are regional rather than detailed in scale. The alternative is to find a method of producing large scale orogenic effects without tectonic cycles. Conceivably, we may yet return to some variant of the convection current concept to supply answers to the problems of heat supply and directed stresses.

The Thelon Front

One striking result of helicopter reconnaissance in eastern Mackenzie was the delineation of the eastern limit of the Slave structural province. Wright (1957, 1960) showed that west to east across a convex zone extending from approximately Bathurst Inlet to Great Slave Lake: recognizable metasediments of the Yellowknife Group disappeared (or were altered to gneisses); diabase dykes apparently decreased in abundance and/or altered in type; massive and unfoliated muscovite and biotite granites were replaced by mainly impure and gneissic to stratiform granitoid rocks and inclusions of paragneiss; and a great arc in regional gneissosity developed, parallel with the zone, in granitoid rocks of the Churchill province. Near the flanks of the zone are younger, less severely folded sedimentary sequences of the Goulburn and Great Slave Groups, which are cut off to the northeast and southeast respectively by still younger, prominent faults[1] (GSC, Maps 1055A, 30-1963). These are the Bathurst Fault (Pl. III) in the north and the Macdonald Fault along the south side of Great Slave Lake to the southwest, outside the map-area.

It is proposed, for the sake of simplicity, to call this section of the boundary between the Slave and Churchill geological provinces the Thelon Front. It is not, in detail, exactly located. Northeast of Beechey Lake, the Bathurst Trench extension (lineament of Western River) appears to define it closely. However, Fraser (1964, pp. 6, 7) showed that the front swings northeastward, north of the present map-area, rather than follow the trench to the northwest. This is indicated by contrasts in structure, lithology, and metamorphic rank, and by limited

[1] The faults are not known to curve with the regional gneissosity; rather, each appears to lose its marked identity along a uniform strike, and the true extent of neither fault is known (Wright, 1957, p. 20).

potassium-argon age determinations. Between Beechey and Artillery Lakes, the front appears to be gradational, probably over some miles, passing east to west from gneissic granitoid rocks (13) with belts of injected paragneiss (12) to massive granites (4) intruding Yellowknife schists (3). Mapped on the present regional scale, however, it appears as an abrupt, clearly defined feature within the map-area.

By reasoning that the massive and uncontaminated granitic rocks (4) had apparently been spared the processes that formed the granitoid gneisses (13) to the east, Wright (1957) concluded that they were probably younger. Potassium-argon dates, however, show that the micas in the massive granites are on the average some 600 to 700 million years older than those in the granitoid gneisses. This result, if surprising and even disconcerting, further accentuates the geological contrast across the boundary zone.

A possible and perhaps reasonable explanation of this situation is based on the tentative conclusion, implied in the preceding section, that the rocks on both sides of the boundary may be Archaean, and that the major metamorphic and orogenic activity of the Churchill province at 1,700 $\pm$ 100 million years ago (Hudsonian orogeny) swept westward to die out along a wide front against unaltered products of the Kenoran orogeny (about 2,500 m.y. old) in the eastern part of the Slave province.

The problem of devising and initiating a mechanism of wholesale metamorphism and granitization without an apparent tectonic cycle has been indicated in the preceding section. The problem now is to stop it—and along a reasonably exact line. Neither problem is new; both apparently apply to the Grenville province and its famous front, where younger, strongly gneissic rocks lie against much older but less metamorphosed rocks of the Superior province (Osborne and Morin, 1962).

It may ultimately transpire that detailed studies along and across the much better exposed Thelon Front will provide clues to the problems of the Grenville Front.

Conclusions

The potassium-argon age determination program of the Geological Survey as applied to the Canadian Shield (Stockwell and Wanless, 1961; Stockwell, 1961, 1963a, b) has been a key instrument in outlining or confirming its major divisions. There is little doubt that this primary objective has been achieved with signal success at a working scale of about 100 miles to the inch.

It is an entirely different matter, however, to use the same areal concentration of age determinations, with the same range in analytical error, to define and subdivide the geological framework within one of the major divisions of the Shield, the part of the Churchill province being considered, at a scale ten times as great. There, an anomalous age becomes more noticeable and more difficult to interpret.

