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DEPARTMENT OF ENERGY, MINES AND RESOURCES

MEMOIR 377

GEOLOGY OF KOGNAK RIVER AREA, DISTRICT OF KEEWATIN, NORTHWEST TERRITORIES

K. E. Eade

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DISTRICT OF KEEWATIN, NORTHWEST TERRITORIES

(NTS 65G, east half, Watterson Lake;

NTS 65H, west half, Henik Lakes)

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By
K. E. Eade

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PREFACE

A major role of the Geological Survey of Canada is to provide a comprehensive inventory and understanding of the geological framework of the nation and thereby permit an estimate of the potential abundance and probable distribution of the mineral and fuel resources available to Canada.

Following the Second World War the Geological Survey commenced an ambitious program designed to complete the reconnaissance geological mapping of the vast, relatively unknown northern reaches of the nation. Data provided by the earliest helicopter-supported operations indicated that Kognak River map-area was geologically complex and that more detailed studies were required to permit an evaluation of the region; these were carried out between 1962 and 1964 under the direction of the author and the results are presented in this report.

All rocks in the area are of Precambrian age and form part of the Churchill Structural Province. The oldest rocks, a volcanic and sedimentary succession, have been metamorphosed to varying degrees. Relatively undeformed sequences of sedimentary rocks unconformably overlie these. Granitic rocks that vary widely in composition and age are abundant and dykes of gabbro and diabase of two different ages were recognized.

Extensive prospecting and exploration work has been carried out in the region, particularly during the past 15 years. Gold and sulphide deposits have been found in several places; some of these are associated with iron-formation and the author presents a theory of formation for the latter that should prove a useful guide to future prospecting for similar occurrences. As some pebble-conglomerate units have been shown to be slightly radioactive, the results of the detailed mapping of these and of related quartzite units presented in this report should be of considerable interest to prospectors.

This report, presenting as it does a thorough account of the stratigraphic, structural, and economic geology of an interesting and complex part of the Canadian Shield, will be of interest to all those concerned with the study of Precambrian geology.

D. J. McLAREN,
Director, Geological Survey of Canada

OTTAWA, October 12, 1973

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Abstract

The geology of an area in the Churchill Structural Province, west of Hudson Bay, is described and the results of three field seasons of mapping are presented in the report. The rocks are entirely Precambrian, partly Archean, and the remainder, chiefly Aphebian, with minor Helikian. Although the Hudsonian orogeny resulted in some metamorphism and igneous intrusion, the effects are much less pronounced than in most parts of the Churchill Province.

The metamorphic grade of Archean Henik Group volcanic and sedimentary rocks ranges from lower greenschist to amphibolite facies. Schists, paragneiss, and granitoid gneiss result from metamorphism and metasomatism of some of these rocks. Plutons, chiefly of granodiorite composition and less commonly quartz diorite, monzonite or syenite, intrude the volcanic and sedimentary rocks. Gabbro or metagabbro dykes trending north to northeast cut the Archean rocks.

Areally limited and previously undifferentiated Montgomery Lake Group sedimentary rocks of early Aphebian age consist of boulder-conglomerate, quartzite, impure quartzite, greywacke, and siltstone. They unconformably overlie Archean rocks and in turn are overlain unconformably by the Hurwitz Group. The Aphebian Hurwitz Group, which occurs widely throughout southern and central District of Keewatin, has the thickest and most varied section in this map-area. Basic sills intrude the sedimentary rocks of the Hurwitz Group in part of the area. Sedimentary rocks occurring west of the Hurwitz Group and separated by major faults are considered to be lateral equivalents of the Hurwitz Group.

An Aphebian quartz monzonite pluton related to the Hudsonian orogeny caused contact metamorphism of the Hurwitz Group in a very limited area, although no intrusive contacts have been seen. Coarse-grained, porphyritic, fluorite-bearing granite, probably early Helikian, occurs only in one small area. The youngest rocks in the map-area are northwest-trending gabbro or diabase dykes.

Metamorphism in the Montgomery Lake and Hurwitz Groups does not exceed the greenschist facies except for limited areas of contact metamorphism in the Hurwitz Group.

The earliest deformation, involving Archean rocks, caused north-trending folds but these are commonly obscured by later deformation. Two Aphebian deformations resulted in north- to northeast-trending folds and west- to northwest-trending folds. The earlier of these deformations was responsible for pronounced cleavage in both Archean and Aphebian rocks.

Prominent east-trending thrust faults are related to the deformation that produced the west- to northwest-trending folds. Normal faults of various trends are abundant and apparent dislocation is considerable on some of them.

Gold mineralization occurs in basic Archean volcanic rocks and in low-grade Archean iron-formation in some places. Minor amounts of chalcopyrite are present in shear zones in the basic volcanic rocks. Pebble-conglomerate lenses in the orthoquartzite of the Hurwitz Group and the pyrite-bearing quartzite of the Montgomery Lake Group may be of interest in the search for radioactive minerals.

Résumé

Ce rapport décrit la géologie d'une région de la province tectonique de Churchill, à l'ouest de la baie d'Hudson, et comprend les résultats de trois saisons de cartographie sur le terrain. Les roches sont toutes d'âge précambrien, en partie de l'Archéen, le reste datant surtout de l'Aphébien et quelques-unes de l'Hélikien. Bien que l'orogénèse hudsonienne ait produit du métamorphisme et des intrusions ignées, les effets sont beaucoup moins prononcés que dans la plupart des parties de la province de Churchill.

L'intensité du métamorphisme des roches volcaniques et sédimentaires du groupe archéen d'Henik varie du faciès à schiste vert inférieur au faciès à amphibolite. Les schistes, les paragneiss et les gneiss granitoïdes sont le résultat du métamorphisme et de métasomatose de certaines de ces roches. Des plutons composés surtout de granodiorite et moins souvent de diorite quartzeuse, de monzonite ou de syénite sont intrusifs dans les roches volcaniques et sédimentaires. Des dykes de gabbro et de métagabbro dont la direction varie du nord au nord-est recoupent les roches archéennes.

Les roches sédimentaires de l'Aphébien inférieur du groupe de Montgomery Lake, d'étendue limitée et autrefois non différenciées sont constituées de conglomérat à boulders, de quartzite, de quartzite impur, de grauwacke et de siltstone. Elles recouvrent en discordance les roches de l'Archéen et sont à leur tour recouvertes en discordance par le groupe de Hurwitz. Le groupe de Hurwitz de l'Aphébien qu'on retrouve un peu partout dans le sud et le centre du district de Keewatin est représenté dans cette région-ci par la plus épaisse et la plus variée section connue. Dans une partie de la région, des filons-couches basiques pénètrent dans les roches sédimentaires du groupe de Hurwitz. Les roches sédimentaires qu'on trouve à l'ouest du groupe de Hurwitz et qui sont séparées de ce groupe par d'importantes failles sont probablement des équivalents latéraux de ce groupe.

Un pluton aphébien de monzonite quartzeuse relié à l'orogénèse hudsonienne est à l'origine du métamorphisme de contact du groupe de Hurwitz dans une région très limitée même si on n'a découvert aucun contact intrusif. On rencontre un granite à grains grossiers, porphyrique contenant de la fluorine seulement—dans une petite région. Ce granite est probablement d'âge hélikien. Les roches les plus jeunes de cette région sont des dykes de gabbro ou de diabase à direction nord-ouest.

Le métamorphisme du groupe de Montgomery Lake et du groupe de Hurwitz ne dépasse pas le faciès à schiste vert sauf dans les zones restreintes de métamorphisme de contact du groupe de Hurwitz.

La déformation la plus ancienne n'affecte que les roches archéennes et est représentée par des plis à direction nord mais ordinairement les déformations subséquentes les ont oblitérées. Deux déformations aphébiennes ont produit des plis à orientation nord à nord-est et ouest à nord-ouest. La première de ces deux déformations est responsable du clivage prononcé des roches de l'Archéen et de l'Aphébien.

Les chevauchements bien définis à direction est sont reliés à la déformation qui a produit les plis orientés vers l'ouest à nord-ouest. Les failles normales aux directions variées sont abondantes et plusieurs montrent une dislocation apparente importante.

On rencontre une minéralisation aurifère en certains endroits dans les roches volcaniques basiques datant de l'Archéen et dans les formations ferrifères de basse teneur de l'Archéen. Il y a de petites quantités de chalcopyrite dans les zones de cisaillement des roches volcaniques basiques. Les lentilles de conglomérats à cailloux dans l'orthoquartzite du groupe de Hurwitz et le quartzite pyritifère du groupe de Montgomery Lake sont d'un certain intérêt dans la recherche de minéraux radioactifs.

INTRODUCTION

Kognak River area (NTS 65G, east half and 65H, west half) is in the southern District of Keewatin between latitudes 61° and 62°, and longitudes 97° and 99°. The centre of the area is 230 miles northwest of Churchill, Manitoba, 133 miles west of Eskimo Point, both on the Hudson Bay coast, and 100 miles east-northeast of the Canadian Meteorological Service station, Ennadai, on Ennadai Lake. Mapping was done by the writer in the 1962, 1963, and 1964 field seasons and in 1965 for four days with helicopter support. Assisting capably with the mapping were R. A. Alcock (1962); D. M. Carmichael and H. L. Pollak (1963); and P. F. Hoffman and L. A. Prieto (1964). J. F. Roberts and J. D. Mason (1962); B. W. Charbonneau, K. E. Denike, R. L. Aucoin (1963); and J. B. Henderson, U. Kretschmar, V. Tanaka (1964) assisted efficiently in the field. Preliminary results of this work have been published (Eade, 1964, 1966).

Geological reconnaissance mapping in the southern part of District of Keewatin (Lord, 1953; Wright, 1967) included this area; that broad study of the regional geology provided the background for the more detailed work carried out in the limited Kognak River area. Aeromagnetic maps, at a scale of 1 inch = 1 mile, are available for all the area (*see* Fig. 3, p. 45). The area is covered by aeromagnetic compilation maps (Henik Lakes, Map 7177G and Watterson Lake, Map 7178G) at a scale of 1 inch = 4 miles. Lee (1959) described the surficial geology of the southern District of Keewatin, including this area.

Aircraft, float- or ski-equipped, based at Churchill, Manitoba, afford access to the area throughout most of the year. A private airstrip near the southeast corner of Cullaton Lake is suitable for larger, wheel-equipped aircraft, but prior arrangements must be made for its use. The area may be reached by canoe from the coast of Hudson Bay by way of Tha-anne and Kognak rivers, but the many shallows and rapids make this a difficult undertaking.

Work was begun before breakup during the three field seasons. By the first week of June, much of the snow cover had disappeared except in protected places. Smaller lakes and rivers were ice-free in the first week of July in 1962, 1963, and 1964, but larger lakes opened two or more weeks later. Large sheets of ice were still in the Henik Lakes early in August. In the final weeks of August, weather conditions worsened and ended the field seasons.

Much of Kognak River area is within the barren lands, with stands of stunted black spruce and tamarack south of Ducker Lake, around the south end of South Henik Lake, and in smaller isolated localities, such as southeast of Ameto Lake. The heavily drift-covered southeast corner of the area supports a sparse black spruce forest. Dwarf birch and willow are abundant. Permafrost is present throughout the area.

The withdrawal of the inland Eskimos to coastal areas left this region with no permanent population, but old camp sites are present in many places. At the time the writer was in the area, Selco Exploration Company Limited maintained a well-equipped base camp on Kognak River, just north of Mountain Lake. This company was the only one carrying on an active exploration program in the region at that time.

Migratory routes of the barren ground caribou cross the area, and for short periods in late May, early June, and in August caribou are plentiful. Wolves and arctic fox were observed many times, and in July 1963 a single brown barren land grizzly bear was seen. Ground squirrels are common and lemmings are abundant during some years. Lake trout, pike, and grayling are plentiful in the lakes and rivers. Ptarmigan are locally numerous, and ducks, geese, and smaller birds nest in the area.

The quartzite of unit 12 commonly forms prominent ridges, particularly in the east half of the area. Between North Henik Lake and South Henik Lake the top of the quartzite ridge is 540 feet above the adjacent lake level. With the exception of the ridges underlain by quartzite, local relief is moderate and rarely more than 100 feet. Outcrop is abundant along the ridges, but elsewhere it is moderate to scarce.

Acknowledgments

In addition to the technical officers and assistants previously mentioned, particular thanks are due Selco Exploration Company Limited and their employees, who provided valuable assistance and co-operation. Thomas Lamb Airways Ltd. and their employees aided the work by providing a radio communication link.

GENERAL GEOLOGY

The area lies within the Churchill Structural Province of the Canadian Shield (Stockwell, 1961), and all known bedrock is of Precambrian age. The oldest rocks are intercalated volcanic and sedimentary rocks of the Henik Group, which have been metamorphosed to various degrees. In places they are relatively unmetamorphosed with well-preserved primary structures and textures, but elsewhere basic schist or gneiss, paragneiss or migmatite, and, in part, foliated granodiorite or amphibolite are all apparently derived from rocks equivalent to the Henik Group rocks.

Massive (i.e., unfoliated) 'granite' rocks of both magmatic and metasomatic origin are abundant. Composition and texture vary greatly, and more than one age is represented.