The analytical error of about ±100 m.y. at 1,700 million years suggests that we are now trying to carry out a delicate operation with a dull scalpel.[1]

Potassium-argon ages, on the other hand, have decisively confirmed the existence and approximate location of a major break between the Slave and Churchill provinces. At the same time, they have shown that the problem there is not as simple as was once thought, by suggesting an analogy with the Grenville Front. Whether or not the gneissic granites east of the Thelon Front are actually Archaean rocks reworked by the Hudsonian orogeny might be proved or disproved by studying zircons, whose original ages may not have been so readily affected as those of the micas. A comparable situation is indicated in parts of the Finnish Precambrian (Wetherill *et al.* 1962), where zircon ages in granitic terrain are in the order of 2,400 million years compared to 1,800 million years for biotite ages.

[1] The apparent telescoping of time in the Precambrian may be responsible for this difficulty. One hundred million years in the Palaeozoic is enough to encompass two distinct orogenies, and a similar period of time in the Precambrian could conceivably cover as much activity.

Chapter VI

ECONOMIC GEOLOGY

Any discusssion of the economic geology of the map-area cannot ignore one simple fact. As of the end of 1962, only one mine had been brought into production in the entire region, and that one—North Rankin Nickel Mines Limited—has closed down due to lack of ore. This undoubted fact should not, perhaps, be viewed in too gloomy a light, but it must be admitted that this situation is not entirely due to lack of exploration and prospecting efforts in the more promising areas.

It is abundantly clear, moreover, that in much of the region, at least at present, the costs of exploration, development, and production are high. Mineral deposits in general must therefore be larger or of higher grade, or both, than would be required to make a mine in more accessible and friendly terrains.

The high cost of operations in this region is an intricately interwoven fabric of many factors including, amongst others, remoteness, almost complete lack of internal facilities and supplies of labour, food, fuel, and construction materials, short summers, and long bitter winters. Some of the generally adverse factors can be overcome or even turned to advantage in specially designed projects. For example, wide ranging and efficient self-contained aircraft operations, as we have seen, have not been seriously hampered by the lack of internal transportation or other facilities, and indeed have been made possible by the lack of forest cover. Similar usages of aircraft have also contributed to effective exploration and prospecting on a more detailed scale (*see* Giant Yellowknife Mines).

In one way or another all adverse factors become part of a single overriding consideration—transportation costs. Dubnie (1961, 1962) has discussed transportation cost problems in relation to the Canadian North at some length. At present, it seems obvious that the best hopes for mineral development in the region under consideration lie near natural transportation routes. The most important of these is undoubtedly that from railhead at Churchill, Manitoba, up the west coast of Hudson Bay, through Chesterfield Inlet to Baker Lake, and (with decreasing economic attractiveness) past the rapids in lower Thelon River, through Schultz, Aberdeen, and Beverly Lakes to, and possibly some distance up, Thelon River to the west. A potentially useful transportation system, not so long or so well endowed by nature, could extend eastward from Reliance at the eastern tip of

Great Slave Lake and up Pike's Portage route to Artillery Lake, from which short transportation links could spread north and possibly east or even southeast. Reliance is serviced by barge (Northern Transportation Company) from railhead at Waterways, Alberta, during the short ice-free season on Great Slave Lake.

The present decisiveness of the transportation cost factor, almost to the exclusion of other factors, on mineral developments over much of the region will become less compelling if, as, and when man-made facilities are introduced, possibly through the building of roads or railroads for the express purpose of assisting in the opening up of the barren grounds. Historical precedents for such actions are not lacking in Canada. Man-made facilities have the added attraction that they can be constructed where geological conditions are most favourable, in contrast to natural transportation routes which occur together with favourable geology mainly by chance.

History of Mineral Exploration

Most exploration and prospecting in the region has been concentrated within the broad, elongated assemblage of greenstones and sedimentary rocks trending northeast from Ennadai Lake to Rankin Inlet. To a lesser extent, attention has been directed to the greenstone-sedimentary belt north of Baker Lake and to the gneissic terrain east of the lake, to areas of Yellowknife rocks north of Artillery Lake, and to gneisses near Eileen Lake. Cursory examination (mainly aerial) of wide stretches of the barren grounds has also been carried out, in part as a by-product of other pursuits.

The Ennadai-Rankin belt was explored in 1928 and 1929 by organizations such as Cyril Knight Prospecting Company Limited, Dominion Explorers Limited, and Nipissing Mining Company. Previous to 1946 preliminary prospecting and some diamond drilling were carried out by Hudson Bay Exploration and Development Company. More recent activities in prospecting have been marked by increasingly heavy use of aircraft, both fixed- and rotary-winged, not only for freighting but also in airborne geological mapping and geophysical surveying. These efforts include those of D. W. Cameron, Kasba Explorations Limited, Canadian Nickel Company Limited (exploration arm of International Nickel Company of Canada Limited), Rankin Inlet Nickel Mines Limited (now North Rankin Nickel Mines Limited), Kennco Explorations (Canada) Limited, Newmont Mining Corporation of Canada Limited, Sherritt Gordon Mines Limited, Mining Corporation of Canada Limited, Selco Exploration Company Limited, and Giant Yellowknife Mines Limited.

That this large and, for this region, relatively accessible greenstone belt has received considerably more attention than is generally realized is apparent from the above. Although the belt cannot be considered as yet to have received exhaustive coverage, future inexpensive discoveries would seem improbable.

Some Geological Considerations

It is apparent that the detailed search for mineral deposits is not compatible with the operational needs of wide-ranging geological reconnaissance by helicopter. Nevertheless, it seems reasonable to attempt a general assessment of the region from an economic point of view, particularly as regards distinguishing the more likely areas or rock-units from the less likely. The significance of the following remarks, however, cannot be divorced from the problems of high costs and the overall disappointing results of recent searches for exploitable mineral deposits in the Ennadai-Rankin greenstone belt.

It is obvious from a glance at the map and legend that geological conditions vary widely over the region; so also do the likelihoods of mineral deposition. Mineral occurrences, gossans, shear zones, and quartz veins are not uncommon in many parts of the map-area, but they occur mainly in sedimentary and volcanic rocks of Lower Proterozoic (Aphebian) or older ages, or in basic intrusive rocks associated with them.

Ennadai-Rankin and Lower Thelon Greenstone Belts

The large sedimentary-volcanic belt between Ennadai Lake and Rankin Inlet is known to contain many occurrences of gold-silver and several of nickel-copper minerals. Indications of lead, zinc, and molybdenum, and of asbestos and soapstone are also known. Lord (1953a, pp. 9, 10), who briefly described many of these showings, reported siliceous iron-formation at or near the base of the Hurwitz quartzite, 5½ miles south of the outlet of Oftedal Lake, and other iron-formation deposits are reported from the Mistake Bay and lower Maguse River areas. Lord also remarked that "Most pitchblende occurrences in the Canadian Shield are in folded and faulted Proterozoic sedimentary, volcanic and minor intrusive rocks, or in nearby Archaean rocks of these classes. Thus, despite the fact that no direct evidence of their occurrence has been noted, about 14,000 square miles of the map-area warrant search for radioactive deposits . . . ." In mapping central Keewatin and eastern Mackenzie in 1954 and 1955, scintillation counters were carried in the aircraft, and although not generally used in systematic traversing, they were used to spot check some major fractures in granitic rocks from the air and local areas and rock specimens on the ground. No high readings were recorded.

A similar, but smaller, sedimentary-volcanic assemblage occurs astride lower Thelon River northwest of Baker Lake. There, geological conditions appear to be much like those in the Ennadai-Rankin belt, but the economic significance of its location, on the average much closer to water transportation, should not be overlooked.

In both these greenstone belts, the possibility of future economic usefulness of the Hurwitz quartzite (9) as a major source of silica should be considered, particularly for those bodies on or nearest to water transportation.