The Montgomery Lake Group, of limited areal distribution, consists of conglomerate, quartzite, and siltstone and unconformably overlies the older Henik Group rocks. The Hurwitz Group, which unconformably overlies the Montgomery Lake Group, is composed of conglomerate, orthoquartzite, slate, shale, argillite, dolomite, greywacke, arkose, and impure quartzite, with intrusive gabbro sills. The Hurwitz Group was deposited in a major Aphebian sedimentary basin extending at least from Kasba Lake (southwest of the area) to the vicinity of Rankin Inlet, on Hudson Bay (northeast of the area). The greatest thickness and most diverse lithology of the Hurwitz Group are preserved in Kognak River area.

A sequence of sedimentary rocks in the northwest quarter of the area, quartzite, arkose, argillite, and dolomite, is considered to be the lateral equivalent of the upper part of the Hurwitz Group.

Dykes of gabbro and diabase occur in two different trends of different ages, the younger postdating Hurwitz Group rocks. Small lamprophyre dykes are rare.

Metamorphism is commonly of low to medium grade. Near some plutons there is evidence of contact metamorphism.

Henik Group

The term Henik Group (1–4) is introduced to simplify reference to a recognizable sequence of metamorphosed volcanic and sedimentary rocks. They are extensively folded and faulted and are intruded by granitic rocks. North and South Henik lakes, from which the name is taken, are prominent physiographic features in this region.

Volcanic Rocks

The volcanic unit (1) is extremely heterogeneous and includes lavas, fragmental or pyroclastic rocks, and minor hypabyssal intrusive bodies, ranging in composition from ultrabasic to acidic. Weak to medium regional metamorphism has affected all these rocks; contact metamorphism has affected them in a few places. Deformation ranges from slight to intense, thus original structures may be preserved or, in schistose rocks, completely destroyed.

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Revised version approved: October 12, 1973

Table of Formations

Time			Group	Lithology
Cenozoic				Morainic material: gravel, sand, clay, silt
Unconformity				
PRECAMBRIAN	PROTEROZOIC	HELIKIAN		Gabbro dykes, biotite lamprophyre sills
			Intrusive contact	
				Granite, pink, porphyritic, commonly fluorite-bearing (Nueltin Lake granite)
		Intrusive contact		
		APHEBIAN		Granite, quartz monzonite, granodiorite, pink, medium-grained
			Intrusive contact	
				Quartzite, arkose, dolomite, argillite, phyllite, greywacke (may be Hurwitz Gorup)
			Hurwitz Group	Gabbro sills
				Intrusive contact
				Impure quartzite, arkose, quartz–sericite schist, impure dolomite, greywacke, conglomerate, andesite
				Greywacke, siltstone
				Dolomite, argillite, siltstone, greywacke, quartz–jasper–hematite and quartz–magnetite iron-formation, tremolitized dolomite
				Slate, shale, siltstone, greywacke
				Orthoquartzite, arkose, pebble-conglomerate
				Boulder conglomerate, greywacke conglomerate, greywacke

Table of Formations (conc.)

Time			Group	Lithology
PRECAMBRIAN	PROTEROZOIC	APHEBIAN	Unconformity	
			Montgomery Lake Group	Siltstone
				Quartzite, impure quartzite, greywacke
				Boulder conglomerate, greywacke, gabbro
	Unconformity			
		ARCHEAN		Gabbro, metagabbro, diabase, metadiabase dykes, biotite lamprophyre and feldspar porphyry dykes
			Intrusive contact	
				Granodiorite, quartz diorite, quartz monzonite, granite, monzonite, syenite
				Granodiorite gneiss, granite gneiss
				Quartz–feldspar–biotite schist and gneiss, paragneiss, migmatite, quartz–hornblende–biotite schist and gneiss
				Hornblende–chlorite–feldspar schist and gneiss, amphibolite
			Intrusive or gradational contact	
			Henik Group (stratigraphic succession unknown)	Dolomite, phyllite
				Iron-formation, jasper–hematite, siliceous magnetite–hematite, quartz–magnetite
				Greywacke, argillite, phyllite tuff; minor conglomerate, quartzite, iron-formation, dolomite, quartz–feldspar–mica and quartz–mica schist, metagreywacke
				Andesite, dacite, basalt, rhyolite, fragmental volcanic rocks; gabbro, diorite

Several distinct bands of rocks of the volcanic unit are present throughout the area; Lord (1953) showed that similar rocks are abundant east and northeast of the area. They are of limited extent to the south and southwest.

About 70 to 75 per cent of the unit consists of andesite and basalt, commonly in thick, massive flows. Locally, good pillow structures are present with pillows 1 foot to 5 feet long. Scoriaceous flow tops and flow breccias occur, and some vesicules in the volcanic rocks are filled with quartz or calcite. These rocks are typically fine grained, dense, dark green on weathered surfaces, green to grey-green on fresh surfaces, and locally have pronounced schistosity.

Medium-grained rock of the same basic composition, in irregularly shaped masses, grades into the lavas, and perhaps represents the inner parts of very thick flows or possibly the channels feeding the flows. These masses do not show chilled margins, indicating approximate contemporaneity with the lavas, although locally crosscutting them. North of Griffin Lake, two small areas within the lavas, in which medium-grained diorite or gabbro predominate, have been delineated, although some fine-grained lavas occur within the medium-grained rocks. A circular boundary, clearly visible on air photographs, outlines one area and it is suggested that this is an eroded volcanic neck or channel that fed the flows. Discontinuous beds of rhyolite tuff are abundant in the lavas surrounding this feature.

Medium-grained gabbro, in irregular masses with chilled, fine-grained margins, cuts the basic volcanic rocks in numerous localities. The chilled contact zones distinguish these masses from the above-described gabbro or diorite bodies that grade imperceptibly into the basic volcanic rocks. Little difference in composition is evident between the two types of bodies, but those with chilled margins are much less altered and contain readily recognizable plagioclase (andesine) and augite. In part, these rocks are quartz gabbro with distinctive blue quartz eyes. Crosscutting relations and chilled margins show that these stocks are younger than the basic volcanic rocks, but their close spatial associations suggest that they may be genetically related.

Ultrabasic rocks[1] occur within the basic lavas in a few localities, but the masses are, for the most part, too small and irregular in shape to show on the accompanying geological map. Several such masses just north of Griffin Lake are red-brown on weathered surfaces, dark green to black on fresh surfaces, and are composed almost entirely of serpentine with abundant accessory pyrite.

The basic lavas and equivalent medium-grained rocks have chlorite as a major constituent, with actinolite in place of chlorite in those of slightly higher metamorphic grade. Plagioclase, the other major constituent, is almost always altered to a very fine grained matte of secondary minerals, epidote, chlorite, and zoisite. In some specimens, clear, secondary albite is developed, particularly in the phenocrysts of porphyritic lavas. Tiny, interstitial grains of carbonate, probably secondary, and scattered, small quartz grains are present in most specimens. Magnetite and pyrite are normally present as accessory minerals, and less commonly, sphene. Biotite, in part recrystallized, is found in some of these rocks.

Dacite flows occur with the other lavas but quantitatively form only 5 to 8 per cent of the volcanic unit. The dacite is light to dark grey or greenish grey on weathered surfaces and dark grey to greenish grey on fresh surfaces. The 10 to 12 per cent quartz in the dacite is the main compositional difference between dacite and andesite. No preferred stratigraphic position for the dacite flows within the volcanic sequence is discernible.

Two miles northeast of North Henik Lake, a small area is identified on the map, 1364A, as unit 16 instead of unit 1(b), serpentinite, within volcanic rocks, unit 1.

Agglomerate, present with the basic lavas in places, forms beds 2 to 20 feet or more thick but limited in lateral extent to several hundred feet. Normally the fine-grained, dark green matrix is andesitic in composition and contains white to grey or green weathering dacitic to rhyolitic fragments. More rarely, both matrix and fragments are quartz latite to rhyolite. Fragments in the agglomerate range from 1 inch to 2½ feet in diameter with an average size of 5 to 6 inches, all set in a matrix of fine- to medium-grained tuff. Shearing of agglomerate results in a schistose matrix with elongate, deformed fragments. Minerals in the agglomerate, as in the lavas, are much altered, the plagioclase to a fine matte of secondary minerals, the mafic minerals to chlorite. The lack of bedded or graded features in these rocks supports the concept of a rapid, chaotic, possibly subaerial mode of accumulation.

Layers of tuff, usually massive although bedded in part, are commonly present with agglomerates in the lavas, but may also occur without agglomerate. In many places the clastic and pyroclastic types are interlensed and are not differentiated. The tuffs, light grey to light or medium green on weathered surfaces and dark green to grey on fresh surfaces, are fine to medium grained or, rarely, coarse grained with subangular to subrounded grains set in a finer matrix. They are now composed of altered plagioclase, rock fragments, and quartz grains in a felt-like mass of secondary minerals of indeterminable composition. In some coarser crystal tuffs, subhedral plagioclase grains are less altered. These tuffs are similar to those of unit 2a, but where intimately associated with the lavas they cannot be mapped separately.

Small amounts of rhyolite, intercalated with the basic volcanic rocks, are extensively sheared, a feature much less evident in the adjacent rock types. This shearing has obliterated any evidence that may be used to distinguish whether the rhyolite was flows or of tuffaceous origin. A white weathered surface is characteristic, with light grey to greenish grey fresh surfaces, and although mostly fine grained to very fine grained, they commonly contain phenocrysts or 'eyes' of quartz or, less abundantly, feldspar. Thin sections of these rocks show the fine groundmass to be composed of a matte of secondary minerals and tiny quartz grains.

Massive quartz-feldspar porphyry, in irregular-shaped masses or dykes, occurs in a few places within the volcanic rocks. It is always less sheared than the adjacent rocks and is probably related in origin to the rhyolite, but is slightly younger than the volcanic pile.

Adjacent to contacts with granodiorite (8), the basic volcanics are transformed to amphibolites and quartz–plagioclase–hornblende gneisses. These medium-grained amphibolites consist principally of common green hornblende and plagioclase, but closer to the granodiorite they grade into hornblende gneiss in which quartz is abundant and foliation is pronounced.

Inclusions of amphibolite and hornblende gneiss occur within the granodiorite close to the contact. The width of these contact zones ranges from 2,000 feet to 2 miles or more.

The complexity and heterogeneity of the volcanic unit make it impossible to separate many of the above-described rock types on the geological map. Figure 1 (*in pocket*) illustrates the detailed geology of a small area of volcanic rocks (unit 1) on the north shore of Ameto Lake in which seven different rock types have been delineated. The area selected for this detailed study is not exceptional and similar subdivisions could be made in many places.

Clastic Rocks

A thick sequence of clastic sedimentary rocks (unit 2), chiefly greywacke and argillite, occurs conformable with, and for the most part, stratigraphically above the volcanic rocks. Thick sections of tuff are included in this unit, as well as minor amounts of conglomerate and quartzite present with the greywacke and argillite.

Greywacke and argillite. The greywacke–argillite appears to form a very thick section, but the lack of consistent marker beds makes it impossible to estimate the stratigraphic thickness. The fine- to medium-grained greywacke, greenish grey or light buff on weathered surfaces and dark grey or greenish grey on fresh surfaces, occurs in beds from 2 inches to 6 feet or more thick. Slump bedding and graded bedding are common, although difficult to observe because of the heavy lichen cover typical of the outcrop surfaces of these rocks. In the graded beds there is a gradation of colour, the finer upper part being darker. Some thick greywacke beds appear very massive and compact, whereas some of the finer argillite beds are very finely laminated. Argillite is normally interlayered with the greywacke, forming the upper part of each graded bed but, as well, may itself compose thick homogeneous beds. Angular fragments of fine-grained argillite are abundant in some of the thick greywacke beds, and in a few localities scattered white quartz pebbles up to 1 inch in diameter are present in the greywacke. Cleavage, well developed in most of these rocks, is always more intense in the finer grained parts.

Composition of the greywacke is variable, but in almost all 44 thin sections of specimens that were examined more than 15 per cent of the rock consisted of detrital matrix and the quartz content was less than 70 per cent. Feldspar and rock fragment content differ from specimen to specimen, so that according to Pettijohn's (1957) classification both lithic and feldspathic greywackes are present, but the former are more abundant. Carbonate, up to a maximum of 30 per cent, occurs in many of the greywackes. Quartz grains, subangular to subrounded, are moderately to poorly sorted with the most common size range being between 0.5 and 1.8 mm, although some grains, possibly second generation, are considerably larger. Strain shadows are present in most grains of quartz. Feldspar grains, mostly plagioclase with only minor microcline, are similar to the quartz grains in size, sphericity, and degree of sorting. Most plagioclase grains are much altered to epidote, sericite, and clinozoisite. Microcline is similarly altered but to a lesser degree. Rock fragments are composed of chert, quartz, and feldspar, or fine-grained quartz, sericite, and biotite. The matrix consists of fine-grained quartz and shreds of sericite, with some biotite or chlorite. Disseminated pyrite grains, common in the greywacke, result in small rusty pits on the weathered surfaces. Rare accessory grains of zircon and sphene occur in some specimens. Greywacke affected by metamorphism has a fine- to medium-grained matrix of quartz and biotite, the latter in poikilitic flakes containing tiny quartz grains.

The argillite is similar in composition to the greywacke. Tiny quartz and plagioclase grains occur in a very fine matte of sericite with some biotite or, less commonly, chlorite. However, most of the matrix is so fine grained that exact mineral composition cannot be determined. Recrystallization is more apparent in the fine-grained beds than in adjacent greywacke laminae.

Quartzite and conglomerate. Medium- to fine-grained quartzite or impure quartzite, buff to grey on weathered surfaces and dull greenish or yellowish grey on fresh surfaces, is interbedded with the greywacke in some localities. Quartz grains, with minor feldspar, are in a matrix of fine flakes of sericite and biotite or chlorite. Lenses of conglomerate occur within the greywacke in a few places. West of Cullaton Lake, a conglomerate lens consists solely of pink to grey granodiorite and granodiorite gneiss boulders up to a foot in diameter, with an average diameter of about 3 inches, set in a matrix of greywacke similar to the adjacent greywacke beds. North of Montgomery Lake, a conglomerate lens in the tuff and greywacke, adjacent to iron-formation (3), contains pebbles and boulders of jasper, white quartz, brown weathering quartzite, and minor granodiorite gneiss, in a greenish grey greywacke matrix of composition similar to the adjacent tuff and greywacke. Much of the conglomerate shows elongation of the pebbles and boulders due to shearing. West of Bray Lake, conglomerate occurs with the greywacke close to basic volcanic rocks. There, the pebbles, which are as much as 4 inches in diameter, consist of fine-grained quartzite, milky to clear quartz, granodiorite or micropegmatite, and aphanitic acid volcanic rocks or chert. Most of them are well rounded, although shearing results in some lenticular shapes. The matrix is greywacke containing abundant, rounded, dark coloured quartz grains, carbonate, and abundant, recrystallized biotite flakes. One of these conglomerate lenses west of Bray Lake is spatially close to the Hurwitz Group orthoquartzite (12), but is separated from it by an outcrop of andesite (1). It is possible that this conglomerate could be Hurwitz Group conglomerate (11), but the andesite overlying it shows that it is a conglomerate lens associated with the greywacke (2).

Tuff. Fine- to medium-grained tuffs are abundant in this clastic unit, although many are difficult to distinguish from greywacke and argillite. The tuffs are typically massive, but also present are well-bedded rocks with thickness ranging from 1 inch to 5 feet or more, and showing rare graded bedding. The colour on fresh surfaces ranges from medium to dark grey or green and on weathered surfaces from light to dark grey to green or a very distinctive bluish green, the bluish green apparently being characteristic of only these tuffs. Subangular to subrounded grains are most typical. Sorting is poor in the medium-grained varieties, but much better in the fine-grained rocks. Angular fragments of aphanitic felsite are common, and crescentic, shard-shaped grains of probable devitrified glass, now consisting of a very fine mosaic of quartz grains, are visible in thin sections of many tuff specimens. Both lithic and crystal tuff, the latter with coarse feldspar grains prominent on weathered surfaces, are represented. Crystal tuff is probably more common, although this has not been verified statistically. Composition of the tuffs has the same range as the volcanic flow rocks but in these clastic rocks, chlorite-rich types, equivalent to andesites, are far less abundant than are more acidic varieties. Plagioclase, chiefly altered to secondary minerals, is always present in subangular to subrounded grains that may be interlocking and are commonly embayed or cusped. Zoning of the plagioclase is visible in a number of specimens. Quartz, along with the plagioclase and rock fragments, is the other common component that forms the coarser grains of the tuffs; these are all set in a very fine matte of white mica, biotite, and extremely fine grained quartz with, locally, some chlorite and up to 5 per cent carbonate. Iron oxides are the common accessories; sphene is less abundant. Shearing of these rocks resulted in an alignment of the micaceous minerals similar to that displayed in the greywacke.

Quartz–mica schist and quartz–feldspar–mica schist. Although these schists occur throughout the area, the greatest number of exposures are present west of South Henik Lake. Schists are mostly derived from clastic rocks, greywacke–argillite or tuff, and lesser amounts, from rocks that may have been originally rhyolite or latite. These fine- to medium-grained rocks have shiny, micaceous, brownish grey to light grey or white fresh surfaces and medium to light grey or brownish grey weathered surfaces. Bedding is preserved in some of these rocks, particularly where bedding attitude differs markedly from the schistosity attitude. Quartz, plagioclase, sericite, and biotite, in varying proportions, are the major components, but carbonate and chlorite may also be present. The dark coloured schists typically contain biotite and chlorite, whereas the light grey or white schists consist of quartz and sericite with some plagioclase. Many of the quartz–sericite schists are characterized by round, clear quartz 'eyes' that are prominent on weathered surfaces. Scattered grains of iron oxides are the only accessory minerals.

Iron-formation

Iron-formation (unit 3) is of the thin-banded, chert or quartz, magnetite and hematite type. Banding, pronounced but thin (an average of $\frac{1}{8}$ to $\frac{1}{4}$ inch), characterizes the unit, with interbands of greyish white quartz, grey chert or jasper, and bands rich in hematite or magnetite. These iron-formation units range from 2 to 300 feet thick, and are rarely more than 5 or 6 miles long, but form *en echelon* lenses. West of Montgomery Lake, a small lens is associated with basic lavas, but most other iron-formations in the area occur within the clastic rocks. Because of the thinness of iron-formation horizons, almost all occurrences are shown on the map in an exaggerated scale. However, the wide iron-formation band south and west of Montgomery Lake includes a high content of interbedded clastic rocks that cannot be delineated on the present scale of mapping.

Iron oxide content of the iron-formation is variable; a number of thin sections from specimens of iron-formation east and west of South Henik Lake show a range from 15 to 60 per cent iron oxides. Magnetite is always more abundant than hematite and is more commonly found alone. In only one thin section of 18 examined was hematite found alone; in the same thin section carbonate (siderite?) was also present. Fine shreds of sericite and biotite commonly occur in minor amounts, in addition to the major constituents of the iron-formation.

Metamorphism is more intense north of Bernier and Griffin lakes than east and west of South Henik Lake. In the metamorphosed iron-formation, magnetite is the only iron oxide, the quartz is recrystallized and more coarse grained, and iron silicate minerals grunerite and cummingtonite are typical. A specimen of iron-formation (3) from a band occurring in the gneisses of unit 6 adjacent to the young granite (20) contains about 5 per cent andalusite, as well as biotite, chlorite quartz, and 20 to 25 per cent magnetite. Andalusite occurs locally, and it is invariably the result of contact metamorphism by the younger granite (20).

Thin (100- to 150-foot) iron-formation bands west and south of Cullaton Lake differ from other occurrences in that pronounced banding is lacking and iron oxide content is lower. Quartz is the major constituent, with some magnetite, grunerite, common green hornblende, and minor plagioclase. The magnetite, normally less than 20 per cent of the rock, is disseminated rather than concentrated in particular beds. Contacts of this iron-formation with adjacent greywacke are gradational with complete gradation from magnetite-rich greywacke to iron-formation. Like the greywacke, the iron-formation is a clastic rock, possibly a fossil black sand deposit.

Whereas most iron-formation shows as magnetic highs on aeromagnetic maps, no significant anomalies result from the narrow, low-grade iron-formation west of Cullaton Lake. Where younger Hurwitz Group rocks overlie most iron-formation the trends of the latter can be traced on aeromagnetic maps beneath the younger strata.

Dolomite and Metadolomite

Thin bands of carbonate rocks of the Henik Group are rare in comparison to the clastic rocks (2) with which they occur. The most prominent band is north of Griffin Lake, in the extreme western part of the area, and consists of dolomite or metadolomite, with some intercalated phyllite (unit 4). It occurs in paragneiss (6) which is derived from rocks equivalent to the clastic rocks (2). What appears to be a single carbonate band is cut and offset into two segments by a fault. The band is at least 250 feet thick, but since no contacts are exposed it probably has a greater width. The dark brown weathering grey dolomite is thin bedded (1 inch to 3 inches) with thin (¼- to ½-inch) beds of intercalated argillite or phyllite. The carbonate part of the rock consists of dolomite with varying amounts of tremolite, biotite, some sericite, and scattered grains of epidote. The argillaceous layers consist of fine-grained quartz in a fine matte of biotite and sericite, with scattered poikilitic biotite porphyroblasts.

Short dolomite bands or lenses are present in the east half of the area at several localities north of Montgomery Lake and at one southeast of this lake. At the latter locality, a stratigraphic thickness of about 300 feet of dolomitic shale with some dolomite interbeds conformably overlies greywacke and tuff (2) and is unconformably overlain by conglomerate (10a) of the Montgomery Lake Group. Although mapped as unit 4, much of the rock consists of fine-grained, greenish grey, quartz–sericite–biotite phyllite or shale with euhedral dolomite rhombs up to 1 mm scattered throughout. Interbeds of light grey to brownish yellow dolomite weather a deep orange-brown. The dolomite is fine grained, but some is recrystallized to coarse-grained marble. Phlogopite or biotite occurs in lenses or thin layers throughout the dolomite, and some sandy laminae contain abundant quartz grains.

North of Montgomery Lake, the dolomite occurs in a mixed tuff and greywacke sequence stratigraphically above iron-formation (3). There, thin- to thick-bedded dolomite is grey to greyish green to light brown with a brown to orange-brown weathered surface, and ranges from very fine grained to coarse-grained marble. Thin interbeds of phyllite within the dolomite are less abundant than elsewhere in rocks of this unit. As well as carbonate, in part altered to tremolite, some quartz and scattered flakes of biotite are commonly present.

Stratigraphy of the Henik Group

Rocks of the Henik Group occur in diverse relationships, although some general relations are apparent. South of Otter Lake, near the south border of the area, volcanic (1) and clastic (2) rocks are folded into a series of tight, probably isoclinal, folds. These two rock types are almost in contact on the outcrops. The structural relations show that the folds plunge southwest and that there the andesite must overlie the greywacke. North of Griffin Lake andesite is in close proximity to greywacke–metagreywacke, although not in direct contact. Bedding preserved in the somewhat metamorphosed sedimentary rocks shows gentle (20 to 30 degree) dips south and suggests that there the andesite overlies the greywacke, unless a fault, of which there is no evidence in the field, separates them. Southeast of Hawk Hill Lake, south of the syenite–monzonite pluton, greywacke, with good graded bedding from which tops of beds are readily determined, underlies dacite and tuff. The outcrops of the different rock types are in close proximity. North of Montgomery Lake, it is possible that andesite overlies the tuff and greywacke. Good graded bedding in the clastic rocks gives the tops of beds, but it appears that there is considerable folding there and, as the rock types are not in close contact, the lavas may be basal to the clastic rocks. The greywacke and tuffs near Ameto Lake contain small masses of andesite and dacite, too small to show on the map, the lava lenses apparently being intercalated in the sedimentary rocks. Much evidence does suggest, however, that most commonly the clastic rocks overlie the main masses of volcanic rocks, but it is evident that diverse relationships do exist.

Dolomite and phyllite (4) occur as lenses within the clastic rocks (2) at different stratigraphic levels but most commonly in the stratigraphically higher part of unit 2. Iron-formation (3), with the exception of one occurrence, is also interbedded with the clastic rocks (2) but for the most part is stratigraphically lower than the dolomite and phyllite (4).

Age determinations on granodiorite (8) that is intrusive into volcanic rocks (1) give Archean ages, as discussed more fully in a later section. The Henik Group, therefore, is an assemblage of Archean age, consisting principally of volcanic and clastic rocks with minor iron-formation and dolomite and phyllite. The typical Archean volcanic–sedimentary assemblage in the Canadian Shield (Goodwin, 1968) results from a three-stage sequence of events: the widespread effusion of basalt and andesite flows; the explosive eruption of felsic pyroclastic material upon the mafic platform; and the erosion of the volcanic rocks with construction of volcanogenic sedimentary blankets and prisms. The stratigraphy of a volcanic–sedimentary assemblage reflects these events in a general way: basic volcanics are the oldest rocks, followed by felsic volcanic rocks, and both are overlain by volcanogenic sedimentary rocks. In detail, however, lateral facies changes abound due to shifting centres of volcanism and sedimentation.

Hornblende–Chlorite–Feldspar Schist and Gneiss, Amphibolite

Basic schist to gneiss (unit 5) occurs in two areas, south of Nowyak Lake, and along Kognak River east of Ducker Lake. Small inclusions and bands of similar rocks that have not been mapped separately occur within the rocks of unit 6. South and southwest of Nowyak Lake rocks of this unit consist principally of common green hornblende, partly altered to chlorite, and oligoclase–andesine plagioclase, with quartz content normally small, but it may be up to 20 per cent. Scattered biotite flakes, epidote grains, and accessory magnetite occur throughout, but garnet only rarely. Texture of these fine- to medium-grained, dark green rocks ranges from cataclastic in the schists to a recrystallized interlocking texture in the gneissic rocks. In the southwestern part of the band, just north of Krekot Lake, basic gneiss and amphibolite predominate, with only minor basic schist. Medium-grained, dark green, massive to well-foliated amphibolites are characterized in some occurrences by distinctive needle-like hornblende grains. Bands of granitic gneiss up to 30 feet wide occur in the basic gneiss, near its contacts with gneisses of unit 6.