Yellowknife Rocks and the Thelon Front

The northwestern part of the map-area is underlain by sedimentary and volcanic rocks of the Yellowknife Group intruded by granites. To the west, this geological assemblage is known to be the host for many gold deposits from Yellowknife (Lord, 1951; Boyle, 1961; Henderson and Brown, in press) to Contwoyto Lake, and for some base metal deposits (Lord 1951; McGlynn, in preparation). These rocks, wherever found, merit reasonably close examination.

The Yellowknife rocks within the map-area are of considerable added interest because of the geological associations near their eastern limit, the Thelon Front (*see* Chapter V), where a long and complex history of folding, faulting, intrusion, metamorphism, and granitization is indicated. Rocks near the Thelon Front, by analogy with areas adjoining and astride other comparable fronts (Grenville Front in Ontario and western Quebec; Churchill-Superior boundary zone in central Manitoba), are likely to contain valuable mineral deposits and should, therefore, be prospected.

Gneissic Terrains

Extensive areas are underlain by the highly heterogeneous unit of gneissic granitic rocks (13), within which are many large and small, mapped and unmapped bodies of greenstones and allied rocks (1a, 7), gneisses and schists (12), and basic and ultrabasic rocks (B, C, E). These should be examined for gold-silver or base-metal deposits as appropriate. It must be admitted, however, that thorough prospecting of such terrain is a formidable task. The elongated body of paragneisses west of Moraine Lake would appear to deserve attention. Gneisses in the Eileen Lake area have been prospected to some extent, but the details of this work are not known to the writer. Nickel mineralization has been reported from banded gneisses along Chesterfield Inlet east of Baker Lake. Kyanite is present in paragneisses west of Ennadai Lake and could, conceivably, be found elsewhere in metasedimentary rocks in quantity sufficient to be of economic interest.

Pegmatite Dykes

Pegmatite dykes are present in many parts of the map-area, particularly in association with folded and intruded sedimentary and volcanic rocks. Except locally, however, these dykes are not prominent in size or abundance. A concentration of muscovite-bearing pegmatites was noted near the northwest shore of Howard Lake, southeast of Artillery Lake. Tourmaline and muscovite have been noted in pegmatites in the southeast and northwest parts of the map-area. White pegmatite bodies seem to be more common or more apparent in and near Yellowknife metasedimentary rocks.

All pegmatite dykes should be inspected for minerals containing lithium, beryllium, columbium, tantalum, and possibly tin.

Dubawnt and Goulburn Rocks

Rocks of the Dubawnt Group (18-22) generally do not show signs of mineralization, but the structural style and outcrop habit of these rocks militated against careful examination for mineral deposits in the course of helicopter mapping.

Goulburn rocks (15, 16) also failed to disclose any mineralization where they were examined. Closer examination of these rocks by L. P. Tremblay[1] tends to confirm this preliminary conclusion.

Some Typical Mineral Deposits

Although only one mine has been brought into production in the region, other properties have received more than passing attention and have been described in the literature to some extent. Several such occurrences and the one producing mine are described below as more detailed examples of the types of mineralization to be expected in the more accessible and geologically interesting parts of the area.

North Rankin Nickel Mines Limited

This property is on the west coast of Hudson Bay about 300 miles north of Churchill. Part of the property was examined and held many years ago by the Cyril Knight Prospecting Company, and thereafter was idle until 1951. In 1953-54 a three-compartment shaft was sunk to a depth of 331 feet, and levels were opened at 200 and 300 feet. In 1957 a 250-ton mill was started, and concentrates were sent by boat to Churchill during the shipping season and thence by rail to Sherritt Gordon Mines for treatment.

It is reported[2] that, as of December 31, 1961, proven and indicated reserves were 107,680 tons, averaging 2.71 per cent nickel and 0.84 per cent copper, and that total production to that date was 19,273,080 lb. nickel and 5,068,134 lb. copper from 357,076 tons of ore, for a total value of $8,380,483. During 1962 all economically extractable ore was mined and the property closed down at the end of the shipping season in October.