Homogeneous basic schist with pronounced schistosity forms the greater part of this unit south of Nowyak Lake. Within these basic schists are scattered lenses of light coloured, very finely laminated felsic gneiss composed of quartz, feldspar, and scattered biotite and hornblende. No primary structures are preserved to indicate the original rock types from which they are derived. It is suggested that the scattered lenses of felsic gneiss are derived from sheared rhyolite or quartz latite tuff, and the surrounding basic schists, from flows or tuff of andesite composition.

In the basic schist and gneiss that border Kognak River east of Ducker Lake, quartz is consistently present, in amounts up to 20 per cent. Other major constituents are actinolite, plagioclase, and hornblende; carbonate is a minor (3 to 5 per cent) constituent of most of these rocks. Both schists and gneisses occur in this band, the latter with pronounced foliation due to layering of the light and dark minerals.

The lithology of unit 5 suggests that it is part of the Henik Group, derived from rocks equivalent to those of unit 1 and to a lesser extent, rocks of unit 2. However, direct field evidence for the assignment of these rocks to the Henik Group is lacking; therefore, they have been treated separately.

Biotite Schist and Gneiss, Paragneiss, Hornblende Schist and Gneiss

A band of quartz–biotite–feldspar schist and gneiss, grading to paragneiss (unit 6), occurs north of Griffin and Bernier lakes and south of the granodiorite gneiss (7). The rocks are intermediate in degree of metamorphism and metasomatism to the granodiorite gneiss (7), the greywacke (2), and metagreywacke (2d).

Unit 6 is composed of quartz, plagioclase (oligoclase), and biotite, but common green hornblende is locally abundant and garnet occurs in some bands. Epidote may be present as scattered grains. Apatite and magnetite are common accessory minerals and zircon, a rare accessory. Coarse porphyroblasts of plagioclase may be present, as well as medium-sized grains. Mafic minerals are altered to chlorite. Pronounced micaceous cleavage is typical of the schists and excellent foliation characterizes the gneissic rocks. The foliation commonly is parallel to relict bedding, particularly where the unit grades into the greywacke and metagreywacke (2) on the south-southeast side of this band.

Poikilitic grains of cordierite in the gneiss of unit 6 adjacent to the pluton of younger granite (20) are considered to be the result of contact metamorphism.

Northeast of Krekot Lake and south of Nowyak Lake, gneiss and schist of unit 6, between the granodiorite and granite gneiss (7) and quartz monzonite (20), grade into the former, but are in sharp contact with the latter. At this locality, unit 6 is more heterogeneous than in the previously described area farther to the south, and in this locality also includes a hornblende-rich sub-unit (6a). A medium-grained, quartz–feldspar–biotite gneiss, grey on fresh surfaces and grey to brownish grey on weathered surfaces, is typical in this area. Foliation, probably the result of metamorphic differentiation rather than a relict bedding, is well developed. Bands of schists of similar composition and scattered narrow bands of dark green amphibolite similar to unit 5 are present in the gneiss.

The hornblende gneiss (6a) is characterized by common green hornblende and lesser amounts of biotite, both of which are partly altered to chlorite. Bands of hornblende plagioclase amphibolite are more abundant within (6a) than in the normal biotite-bearing gneiss (6).

Dykes and concordant lenses of pegmatite are abundant in both units 6 and 6a south of Nowyak Lake.

Small areas of gneiss and schist of unit 6 are scattered throughout the east half of the area. East of Otter Lake, quartz–oligoclase–biotite schist, garnetiferous in part, and containing some relict bedding occurs with thin bands of amphibolite and a few small masses of metagabbro, all of which are cut by dykes of aplite. Small isolated occurrences of rocks of this unit in a drift-covered area south of Imikula Lake consist of biotite-rich (30 per cent) quartz–plagioclase–biotite schist and amphibolite gneiss composed of plagioclase and partly chloritized hornblende. In the northeast corner of the area, unit 6 consists of a heterogeneous mixture of amphibolite and paragneiss, the latter containing a few thin iron-formation bands not known elsewhere. The paragneiss, which is well foliated, contains about 5 per cent epidote and 1 per cent calcite, as well as quartz, plagioclase, and biotite.

The rocks of unit 6 are, for the most part, probably derived from greywacke, argillite, and tuff, equivalent to the clastic rocks of the Henik Group (unit 2), as many of the schists and gneisses show well-preserved relict bedding. Small scattered bodies of amphibolite and amphibolite gneiss within the schists and gneisses (6) are probably derived from gabbro or basic volcanic rocks that occurred in limited amounts in the sedimentary sequence.

Granodiorite Gneiss and Granite Gneiss

Granodiorite and granite gneiss (7) is characterized by excellent foliation due to mineral layering. Both biotite and hornblende are present, with the former commonly the more abundant. Muscovite occurs locally but in small amounts. Distinguishing features are the bands or inclusions of biotite-rich schists or amphibolite and bands of massive, homogeneous granodiorite.

In the west half of the area, granodiorite gneiss of unit 7 lies between the schist and gneiss (unit 6) and the south part of the quartz monzonite–granite pluton (unit 20). It is a medium-grained, granitic textured rock, commonly grey but found also in shades of pink. Plagioclase (oligoclase–andesine) is consistently highly altered to sericite and clinozoisite, whereas the mafic minerals, biotite and the less abundant hornblende, are partly altered to chlorite.

Epidote, and in some specimens zoisite, both probably of secondary origin, are scattered throughout. The accessory minerals consist of abundant sphene and rare apatite and zircon. Mafic-rich inclusions or schlieren are prevalent. The mixed character of the rocks of this zone is marked by their moderate microcline content in comparison with the adjacent rocks, which is abundant in the massive granitic rocks (20) and essentially nil in the metamorphic rocks (6). Thin sections show that the microcline is a late mineral, as it embays and replaces much of the plagioclase. Quartz-feldspar pegmatite masses and stringers are abundant in this intermediate zone of gneiss and in some localities two generations of pegmatite are present, with a quartz-rich pegmatite cutting an older pegmatite.

South of Nowyak Lake, a band of gneisses of unit 7 occurs between gneiss and schist of unit 6 and the basic schist and gneiss (5). These gneisses differ from those previously described in that inclusions and schist bands are rare; they are more homogeneous, primarily pink and less commonly grey, and the composition ranges from granite to granodiorite as microcline is abundant, commonly forming 20 to 30 per cent of the rock. Oligoclase is normally slightly altered to sericite, but much less so than in rocks of this unit farther south. Similarly, mafic minerals, less abundant than to the south, are also less altered to chlorite. Magnetite is a common accessory mineral; apatite is rare. The granodiorite gneiss to granite gneiss (7) has a well-defined contact with rocks of unit 5, the basic schist and gneiss, but it is in gradational contact with gneisses of unit 6.

In the northwest corner of the area, grey to pink granodiorite gneiss of unit 7 contains some bands and inclusions of biotite paragneiss and schist which are, in part, garnetiferous. Biotite is by far the most abundant mafic mineral; hornblende is also present in some places. Muscovite occurs in very small amounts in some bands. The plagioclase is almost completely altered to sericite and clinozoisite. Sphene, apatite, and zircon are accessory minerals. The contact between this gneiss (7) and the volcanic rocks (1) to the south is drift covered, but where the two rock units outcrop close to each other, no mingling of the two rock types is seen and intense shearing suggests that the contact is a fault.

Southeast of Imikula Lake, in the northern part of the area, grey to pinkish grey, medium-grained granodiorite gneiss (7) contains only scattered inclusions and schlieren, but foliation is prominent and plagioclase grains commonly show pronounced lineation. Biotite is abundant in the gneiss; hornblende is rare. This area of granodiorite gneiss is distinctive for its relative lack of inclusions and its homogeneity, as compared to other areas of gneiss of unit 7. To the southeast it passes gradationally into granodiorite (8) as foliation becomes less marked.

East of South Henik Lake, grey to pink granodiorite gneiss of unit 7 contains abundant bands of paragneiss, some migmatite, numerous amphibolite inclusions, and scattered, small, irregularly shaped bodies of massive granodiorite. Whereas biotite and hornblende are both represented, unlike most occurrences of unit 7, hornblende is the more common. Locally, muscovite occurs abundantly with biotite. Oligoclase is fresh and unaltered, and specimens show only slight sericitization of the feldspar. Sphene and magnetite are abundant accessory minerals; apatite is rare. These gneisses pass gradationally through a mixed zone, $\frac{1}{4}$ to $\frac{1}{2}$ mile wide, of paragneiss, mixed gneiss, and metagreywacke into the adjacent greywacke (2) to the north. The gneisses in this northern part are much sheared, probably due to a thrust fault nearby. The gneisses of unit 7 east of South Henik Lake are more heterogeneous and variable in character than are those in any of the previously described localities.

West of Griffin Lake, a small area of granodiorite gneiss (7) is bounded to the south by massive granodiorite (8) and to the north by a fault. This grey to pink biotite–hornblende gneiss is well foliated and grades south into massive granodiorite of similar composition.

Granodiorite, Quartz Diorite, Quartz Monzonite, Granite (*unit 8*)

A large granodiorite mass northeast of North Henik Lake is a homogeneous, medium-grained, grey, granitoid textured rock which probably intrudes volcanic rocks (1). Both biotite and hornblende may be present, but biotite is more abundant. The plagioclase (oligoclase) is much altered to epidote and clinozoisite and hornblende is partly altered to chlorite. Apatite, sphene, and zircon are accessory minerals. Locally, the rock is porphyritic, with prominent white plagioclase phenocrysts. Although most of this pluton is granodiorite in composition, in its southern part, near Ameto Lake, it grades into dark grey quartz diorite and diorite as plagioclase becomes more calcic (andesine) and quartz less abundant. The latter mineral commonly forms bluish round quartz 'eyes.' The change in composition is due either to assimilation of volcanic rocks, as the diorite–quartz diorite phase is near a contact with volcanics (1), or to differentiation in the pluton.

Angular to subrounded inclusions of amphibolite or hornfels occur in the granodiorite and diorite–quartz diorite phase adjacent to contacts with the volcanic rocks (1). Contamination by assimilated volcanic material results in a greenish cast to the rocks. Chlorite is abundant in this mixed rock and some carbonate is common. Small, irregularly shaped stringers and dykes of granodiorite occur in the volcanics adjacent to the contact. The zone within the granodiorite and the volcanics in which contact effects are visible is one-half mile wide, at most, and normally, much less. Inclusions and schlieren are rare or absent in the granodiorite body, except near the contacts. On the north side of the granodiorite body, the contact with granodiorite gneiss (7) is gradational.

Irregular dykes and stringers of pink alaskite granite, and less abundantly, pink granite pegmatite, both containing few or no mafic minerals, cut the grey granodiorite. These rocks are probably a late phase of the granodiorite.

West of the south end of South Henik Lake, the granodiorite is a grey, medium-grained, granitic textured, massive, equigranular rock which weathers to a yellowish or pinkish grey. Biotite, the predominant mafic mineral, tends to occur in randomly oriented clumps or pods, although locally these pods may be oriented and define a foliation plane. Hornblende is rare. Quartz and oligoclase, the latter partly altered to epidote and sericite, are the other major constituents with only minor microcline. Apatite, zircon, and sphene are minor accessory minerals. The granodiorite, adjacent to its contact with quartz–mica schist (2b), contains subangular inclusions of the schist, up to a maximum of 5 by 12 feet. The schist inclusions are not visibly altered by the granodiorite, which shows no evidence of chilling at its contacts with schist, even in the dykes and sills of granodiorite cutting the schist, although the latter may be contorted near the igneous rock.

East of Otter Lake, similar granodiorite, containing abundant biotite and only minor hornblende, is chiefly massive but extensively sheared. Secondary minerals, sericite, epidote, and chlorite, are abundant in this sheared rock. On the south side of this granodiorite pluton, a narrow zone of mixed gneiss and paragneiss is in contact with greywacke (2). Locally, within this pluton, the lithology ranges from a dark grey diorite to a pink, microcline-rich granite. The latter is commonly porphyritic with subhedral pink feldspar phenocrysts averaging $\frac{1}{4}$ inch long.

The small granodiorite stock 2 miles south of North Henik Lake consists of homogeneous, medium-grained, grey to pinkish grey rock, in which the plagioclase is light yellowish green due to extreme alteration to epidote.

Around Carnecksluck Lake, the large area of rocks of unit 8 ranges in composition from granodiorite to quartz diorite, with minor diorite phases, and in grain size from chiefly medium grained to partly coarse grained or, rarely, porphyritic. These rocks are white to pinkish grey or dark grey on fresh surfaces and pink to grey on weathered surfaces. Plagioclase ranges from oligoclase to andesine with the latter commonly in zoned crystals. Biotite is the most abundant mafic mineral, although hornblende is typical of parts of the pluton. Both are partly altered to chlorite. Epidote is ubiquitous, both as discrete grains and as alteration of the feldspar. Sphene is an abundant accessory mineral, but apatite and zircon are rare. Schlieren and inclusions are rare or absent in these rocks, except close to the contact with the volcanic rocks (1). Along the north and northwest contacts with the volcanic rocks the zone of mixed rock with schlieren and inclusions is much narrower than it is on the southwest and south, possibly indicating that on the north and northwest the dip of the contact is steep in comparison to its attitude on the south and southwest.

Northeast of Bate Lake, the granodiorite is extensively sheared and the foliation is probably entirely due to the shearing. Where not sheared this granodiorite is a medium-grained, pinkish grey, biotite rock containing fewer mafics than other granodiorite bodies. In some places, muscovite is present, but little or no biotite. The cataclastic granodiorite is distinguished by a distinct red colour and a pronounced elongation of mineral grains. A narrow zone of mixed rock marks the contact with the volcanic rocks (1) in which inclusions and schlieren of altered basic volcanics are abundant in contaminated greenish grey granodiorite.

South of Griffin Lake, grey to pinkish grey, biotite granodiorite (8) contains some schlieren and biotite-rich gneiss bands. It grades into a small area of granodiorite gneiss (7) just west of Griffin Lake. The typical granodiorite in this body is somewhat finer grained than most of the previously described rocks of this composition.

In the northwestern part of the area a number of small granodiorite plutons intrude the volcanic rocks (1). Rocks forming these small bodies are all similar, medium-grained, white to light grey leucogranodiorite. Amount of biotite is limited, commonly 5 per cent or less, and in some places only muscovite occurs. The plagioclase (oligoclase) is altered to sericite. Sphene is a common accessory mineral. Inclusions or schlieren are absent and some plutons have a fine-grained chilled contact zone. The lack of mafic minerals and the white colour of the fresh and weathered surfaces distinguish the rocks in these small bodies from other rocks in unit 8.

Hornblende–Biotite–Quartz Diorite

Of the four small plutons of this rock west of Nowyak Lake, three are within volcanic rocks (1) and the other is in granodiorite (8). This medium- to coarse-grained, equigranular, grey to dark grey rock (8a) is massive, except for some foliation adjacent to contacts. In some places the composition varies to granodiorite. The andesine feldspar (oligoclase in the granodiorite phases) is altered to sericite with some epidote. Biotite and hornblende, both altered to chlorite, are equally abundant. Sphene is an extremely plentiful accessory mineral; apatite and zircon are rare. Inclusions are rare or absent, and no contact metamorphism associated with these plutons is evident in the rocks they intrude.

Hornblende Monzonite and Syenite

A composite stock, roughly circular in outline, east of Hawk Hill Lake, contains rock types found nowhere else in the area. The western part of the body consists of a pink, medium-grained, weakly porphyritic hornblende monzonite (8b), containing less than 10 per cent quartz. The oligoclase is strongly saussuritized, but the perthitic microcline is fresh. Green to bluish green hornblende is partly altered to chlorite. Scattered grains of epidote are present throughout. Sphene and magnetite are common accessory minerals, and apatite and zircon, less common. Near the contacts of the pluton, the monzonite contains inclusions and bands of quartz–feldspar–biotite–hornblende gneiss.

Eastward, the monzonite grades into more quartz-rich, medium- to coarse-grained pink rock which ranges from granodiorite to quartz monzonite, depending on the potassic feldspar content. Antiperthite is abundant; slightly chloritized biotite is the chief mafic mineral, with scattered epidote grains; and hornblende is rare or absent. Accessory minerals are similar to those of the monzonite, although sphene is not as common.

The northern part of the stock consists of coarse-grained to pegmatitic syenite (8c), composed of more than 85 per cent perthite and microcline, minor quartz, about 8 per cent aegirine-augite, 2 to 3 per cent arfvedsonite, 1 to 2 per cent apatite and minor sphene. The arfvedsonite appears to have crystallized before the pyroxene, as the aegirine-augite surrounds and partly replaces arfvedsonite (*see* Pl. II). The main part of the syenite is separated from the monzonite and granodiorite by a narrow zone of fine-grained diorite or metadiorite, shown on the map as part of the volcanic unit (1). However, this diorite may originally have been a fine-grained dyke rock. A fault along the north margin of the basic band results in intense shearing of the diorite. Bands and stringers of syenite occur in the diorite, developing a banded gneiss in some places.

The stock is intrusive into the greywacke–tuff (2), and near the contact the igneous rocks contain inclusions and partly assimilated schlieren of the clastic rocks. The stock is pre-Hurwitz Group in age, as conglomerate (11) lies unconformably on the monzonite.

Breccia Dyke

A dyke of igneous breccia (8d) occurs 4 miles north of the central part of Ameto Lake, within granodiorite and within a quarter mile of the contact with volcanic rocks (1). This dyke is exposed for 40 feet of its length and for about 8 feet of its width. The fragments are angular to subrounded (*see* Pl. I), up to a maximum of a foot long but most range from 1½ to 4 inches, and form 50 to 60 per cent of the rock. Most of the fragments are dark green hornblendite, but also included are pink biotite granodiorite, green, actinolite-rich amphibolite, gabbro, diorite, fine-grained aphanitic igneous rocks and, rarely, mica-rich foliated schists. The matrix is medium-grained, grey, hornblende–biotite granodiorite, indistinguishable from the surrounding granodiorite mass. Only one contact of the dyke is exposed, marked solely by the disappearance of fragments. Thin sections of fragments of the breccia show a marked reaction rim on those of mafic composition. Rather similar breccia bodies, but with associated soapstone masses, have been described from Greenland where it has been suggested (Bondesen, 1964) that the breccia is emplaced by gas drilling in connection with the intrusion of the soapstone in a "solid–subsolid" state. However, in the present dyke no soapstone is exposed. Blake *et al.* (1965) have attributed mafic breccia dykes in granitic masses to the intrusion of basic dykes into partly fluid granite, with more rapid solidification of the basic dyke and its subsequent brecciation and development of reaction rims by the still-mobile granite. This process does not explain such exotic fragments as the schist inclusions in this dyke. The lack of nearby tectonic features suggests that the breccia is an explosion breccia, perhaps an intrusive explosion breccia. Angular to subrounded fragments of the local granodiorite plus exotic mafic fragments, probably from depth, would indicate this. The lack of any chilled margin suggests formation before the cooling of the granodiorite pluton.

Gabbro and Metagabbro Dykes

Northeast-trending dykes (unit 9), commonly metamorphosed and sheared, are found throughout the area, but are particularly abundant 2 to 3 miles west of the south end of South Henik Lake. West of Griffin Lake, only one northeast-trending dyke is shown on the map, but there are several other narrow dykes of this trend at this locality. The dykes, ranging from 50 to 150 feet wide and apparently dipping vertically, are composed of medium-grained gabbro with fine-grained chilled margins. The rock is dark greenish grey on fresh surfaces and medium greenish grey on weathered surfaces. Although some dykes are massive and homogeneous, many are sheared with foliation parallel to shearing. Plagioclase (labradorite to andesine) and common green hornblende are the principal constituents with minor remnants of augite preserved within hornblende grains. As much as 10 per cent biotite is found in some specimens. The feldspar is highly altered to sericite, epidote, and clinozoisite, and much of the hornblende and biotite seems to be secondary. The common accessory mineral is hematite; minor magnetite is rare. A few dykes are porphyritic, containing large labradorite phenocrysts in an andesine feldspar groundmass. Ophitic or diabasic texture is rare, and if originally present, has probably been destroyed by recrystallization. Contact effects are negligible, with the exception of euhedral pyrite in granodiorite adjacent to a dyke at one place. Shearing, although common, differs in intensity; for example, west of South Henik Lake shearing is far more intense in the dykes in quartz–mica schist (2b) than in those in the nearby granodiorite (8).

A single short segment of an east-trending metagrabbro dyke occurs in the greywacke (2) west of Otter Lake. It is a medium-grained dark green rock, with light green to brownish weathered surface, composed of altered plagioclase and hornblende, the latter almost completely altered to chlorite. A faint foliation in the rock parallels cleavage in the adjacent greywacke. Quartz veins and quartz-feldspar pegmatite segregations cut the metagabbro. This dyke is possibly related to the northeast-trending dykes, as the degree of deformation and metamorphism is similar.

North-northwest-trending gabbro dykes, seldom exceeding ½ mile long and 80 feet wide, are confined to the granodiorite (8) and monzonite (8b) part of the composite stock east of Hawk Hill Lake. This gabbro, medium grained with fine-grained chilled margins, dark grey to black on fresh surfaces, dark to light brown on weathered surfaces, is massive but with distinct diabasic texture. Biotite is the chief mafic mineral, forming up to 15 per cent, whereas green hornblende makes up only 7 per cent. The plagioclase (labradorite), much altered to epidote and secondary white mica, occurs both as lath-like grains and as phenocrysts up to ½ inch long. Scattered grains of quartz are common and iron oxide, probably hematite, is the only accessory mineral. These rocks are distinctly less altered and less sheared than are nearby northeast-trending dyke rocks. However, they are included in this unit, as they do not cut the nearby Hurwitz Group rocks.

All the dykes included in this unit show little or no response on aeromagnetic maps.

Biotite Lamprophyre Dykes

Lamprophyre dykes (9a) are few. Two northeast-trending ones cut granodiorite gneiss (7) just south of Nowyak Lake, and one trending northwest cuts volcanic rocks (1) west of Nowyak Lake. All are narrow, from 4 to 10 feet wide, and ½ mile or less long. The rocks, medium grey on fresh surfaces with dull grey weathered surfaces, are fine to medium grained and porphyritic. Plagioclase (andesine to labradoirte) is the major constituent, with minor quartz, and abundant biotite in both the groundmass and in coarse phenocrysts. Carbonate, magnetite, and sphene are accessory minerals. The dyke in the basic volcanics is highly altered and is cut by seams of tremolite up to $\frac{1}{2}$ inch wide. The dykes cutting the granodiorite are less altered but are irregular in shape, apparently following irregular joint planes. Small blocks of granodiorite occur within the dykes. The prominent dark brown to black biotite phenocrysts of the lamprophyres make these dykes readily recognizable in the field.

Feldspar Porphyry Dyke

A single short dyke (9b) trending north and 25 to 30 feet wide cuts greywacke (2) west of the northwest arm of Ducker Lake. About 40 per cent of the rock consists of coarse plagioclase phenocrysts, up to $\frac{3}{4}$ inch long. The groundmass also contains abundant plagioclase, with minor quartz and biotite, and apatite and pyrite as accessory minerals. Whereas all the feldspar shows alteration to sericite and carbonate, that in the groundmass is more highly altered than the phenocrysts. The dyke is close to a contact of the greywacke with orthoquartzite (12), but is not known to cut Hurwitz Group rocks.

The feldspar porphyry (9b) and also the biotite lamprophyre (9a) are possibly related to the rocks of unit 8.

Montgomery Lake Group

The Montgomery Lake Group (unit 10) outcrops extensively on the east side and south of Montgomery Lake, hence this name is proposed by the author. Some small outliers occur to the north and southwest of the main locality. During earlier reconnaissance geological mapping (Lord, 1953) some of these rocks were observed but on the map were included in the unit with the orthoquartzite (12), now known as the Hurwitz Group. The present work shows that the orthoquartzite unconformably overlies rocks of unit 10. Recognition of this unit is important in the interpretation of the regional geology, for certain quartzite bands that have been equated with the Hurwitz Group orthoquartzite could be equivalent to the older Montgomery Lake Group quartzite. Further mapping in the southern District of Keewatin will be necessary to show whether the Montgomery Lake Group is extensive or if it is restricted to this general locality.

A type section of the Montgomery Lake Group, overlying andesite (1) east of Montgomery Lake, comprises as much as 650 feet of boulder-conglomerate and greywacke; 1,500 feet or more of quartzite and impure quartzite; and 200 feet of siltstone. An additional unknown amount of the section has been removed by erosion.

Conglomerate

A basal boulder–cobble conglomerate (10a) is particularly well exposed on the east shore of Montgomery Lake (Pl. XIII). The matrix of this conglomerate, medium greenish grey and weathering to a light greenish grey, constitutes 30 to 40 per cent of the rock, and is composed of quartz, feldspar, and rock fragment grains with shreds of chlorite and sericite. The pebbles, cobbles, and boulders, which range from 2 to 15 inches in diameter, are rounded to well rounded and are roughly sorted into beds of different sizes. On the east shore of Montgomery Lake the different types of pebbles and boulders in the conglomerate are pebbles and boulders of greywacke, tuff, granodiorite, granite, quartz latite, and pebbles of rhyolite, andesite, chert, jasper, slate, quartz, and quartzite. A few lenses of laminated greywacke occur within the conglomerate. The conglomerate is unconformable on the andesite (1). It is estimated that more than 620 feet of conglomerate is present on the east side of Montgomery Lake but a few miles to the southwest, on the south side of the lake, a covered interval of less than 50 feet separates andesite and a light to dark grey greywacke or impure quartzite (10b).