The mineral bodies occurred near the foot-wall of a southerly dipping serpentinite sill 200 to 300 feet in width and ¾ mile or more in length (Drybrough, 1931). The metallic minerals include, in order of abundance, pyrrhotite, pentlandite, chalcopyrite, magnetite, pyrite, violarite, marcasite and gersdorffite(?) (Pelzer, 1950, p. 79).

Canadian Nickel Company Limited

This company, a wholly-owned exploration arm of the International Nickel Company of Canada Limited, devoted considerable attention in the mid-1950's to

[1] Personal communication, 1962.
[2] Canadian Mines Handbook, 1962.

a nickel prospect at Ferguson Lake, about 150 miles due west of Rankin Inlet on the west shore of Hudson Bay. Extensive drilling was carried out, but no exploitable orebodies were reported.

The rocks in the general area (map-unit 13a) are highly impure, pink to grey, granitic to dioritic gneisses, with abundant inclusions of basic volcanic rocks and derived schists and gneisses, metasediments, and gabbro and other basic rocks. In 1952 and 1954, when the property was visited, diamond drilling was being concentrated along a belt of, in part, coarse-grained hornblendite. This body, several thousand feet long and averaging about 100 feet wide, appears to be approximately conformable with the attitude of the enclosing granitic gneisses, striking east and dipping 35°N. Within the hornblendite are several bright gossans, carrying nickeliferous pyrrhotite and some chalcopyrite but apparently no pentlandite. No estimates of grade or tonnage have been published.

Giant Yellowknife Mines Limited

Most of the information in this section, except for that on the Mistake Bay iron deposits, is condensed from a published report by Baragar (1962, pp. 23-28), who visited the properties in late July, 1961.

After an aerial reconnaissance of southern District of Keewatin in 1959, the exploration arm of Giant Yellowknife Mines Limited undertook an extensive, helicopter-supported mapping and exploration program of some 5,800 square miles in 1960 (Brown, 1964). The approximate area extended from the Dawson Inlet-Wilson Bay section of the west coast of Hudson Bay (about 50 miles north to south) westward for some 120 miles to the Heninga Lake and Padlei districts. Three groups of claims were staked as a result of this exploratory work, and these were examined in more detail in 1961 along with iron deposits discovered in the Mistake Bay area.

Peter Group

The Peter group of 108 claims lies between the two northeasterly arms of Kaminak Lake southwest of Quartzite Lake. A belt of mineralized schist, more than 2 miles long and up to a mile wide, trends east-northeast parallel with steeply dipping felsitic volcanic rocks to the north and west and basic volcanic rocks to the south.

The schist is a light buff to grey, talcose, sericite schist, probably derived from an acid volcanic rock. Finely disseminated pyrite is common in the schist, as are quartz-carbonate stringers and veins. Sampling in 1960 is reported to have yielded encouraging assays in gold, but in 1961 assay returns from 5,200 feet of drilling in 12 holes were disappointing, and plans for further work were abandoned.

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Dee Group

The Dee group of 64 claims is near Spi Lake, about a mile southwest of Carr Lake. The claims are underlain by a northwesterly striking succession of acidic lavas, fragmental rocks, and tuffs interbedded with intermediate to basic volcanic rocks. Northwest of the claims this assemblage is cut by a granite plug. Diabase dykes up to a hundred feet wide are common and intrude all other rocks.

Most of the known mineralization is on the easterly of two narrow peninsulas extending into Spi Lake from the northwest; outcrops occur only at its tip and base. At the tip of the peninsula are several patchy gossan zones, with gossans up to 120 feet long in brecciated acidic volcanic rocks and bedded tuffs. The several gossans contain: sphalerite, chalcopyrite, pyrite, pyrrhotite, and some galena; massive pyrrhotite and chalcopyrite, and disseminated pyrite and sphalerite; disseminated pyrite and sphalerite; disseminated pyrrhotite and chalcopyrite; and massive pyrite. The host rocks appear to be unsheared, but some of the gossan zones are cut by diabase dykes.