One-half mile east of the extreme southeast corner of Montgomery Lake, the basal beds are much thicker than elsewhere. More than 700 feet of conglomerate with scattered lenses of coarse-grained sandstone or grit is exposed. There, too, a 300-foot-thick, fine-grained porphyritic gabbro or andesite occurs 30 feet above the base of the group. This gabbro or andesite is probably a sill, but as its precise relationships could not be determined because of drift-cover, it could be interpreted as an extrusive rock. In the conglomerate, the cobbles, up to 12 inches in diameter, are primarily of milky white, coarse- to medium-grained quartz, with lesser amounts of white quartzite and light grey chert or rhyolite. The matrix contains much chlorite and sericite, as well as quartz, feldspar, and rock fragments. Dark grey, medium-grained impure quartzite to greywacke overlies the conglomerate.

In the extreme southeast part of the exposed Montgomery Lake Group, thick conglomerate lenses pass along strike into impure quartzite or greywacke containing only scattered pebbles. There, the clasts of the conglomerate are smaller, up to a maximum diameter of 7 inches, and the predominant rock type is a distinctive medium-grained, dark grey crystal tuff. Similar tuff (unit 2a) outcrops north of Montgomery Lake. Less common are pebbles and cobbles of quartz, quartzite, and andesite.

Where the Montgomery Lake Group unconformably overlies iron-formation (3), lenses of conglomerate 60 to 100 feet thick contain chiefly jasper, quartz, and iron-formation pebbles and only scattered andesite pebbles. In a few places the conglomerate with iron-formation clasts is overlain by approximately 100 feet of friable, red, gritty ferruginous slate, the gritty particles consisting of angular quartz grains. This slate, where present, is considered to be part of the basal beds as it, in turn, is overlain by the grey impure quartzite or greywacke.

The conglomerate south of Montgomery Lake contains well-rounded pebbles, averaging 2 to 3 inches in diameter, of medium-grained crystal tuff (most common), fine-grained white quartzite or recrystallized chert, leucogranite, slate, and rhyolite.

It is apparent that the conglomerate is chiefly lens-like, from nil to 700 feet or more thick, and that the concentrations of specific lithologies of pebbles and cobbles at different localities suggest nearby local sources.

Quartzite, Impure Quartzite, Greywacke

Quartzite with some impure quartzite and greywacke (unit 10b) forms the greater part of the Montgomery Lake Group. Typically, these fine- to medium-grained rocks are light to medium grey with grey weathered surfaces, although in part they weather a distinctive light greenish or yellowish grey. Beds vary from massive to thin bedded, and are most commonly from ½ foot to 4 feet thick. Crossbeds are present in the thin-bedded (1 foot or less) parts, and large-scale, festoon-type crossbeds occur in some thick beds.

In the lower part of unit 10b beds contain, in addition to abundant quartz, some microcline and plagioclase feldspar and rock fragments in the quartz and sericite matrix. Upward in the section, quartz content increases to a maximum of 90 per cent, with feldspar and rock fragment grains becoming rare. These rocks fall in the subgreywacke to quartzite classification of Pettijohn (1957). Thin sections reveal that these rocks have a cataclastic texture with sutured grains and mortar structure being typical. The matrix consists of tiny grains of quartz and muscovite or sericite. Small euhedra of pyrite are common, and the weathered surface may be rusty brown from weathering of the pyrite. Locally, lenses of pebble-conglomerate containing white quartz pebbles, averaging ½ inch in diameter, occur in the quartzite.

Strong shearing in much of the quartzite obliterates primary structures and results in sericite developed on the numerous closely spaced shear planes. Younger than the shearing are numerous small, undeformed quartz veins, ½ to 1 inch wide. Rarely, small-scale, tight, disharmonic folds are present where shearing is less intense.

In outcrop, the common presence of abundant pyrite euhedra and a more glassy appearance distinguish this quartzite from quartzites in the Hurwitz Group.

Northeast of Montgomery Lake, the relationships of all three groups, the Henik, Montgomery Lake, and Hurwitz Groups, are exposed. Greywacke and tuff (unit 2) of the Henik Group is unconformably overlain by pyritiferous grey quartzite to subgreywacke of the Montgomery Lake Group. The latter, in turn, is overlain unconformably by orthoquartzite of the Hurwitz Group.

Siltstone

East of Montgomery Lake, thinly bedded limy siltstone (10c) overlies the quartzite and subgreywacke (10b) member. It is a very fine grained, dark grey rock that weathers medium grey to rusty. Thin, $\frac{1}{8}$-inch bedding laminations are typical, although some beds may be thicker. Small ripple-marks occur on a few of the thicker siltstone beds, and small-scale crosslaminations, in some thin beds. Cleavage is well developed but not to the extent that it obscures primary structures. Thin sections of these fine-grained rocks show that they are composed of approximately 50 per cent quartz, 35 per cent carbonate, and the remainder of sericite and chlorite, scattered feldspar grains, pyrite euhedra, and dust-like limonite.

Hurwitz Group

The name Hurwitz Group was first applied by Wright (1955, p. 6) to the white quartzite and associated greywacke, conglomerate, impure quartzite, dolomite, and sedimentary schist, first mapped by Lord (1953, units 4–7) in southern Keewatin. The group is named for Hurwitz Lake (60°50′N, 98°W), near which the white orthoquartzite was first mapped in 1952. As stated in an earlier note (Eade, 1964, p. 3), the original definition of the group by Wright included greywacke, conglomerate, argillite, slate, and phyllite. Present mapping has shown that orthoquartzite unconformably overlies these rocks which belong to the Henik Group. The base of the Hurwitz Group (units 11–18) is, therefore, redefined as the orthoquartzite (12) or, if it is present, the boulder-conglomerate, greywacke conglomerate, and greywacke (11), whichever is the stratigraphic lowest.

Regional geological reconnaissance mapping (Lord, 1953; Wright, 1955) showed the Hurwitz Group in scattered localities over a great distance, from Kognak River area northeastward to the Hudson Bay coast and southwestward to Kasba Lake. In many places only the orthoquartzite (12) is preserved, the thickest section of Hurwitz Group, with the most varied lithology being in Kognak River area.

Although the Hurwitz Group is of Aphebian age and hence pre-Hudsonian orogeny, within Kognak River area rocks of the group have, for the most part, undergone only slight metamorphism, probably equivalent to the greenschist facies. Locally, contact metamorphism by plutons associated with the Hudsonian orogeny affects rocks of this group.

Orthoquartzite (12) outcrops extremely well, but overlying formations commonly occur only as isolated outcrops in extensively drift-covered areas; hence it is almost impossible to determine a detailed stratigraphic section of the part of the group overlying the orthoquartzite.

Conglomerate

Conglomerate (11) at the base of the Hurwitz Group in scattered localities forms lenses ranging in thickness from a few feet to as much as 1,200 feet east of Bray Lake. Lithology is variable both along and across the strike of the lenses. Basically the unit consists of a medium- to coarse-grained, grey-green greywacke with boulders, cobbles, and pebbles scattered through it with some intercalated lenses of conglomerate with greywacke matrix. The greywacke consists of quartz, feldspar, rock fragments, sericite, and chlorite, all in varying proportions. The subangular to subrounded grains are poorly sorted as to size. In some places the greywacke is almost indistinguishable from the underlying greywacke (2). Normally the older greywacke (2) is more sheared and contains some carbonate, which is absent from unit 11. The clasts in the conglomerate range from $\frac{1}{2}$ inch to 14 inches in diameter with an average of 3 inches. Variety of rock types represented are white quartz, pink granodiorite, andesite or meta-andesite, jasper and iron-formation, pinkish or brownish quartzite, greywacke, grey chert or rhyolite, soft greenish argillite, red argillite, yellow brown slate, felsites and felsitic tuffs, porphyritic andesite and diorite, red dolomite and red quartz-feldspar porphyry. Each locality where conglomerate is present seems to be characterized by a specific "exotic" type of pebble or cobble, and the relative abundance of particular rock types varies from lens to lens in the stratigraphic section. For example, in the conglomerate southwest of Oftedal Lake, well-rounded granodiorite pebbles are prevalent in the lower part of the unit, but upward in the section, subrounded white quartz pebbles predominate.

The greywacke interlayered with the conglomerate grades into shale, arkose, or impure quartzite and grit. Locally, graded bedding may occur or rarely crossbedding. These beds become more quartzose upward and eventually grade into the pure quartzite of overlying unit 12, but the actual transition from impure quartzite to orthoquartzite takes place in a few tens of feet.

The heterogeneity from place to place and within the section at any one locality is characteristic of this conglomerate unit. The limited areal extent and the lens-like form, with locally thick development, suggest deposition in isolated local basins, with much of the material derived locally and with rapid infilling, resulting in the predominance of poorly sorted angular grains.

Orthoquartzite

White to pink orthoquartzite at or near the base of the Hurwitz Group constitutes a distinctive and resistant stratigraphic marker of inestimable value. The quartzite is normally topographically prominent, particularly where the unit is thick, and ridges of quartzite commonly stand 300 to 400 feet above the surrounding terrain (Pl. III).

Typically, the orthoquartzite is white, less commonly pink to red, fine grained to glassy, and varies from thin bedded ($\frac{3}{4}$ inch to $1\frac{1}{2}$ inches) to thick bedded or massive. The thickness of the formation ranges from about 4,000 feet in the northeast part of the area to some 500 feet in the western part. The accompanying sections (*see* Appendix) from various localities show some of the variations in thickness and lithology of the unit. In general, the lower part of the quartzite unit is white and the upper part is pink and white, but where the unit is thin, it may all be white. In the lower part of some of the thicker sections the quartzite is, in part, a distinctive green, salmon or purple shade, but this is not typical. In the lower part of the thick sections, medium- to coarse-grained grit beds may be in contrast to the fine-grained to glassy character of most of the quartzite. Such grit beds are normally red to buff and may be arkosic.

Lenses of conglomerate or quartzite beds with scattered pebble trains are present in the quartzite where the unit is thick, with the thicker conglomerate lenses confined to the lower half but thin lenses and pebble trains occur anywhere in the section. Pebbles are normally well rounded, up to 2 inches in diameter but averaging $\frac{3}{4}$ inch, and are mostly white quartz; some are jasper and smoky quartz. They are commonly closely packed in the matrix (Pl. IV).

Typically, the orthoquartzite is composed of 97 per cent or more quartz, with only scattered sericite, feldspar, and magnetite. Less pure quartzites, containing 80 to 85 per cent quartz, occur in the lower part of the unit and contain feldspar, sericite, and dust-like hematite, or in the purple tinged quartzite, relatively abundant magnetite. Thin sections of some specimens show that either epidote or clinozoisite is present, probably the result of metamorphism, but externally the quartzite shows little effects of metamorphism other than the local development of a white porcelain-like appearance.

Little original sedimentary texture is preserved, and it now varies from a complex texture with sutured borders on grains to a mosaic of generally tiny grains with planar to irregular boundaries, with the grains, normally clear and dust-free, tightly packed, suggesting that there has been much solution and recrystallization of the quartz. In some parts, mosaics of rather coarse grains with planar, interlocking boundaries indicate almost complete recrystallization of the quartz.

Crossbedding is rare. East of North Henik Lake where crossbedding is present locally, the bedding planes are well defined by very fine black iron oxide grains.

Ripple-marks are a characteristic feature of this unit and in many localities are the only means of definitely determining bedding planes. Where the unit is thick, ripple-marks are common in two parts of the section, in the lower white, thin-bedded part and in the upper pink, bedded part. Where the quartzite unit is thin, in the western part of the area, ripple-marks are normally confined to the upper part of the section. Ripple-marks in any one locality may be either symmetrical or asymmetrical and probably both forms result from wave action rather than from current action. The actual shape of the ripples is varied; Plates V and VI illustrate two different shapes. The average wave length of the ripples is $1\frac{1}{2}$ inches with average amplitude of $\frac{3}{8}$ inch, but these are norms only. Wave lengths have been observed up to 4 inches and amplitudes up to $\frac{1}{2}$ inch. Normally the crests are sharp and the troughs rounded, so that with a number of observations at one locality they may be used to determine tops of beds. The trend of ripple crests may change radically in adjacent beds; one trend may be superimposed on another in the same bed as shown in Plate VII. Statistically, however, there is a preferred orientation in any one locality. Detailed determinations on trends of ripple crests were made at a number of places, with about 50 readings at each place on different beds within a restricted outcrop locality. Trend of ripple crests, their plunge and asymmetry, if any, were recorded. After corrections for declinations, using a stereo net, results were plotted on rose diagrams. Figure 2 (*in pocket*) shows the preferred orientation and asymmetry at the various localities.

The ripple-crest trend determinations show a consistent northern trend in one small area on the southeast side of North Henik Lake where seven localities were measured. However, determinations elsewhere are not consistent with this trend. For example, on the northeast side of Ameto Lake the trend is northwest, 90 degrees different from the North Henik Lake area. Down-current directions from asymmetrical ripple-marks are consistently to the northwest in the vicinity of North Henik Lake, but elsewhere this is not so. Potter and Pettijohn (1963) summarized the results of studies of ripple-mark orientation in a number of areas and concluded that ripples should define depositional strike. On the basis of the limited study made of the ripple-marks in this area, the depositional strike is north to northeast, but there is no evidence of the dip direction of the paleoslope.

Brecciation and shearing related to regional folding and faulting is marked in the orthoquartzite. Shear zones in the quartzite, from 1 inch to 15 inches wide, result in sericitic white to grey powdery or granular seams cutting the quartzite that are in some places recemented by later quartz. Near faults and fold axes it is common to find blocks of glassy or very fine grained quartzite enclosed in powdery, grey weathering, medium-grained quartz matrix, or the quartzite may be fractured into a multitude of fine fragments cemented together by a quartz stockwork. Plate VIII illustrates such a breccia at the nose of a small fold southeast of Otter Lake.

A prominent lineation is commonly developed in the orthoquartzite, apparently related to the regional deformation rather than a depositional feature, as a similar lineation may be found in both underlying and overlying rocks. Kretschmar (1965) studied lineations in a small area of the orthoquartzite north of Bernier Lake and reached the same conclusion.

Quartz veins are present in many places in the orthoquartzite but they are difficult to see. Not only are quartz-filled gash fractures common adjacent to faults but crosscutting quartz veins are common even where there is no obvious structural dislocation. Some of the veins probably developed by solution of silica from the quartzite itself, which was transported for short distances and redeposited in small fractures. However, late, crosscutting veins may possibly represent introduced silica.

Grey or pink quartzite of this unit locally shows round, white bleached spots from ½ inch to 4 inches in diameter, with an average of ¾ inch. The spots comprise 10 to 15 per cent of the surface. Plate IX illustrates such spots in a grey quartzite. The rock does not break preferentially around such spots.

The uppermost beds of unit 12, immediately below the slate and shale (13), commonly consist of brecciated quartzite stained red by disseminated hematite, with the fragments cemented by a stockwork of quartz and hematite. Although the brecciated beds have a stratigraphic thickness of only 2 to 3 feet, they are present throughout the area.

The rocks underlying the quartzite (12) are typically fresh and unweathered, and have small, local surface irregularities that the contact follows. In a few places, however, underlying basic volcanic rocks are deeply weathered and rotten for 8 to 10 inches below the orthoquartzite, the result of pre-Hurwitz Group weathering. The underlying rocks also commonly show some shearing. The basal quartzite beds are impure quartzite, commonly sheared and containing sericite. The basal beds are normally more sheared than beds higher in the section.

The orthoquartzite is probably the product of sedimentation marginal to a low-lying, stable land surface. The purity of the quartzite indicates derivation from a mature land surface. The source rocks were, in part, at least quartz-rich—perhaps rhyolites or second or third cycle sedimentary rocks. The broad areal extent of the quartzite suggests that the site of deposition was also stable. Shallow water during much of the depositional history is indicated by the ripple-marks through the quartzite section. The formation appears to be typical of stable shelf or foreland facies.

Slate, Shale, and Siltstone

Slate, shale, and siltstone (unit 13), with minor greywacke, occur conformably stratigraphically above the orthoquartzite (12). Rocks of this unit do not outcrop well and the only evidence may be slaty fragments littering the ground. Areas underlain by these rocks, particularly in the east half of the area, typically have a smooth, featureless topography that is recognizable on the ground and on air photographs. Some variation in the composition of the unit from the east to the west half of the area is recognized.

Fine to very fine grained, black to grey, red to brown, or green slate, shale, and siltstone, with minor medium-grained greywacke is typical of this unit in the east half. The rocks are normally thinly bedded, with beds $\frac{1}{16}$ to ¼ inch thick, but in some places up to as much as 1½ inches. Some of the thicker beds show graded bedding. Slaty cleavage, so prevalent in these rocks, may obscure the bedding. Tiny pyrite grains are disseminated through many of the black slates, and some are rich in graphite. East of Ameto Lake the red to black slates are ferruginous and rich in disseminated hematite and magnetite. Magnetite octahedrons are disseminated in accompanying fine- to medium-grained beds. Thin sections of these slates, shales, and siltstones show that tiny quartz grains are the major constituent and are accompanied by varied proportions of sericite and chlorite. In the black slates, very finely disseminated, black, opaque, probably carbonaceous material is a major constituent. Stratigraphically higher in this formation, fine-grained carbonate is present and in the uppermost part, rare interbeds of dolomite occur. Regional metamorphism of rocks in this unit results in recrystallization in some places, and in the development of biotite.

Although lenses of fine- to medium-grained greywacke occur within the very fine grained rocks in the eastern part of the area, such lenses are far more common in the west half. The accompanying shale and slate is also coarser grained in the western part. Hence the whole unit becomes slightly coarser grained westward. The greywacke to subgreywacke is chiefly grey to greenish grey or buff, locally green or pinkish, and forms beds 3 inches to 3 feet thick, that are, in part, graded.

On the north side of Griffin Lake, in the extreme west of the area, this unit is very thin or absent, as in some places dolomite (14) lies directly on the orthoquartzite (12).

Dolomite, Argillite, Siltstone, and Greywacke

The lower part of this unit (14) consists principally of dolomite, with minor, intercalated argillite, but upward argillite becomes more common and dolomite, less so. In parts of the area greywacke (equivalent to that of unit 15) is included in this unit; it cannot be shown separately, either because of the scarcity of outcrop or because of the thinness of the greywacke or map-scale limitations.

The fine-grained to very fine grained, massive to thin-bedded (½ to 1 inch) dolomite typically weathers brown to dark brown, and less commonly, to grey. On fresh surfaces it is white to cream to grey or dark grey or, rarely, pink to salmon. Grey dolomite commonly contains some argillaceous material, and siliceous dolomite containing subrounded grains of quartz may be interbedded with normal dolomite. Thin sections of dolomite show that carbonate grains range in size from 0.018 to 0.07 mm or more in some specimens. Normal dolomite contains perhaps 2 per cent quartz in scattered grains, minor sericite, an occasional feldspar grain, and in places where beds are slightly metamorphosed, scattered biotite flakes. Siliceous dolomite has considerably more quartz grains, up to 20 per cent in some specimens. Near the southeast corner of Cullaton Lake, dolomite beds have disseminated magnetite octahedra, and the accompanying interbedded argillite, tiny disseminated pyrite crystals.

In the east half of the area, the lower part of the unit has a few thin beds of impure grey quartzite, composed of quartz, sericite, and carbonate, interbedded with dolomite and siliceous dolomite. Such beds are present in the vicinity of Otter and Ducker lakes, but since they apparently occur as lenses, they are not useful as horizon markers. Stromatolites are generally rare in the dolomite of this unit, but southeast of Bray Lake, many beds contain stromatolites (Pl. X). Dolomite beds that are pebbly have subrounded to subangular pebbles or fragments of dolomite. Scattered beds of silty dolomite or calcareous siltstone have rare, small-scale crossbeds. The pink to salmon coloured dolomite does not form stratigraphic units and is probably related to deformation as it invariably occurs adjacent to a fault.

Stringers or segregations of grey to white quartz or chert are common in much of the dolomite and, being more resistant to weathering, protrude on the outcrop surfaces. These stringers show clearly the crenulations and folds of the dolomite. In some places quartz grains show prominent lineation. Plate XI illustrates small folds as outlined by the quartz segregations. Many of the segregations or stringers parallel the bedding, but some are crosscutting.

Argillite, interbedded with dolomite, is thinly bedded, fine grained, light to dark grey to black. Beds average ¼ inch thick, but prominent cleavage commonly obscures the bedding. In the lower part of unit 14, 1- to 3-inch layers of argillite comprise 5 to 7 per cent of an outcrop, but upward dolomite becomes less dominant and in the uppermost part of the unit, 1- to 2-foot layers of dolomite make up only 7 to 10 per cent of an outcrop. The argillite consists of tiny quartz grains with greenish to brownish biotite, sericite, or chlorite, scattered grains of feldspar, and in a few specimens accessory grains of iron oxide. Some of the beds are calcareous with a probable gradation from calcareous argillite or siltstone to impure dolomite beds. Minor white to grey quartz stringers and segregations cut the argillite, but these are never so abundant as in adjacent carbonate beds. Some undeformed stringers are post-regional deformation, but most are folded or contorted.

Regional metamorphism resulted in recrystallization and in the development of biotite in some of the dolomite and argillite. Just north of Bernier Lake, contact metamorphism affects both dolomite and argillite of unit 14. Coarse blades of tremolite and some diopside replace the dolomite, and medium to coarse metacrysts of biotite are scattered through the argillite interbeds. This metamorphism is restricted in areal extent and is thought to be due to young granite intrusion (20).

Iron-formation: Minor occurrences of iron-formation (14a) are associated with the dolomite and argillite to the east and southeast of Bernier Lake. It is quantitatively very minor in comparison with the iron-formation (3) of the Henik Group. The Hurwitz Group iron-formation is a fine to very fine grained, finely laminated, grey to red rock composed of quartz–magnetite–hematite or jasper–magnetite–hematite. It is highly contorted and broken into discontinuous bands or boudin-like forms in a matrix of dark brown weathering siliceous dolomite. The lenses or bands of iron-formation are 1 inch to 6 inches thick, but a number of such bands occur in each outcrop. The iron-formation has no economic significance but it, as well as the disseminated magnetite in dolomite elsewhere, indicates the local abundance of iron during deposition of the carbonate–argillite beds.

Greywacke

In many places the dolomite (14) is overlain by a thick member composed chiefly of greywacke, with lesser amounts of slate and siltstone (15). Albeit a thick member when present, in parts of the area greywacke is absent and the dolomite is overlain by a more diverse assemblage, unit 16. The lower part of the unit grades into the underlying argillite–dolomite, with considerable carbonate in the fine-grained greywacke and some thin interbeds of dolomite. The upper part of unit 15 becomes more quartzose as it grades into the overlying impure quartzite (16). Thus the unit appears to be transitional from argillite–dolomite to impure quartzite. Prominent outcrops occur only where the rocks are massive and lacking in pronounced cleavage. This is unusual as cleavage is normally moderate to intense and the rocks break into blocks that are frost heaved, resulting in large areas of felsenmeer.

The greywacke is greenish grey to grey to brown (typical of the carbonate-rich rocks) or rusty on weathered surfaces, whereas on fresh surfaces it is light to dark grey, with the light grey in the upper, quartzose part of the unit. Grain size ranges from medium to fine, with some graded bedding. The fine-grained greywacke grades imperceptibly into very fine grained argillite or siltstone. These rocks may be massive or thick bedded but locally bedding is good, particularly in the finer grained parts. Slump bedding, due to pre-consolidation slumping of the sediments, occurs in a number of localities, and crossbedding, some of it the festoon type, occurs in a few places. Lenses of carbonate and angular fragments of greenish grey argillite are present in some of the greywacke.

Thin sections of specimens from this unit show that quartz, feldspar, rock fragments, biotite, sericite, chlorite, and carbonate may all be major constituents but in widely varying proportions. Carbonate content may be up to 20 per cent in the lower part of the unit but stratigraphically higher is only 2 to 3 per cent. Tiny, subrounded quartz grains are the major component throughout. Feldspar content, which ranges from 4 to 20 per cent, is either fresh or much altered. In all these rocks greenish brown biotite is present, and in some that are slightly metamorphosed, secondary poikiloblastic grains of brown biotite are common. Rock fragments are relatively rare, except in some of the medium-grained beds of greywacke.

North and northwest of Bernier Lake, in the west half of the area, the greywacke has undergone contact metamorphism related to the young granite (20) that resulted in the formation of garnet porphyroblasts, much recrystallization of the biotite, and, in a few places, 1-inch knots of poikiloblastic cordierite. This contact metamorphism, however, is a local effect.

Cleavage is prominent, particularly in the finer grained parts, which results in phyllites or schists with prominent micaceous cleavage surfaces. These rocks seldom outcrop but form broken, rubbly exposures.

Veins of white quartz, commonly parallel to the cleavage and up to 5 inches wide, cut the greywacke. In two different places, thin veins of quartz-feldspar pegmatite cut rocks of this unit.

Impure Quartzite, Arkose, Quartz–Sericite Schist

The uppermost formation of the Hurwitz Group, consisting primarily of impure quartzite (unit 16), is widespread and commonly forms good outcrops. A distinctive weathered surface ranging from buff to pink to orange-brown, or less commonly grey, is typical. The fresh surface is grey although, in part, it may have a pink or greenish tone. The rocks are medium to fine grained, and range from thin bedded (½- to 3-inch beds) to thick bedded or massive. Bedding is commonly thin, an average of 2½ inches, with finely disseminated magnetite grains marking the bedding planes. Ripple-marks occur in a number of localities, although they are not as common or as widespread as in the orthoquartzite (12). The ripple-marks in this unit are more consistent in size, shape, and general character than those in the orthoquartzite, typically being symmetrical with an amplitude of about ¼ inch and a wavelength of 1 inch to 1¼ inches. Crossbedding is present in a number of places (Pl. XII). In a very few beds, stratigraphically low in the formation, elongate (2 to 3 inches by ⅛ inch) fragments of greenish argillite occur in the impure quartzite.