At the base of the peninsula weakly mineralized acidic tuffs are exposed over a strike length of about 300 feet and a maximum width of about 40 feet. Sulphides consist mainly of finely disseminated pyrite and sphalerite distributed in patches along this zone, which is roughly on strike with mineralized bedded tuffs on the west side of the tip of the peninsula. Several thousand feet of diamond drilling have been completed on the Dee group.

Torin Group

The Torin group of 81 claims is on lower Ferguson River, 9½ miles northwest of Tavani. Two mineralized zones occur near the contact of a northeasterly striking volcanic assemblage on the north and an intrusive complex of anorthositic and other gabbros on the south. The contact is presumably parallel with the strike of the volcanic rocks.

The most westerly of the mineralized zones is in a band of chlorite-carbonate schist, exposed for about 300 feet with a maximum width of about 65 feet. Drilling indicates that the schist is associated with and probably altered from a serpentine lens that extends southward. A chip sample taken across 7½ feet of disseminated pyrrhotite and chalcopyrite gave: nickel, 0.86 per cent; copper, 0.37 per cent; gold, 0.005 ounce a ton; and silver, 0.11 ounce a ton. About 300 feet to the east is a second serpentine lens with accompanying chlorite-carbonate schist which can be traced nearly 400 feet eastward. Thus the contact area between the volcanic rocks and the anorthositic gabbros appears to be a locus of serpentine intrusion and a zone of structural weakness. Severe shearing is found around the margins of the ultrabasic lenses and extends into the country rock beyond their terminations.

The eastern mineralized zone, on strike with and some 1,200 feet east of the western zone, is in a shear zone in volcanic rocks. The shear zone begins at the

borders of the eastern serpentine lens and extends for about 250 feet, with a maximum width of about 8 feet. The mineralization is largely disseminated pyrite and chalcopyrite. A grab sample gave: nickel, none detected; copper, 0.89 per cent; and cobalt, 0.02 per cent.

Mistake Bay Iron Deposits

In 1960, several occurrences of magnetite iron-formation were discovered in the area immediately north of Mistake Bay; all are within three miles of tide-water. In 1961, investigations by aerial and ground magnetometer, and by trenching and drilling, revealed five areas of well-bedded and drag-folded iron-formation in argillites (presumably of map-unit 11), which are apparently intruded by quartz-albite-sericite porphyry.

A considerable tonnage of lean ore, with 20-22 per cent recoverable iron, may be present. This material has low impurities, and good concentrating and pelletizing possibilities, but requires grinding to minus 325 mesh.

Algood Gold Mines Limited

A gold prospect, north of Regan Lake in the northwest corner of the map-area, has been examined by Algood Gold Mines Limited (Lord, 1951, pp. 68-70). Gold, in association with arsenopyrite and, in one place, pyrite, magnetite, and hematite, occurs in quartz and in mineralized slate and greywacke (3) of the Yellowknife Group.

Summary and Conclusions

Much of the region mapped has obviously not received anything like the amount of detailed exploratory work that might be expected to produce mines. Nor is it likely to in the near future because of the obvious high cost of operations other than those in areas close to water transportation.

The most attractive area, the Ennadai-Rankin greenstone belt, has received much more attention than any other segment, and it has disclosed innumerable gossans, quartz veins, shear zones, and mineralized areas. Many of these are of no or little value, several are serious prospects, and one has produced a short-lived mine.

As Lord pointed out (1953, p. 10) in referring to southern Keewatin, "It would be unusual, indeed, if the widespread greenstones and associated rocks (1)[1] did not contain commercial deposits of gold and other metals . . . ." This remark should also be applicable to the other greenstone belts of the region.

The Ennadai-Rankin area is known to contain gold, silver, nickel, copper, lead, zinc, molybdenum, and iron. In addition, of possible interest are asbestos,

[1] Map-unit 7 of this report.

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kyanite, and quartzite. The problem is to find the places where these are sufficiently concentrated.

The writer cannot help but feel optimistic about the ultimate future of this greenstone belt, and, once major deposits are developed in it and overall costs lowered through the development of a more general transportation network, it should be possible to push on from this base into the less promising but almost completely unexplored areas.

Prospecting and staking are forbidden in the Thelon Game Sanctuary.

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