Quartz is, by far, the major constituent. Grains are rounded to subrounded with moderate to poor sorting. Fine flakes of sericite, the other major constituent, form the matrix and may constitute as much as 40 per cent of the rock. Feldspar grains, both microcline and plagioclase, may form as much as 30 per cent of the rock or as little as 2 to 3 per cent, and in a few specimens rock fragments are scattered through the quartz–sericite–feldspar. In almost all specimens biotite occurs in limited amounts, but particularly in those containing abundant feldspar and rock fragments where as much as 8 per cent may be present. Magnetite is a common accessory mineral. Carbonate is a minor constituent throughout the unit, but north of North Henik Lake and northeast of Nowyak Lake stratigraphically high beds are rich in carbonate and could be called siliceous dolomites (*see* Section loc. 11, in Appendix). Such carbonate beds are too restricted to be shown separately. The abundance of fine-grained matrix and the feldspar and rock fragments with the quartz and sericite indicate that most rocks in this unit are feldspathic to lithic greywackes.

At the base of the formation over a short interval, a maximum of 150 feet, there is interbedding of greywacke (15) or argillite (14) with the impure quartzite.

Regional metamorphism of the impure quartzite results in some recrystallization of the quartz into coarser grains and of sericite into coarse, poikiloblastic flakes. In general, these rocks are less affected by metamorphism than those of units 14 and 15.

Shearing is prominent and in some places obscures most of the primary structures. In some localities, for example, just north of Ducker Lake, in the south-central part of the area, the rocks consist of grey quartz–sericite schist and the abundance of sericite results in distinctive silvery, glistening cleavage surfaces.

Quartz veins, up to 7 inches wide, are common in these rocks. They parallel the shearing and are obviously post-shearing. In a single locality south of the east end of Griffin Lake, a 7-foot-wide dyke of vuggy, greyish pink leucocratic granodiorite cuts pinkish, impure quartzite of unit 16 without any contact effects. This dyke rock is probably related to the young pink granite of unit 20.

At the outlet of Mountain Lake, a small area of sedimentary rocks included in unit 16 is preserved in a thin fault slice within greywacke of unit 2; the lithology is also similar to the rocks of unit 19. The lowest beds exposed, adjacent to the fault, are 75 feet of white siliceous dolomite, in part micaceous and talc-bearing, with the dolomite completely recrystallized. Overlying the dolomite is 55 feet of grey to buff, medium-grained, impure quartzite or feldspathic greywacke and stratigraphically above this, a sill or flow, at least 30 feet thick, of andesite or fine-grained gabbro. Drift covers the rest of the area to the river, which is the locale of the other bounding fault. In appearance and composition these beds are similar to those in unit 19 and not too dissimilar to those in unit 16, but this very small area is the only place where sills or flows are associated with quartzite and dolomite. If these rocks found in the fault slice belong stratigraphically high in unit 16, a part not preserved elsewhere in the area, it indicates that some igneous rocks were present in the upper part of the Hurwitz Group, and all, except this occurrence, have been removed by erosion.

Dolomite and sandy dolomite. In a small area north of Ducker Lake and east of Cullaton Lake, dolomite and sandy dolomite (16a) overlie the impure quartzite. Although outcrop is not abundant, the carbonate beds appear to be conformable and, in part, interbedded with the impure quartzite. The dolomitic beds consist of buff coloured, finely bedded, fine-grained dolomite, or greenish grey or dark grey carbonate-rich siltstone, or sandy dolomite containing many quartz grains. The last may be crossbedded. The stratigraphic thickness of carbonate beds is probably less than 100 feet, as in the lower part there is considerable interbedded impure quartzite. Regional structure and stratigraphy indicate that the dolomitic beds are stratigraphically high in unit 16.

Arkose and conglomerate. North and northeast of these dolomitic beds but separated from them by a fault, grey to pinkish grey, impure quartzite is overlain by pink arkose with grey to pink interbedded pebbly sandstone or pebble-conglomerate (16b). The sandstone and the matrix of the conglomerate consist of quartz, sericite, and some feldspar. Scattered throughout are subrounded to subangular pebbles, ¼ inch to 6 inches in diameter. Most of the pebbles consist of reddish, argillaceous sandstone, but some of the larger ones are grey quartzite or impure quartzite. A few thin beds of pink siliceous dolomite overlie these conglomeratic beds. It is suggested that the conglomeratic sandstone beds are a local intraformational conglomerate in the upper part of the impure quartzite unit but stratigraphically below the dolomitic beds (16a).

Gabbro Sills

Gabbro sills (unit 17) from 500 to 1,200 feet thick intrude the slates of unit 13 in the southern part of the area. None are known in any other unit, but they are believed to be younger than units 14–16. Length of the sills is unknown, and the mapped outcrops may be parts of a single sill or, more probably, of a number of separate sills. On the north shore of Otter Lake, and north of the east end of Ameto Lake, are two or three parallel sills at different stratigraphic levels. Fine-grained zones within the sills suggest that they are composite intrusions. Rarely, small dykes of similar gabbro cut the sills.

The dark green to black gabbro, green to brown on weathered surface, is medium to coarse grained with fine-grained margins. Only rarely is diabasic texture evident in the rock. For the most part, the rock is massive but locally considerable shearing is evident.

Although in outcrop the gabbro appears to be fresh, thin sections of specimens reveal much secondary alteration and minor recrystallization. Andesine composes 25 to 30 per cent of the rock and is highly altered to epidote, zoisite, or sericite. In many specimens the feldspar grains are crushed and form a mosaic of fine grains. In others there is some incipient recrystallization of the feldspar. Common green hornblende (65 to 70 per cent) normally is rather coarse grained, but these grains are rimmed by recrystallized fibrous and acicular hornblende. In some specimens the hornblende is almost completely altered to chlorite. Scattered flakes of biotite and grains of quartz in these rocks may be associated, as they commonly are found together. Apatite, pyrite, ilmenite, and magnetite are common accessory minerals. Some specimens are so highly altered that the rock consists of a fine matte of secondary minerals. The alteration, probably deuteric, evidently follows no pattern, as zones of almost completely altered gabbro occur indiscriminately in relatively fresh gabbro. Quartz veins and, less commonly, quartz–calcite veins cut the gabbro.

Slate at both upper and lower contacts with the gabbro is converted to a hard, dense, dark hornfels for a distance of 1 to 2 feet adjacent to the contact. The contact is not always smooth, as tongues of gabbro may protrude into the slate.

Feeder dykes to the sills are not known and only one very small (18-inch-thick) dyke of similar gabbro is known to cut orthoquartzite (12). Low magnetite content of the gabbro results in little or no response on aeromagnetic maps. As the gabbro shows some cleavage and deformation, the emplacement of the gabbro sills apparently predates the folding of the Hurwitz Group.

Undivided Upper Hurwitz Group

Near the centre of the area, north of Bray Lake and west of Oftedal Lake, the upper part of the Hurwitz Group (unit 18), that is, units overlying the orthoquartzite (12), occur in the trough of a northeast-trending syncline. Outcrop is scarce with only scattered exposures of bedrock along some of the streams and rivers or occasionally projecting above the extensive glacial drift-cover. Lack of information precludes the defining of contacts between units with any degree of accuracy; hence all have been included in this one unit.

Quartzite, Arkose, Dolomite, Argillite

Sedimentary rocks of mixed lithology (unit 19) are apparently preserved in down-dropped fault blocks in several places in the northwest part of the area. Contacts are faults, except in two places where they are unconformities with underlying volcanic rocks (1). Similar lithology in the different areas indicates that the rocks belong to the same unit. This unit is subdivided into a lower, predominantly quartzite part, and an upper, predominantly dolomite part.

North of Nowyak Lake a small area of this unit, composed of the lower, quartzose part, is separated by a fault from volcanic rocks on the northwest side but unconformably overlies volcanic rocks on the south side. The lowest exposed beds, within 50 feet of andesite outcrops, consist of pebble-conglomerate, pebbly quartzite, and quartzite. The quartzite, a protoquartzite according to Pettijohn's (1957) classification, is grey to pink, medium grained, and consists of 65 to 70 per cent poorly sorted, rounded to subrounded quartz grains, 15 to 18 per cent sericite matrix, and the remainder, of feldspar grains with a few rock fragments. Pebbles are common locally in conglomeratic zones and elsewhere are scattered sparsely through the quartzite. The lowermost pebbly section is only 50 feet thick and passes upward into quartzite free of pebbles. The pebbles, a maximum ¾-inch diameter, are rounded and consist principally of white quartz; some are jasper and pink granite. The quartzite is thinly bedded, commonly in beds an inch or less thick with minor crossbedding. Higher in the quartzite section other quartz and jasper-pebble conglomerate zones are associated with pink to purplish red grit beds. Near the top of the limited section there, a few 6- to 8-inch beds of brown weathering, cream coloured, siliceous dolomite are interbedded with grey quartzite. Cleavage is pronounced in all these rocks. Veins and stringers of quartz and, rarely, of pink quartz-feldspar pegmatite cut these sedimentary rocks.

Ten miles west of Nowyak Lake, a more varied and better exposed section of this unit is bounded on the northwest by a major northeast-trending fault and in the south, at least in part, by faults. The lower 3,500 feet of exposed section (*see* Section loc. 16, in Appendix) consists of well-bedded, grey to pink or greenish, impure quartzite or protoquartzite, grading to feldspathic greywacke with minor interbedded argillite and dolomite. Thin sections of the quartzite show that the grains are poorly sorted, subrounded and, in addition to the abundant quartz, they contain considerable feldspar and scattered rock fragments, all in a sericite matrix that makes up 10 to 15 per cent of the rock. The upper 2,500 feet of the unit in this locality is predominantly dolomite, white to grey to red, with interbeds of finely laminated, grey to red to green argillite and shale, and grey to green, impure quartzite or greywacke. The dolomite is chiefly thin bedded, with beds averaging 3 inches thick. It is siliceous, containing both chert and rounded quartz grains. In the lower part of the carbonate-rich part of the unit a very distinctive red dolomite containing abundant gritty quartz grains constitutes a distinctive marker. Thin sections of the red dolomites show disseminated hematite dust on most of the mineral grains. The argillite and shale interbeds are probably partly recrystallized. They consist of quartz grains in a matte of very tiny quartz grains, and sericite and biotite. Although cleavage is present in all rocks of this unit, it is far more pronounced in the fine-grained argillite or shale. Minor crenulations are also typical of these fine-grained rocks. Quartz veins and stringers are present throughout.

A small remnant of protoquartzite similar to that described occurs on the southwest side of the major northeast-trending fault that bounds the two previously described occurrences of unit 19 on the northwest. The contact on the south side is not exposed, and it is assumed the quartzite unconformably overlies volcanic rocks (1). The lithology is similar to beds found stratigraphically low in the section in the other occurrences.

Southwest of Nowyak Lake a band of interbedded dolomite and phyllite or slate is bounded by faults and apparently preserved in a down-dropped fault block, with about 7,700 feet of section exposed (*see* Section loc. 15, in Appendix). Dolomite, much of it siliceous, is brown weathering with grey to white, fresh surfaces or, rarely, red to pink tinged. Bedding is partly obscured by prominent cleavage, but the rock appears typically to be thin bedded. Biotite and sericite are abundant on cleavage planes of the dolomite. Stringers of grey quartz and chert, both concordant and crosscutting, are abundant in the dolomite. Phyllite and slate interbedded with the dolomite are grey to black, and the intense cleavage almost completely obscures the thin bedding laminations. Quartz, biotite (chiefly recrystallized into poikilitic flakes), and chlorite, with minor sericite and feldspar, form these rocks. Euhedral pyrite is a common accessory in the phyllite and slate. Near the faults bounding these rocks, the argillaceous rocks are converted to quartz–biotite schists. A few beds of fine- to medium-grained impure quartzite or feldspathic greywacke are interbedded with the siliceous dolomite and the phyllite and slate. Northeast of this band of sedimentary rocks, on a small island in Nowyak Lake, are similar sedimentary rocks, consisting of siliceous dolomite, fine-grained phyllite, and a few beds of light grey to pink, impure quartzite.

Near 61°39′30″N, 98°47′W, adjacent to the granite (20) on the southeast side of the bounding fault of the sedimentary band, dolomite is metamorphosed to a coarse-grained, tremolite-rich rock. This is interpreted as due to contact metamorphism related to the granite intruded along the fault zone. Late movement took place on this fault, as both the granite and metadolomite are sheared.

The rocks southwest of Nowyak Lake are similar to the upper part of the section west of Nowyak Lake. The lower quartzite-rich part of the unit (19a) is not present, but the upper dolomitic part is better represented there than anywhere else.

From the limited sections available of rocks of unit 19 the following conclusions are made. Although the basal beds may be conglomeratic, with lenses of pebble-conglomerate in the impure quartzite, the most typical basal rock is an impure quartzite, a protoquartzite to feldspathic greywacke, an immature rock, characterized by poor sorting, relatively common feldspar grains, and some rock fragments. Rapid denudation of an old land surface and rapid deposition of the debris are indicated. The upper part of the section, with intercalated siliceous dolomite and argillaceous beds, represents a deeper water environment in the sedimentary basin, but the abundance of quartz grains in the dolomite suggests turbulent conditions during deposition.

Although the rocks in the lower part of unit 19 bear some resemblance to the quartzite (10b) of the Montgomery Lake Group in that both are protoquartzite, they are not considered to be correlatives because the pyrite, typical of unit 10b, is lacking in unit 19. It is probable that rocks of unit 19 are the lateral equivalent of those of unit 16, the uppermost formation of the Hurwitz Group. Near Nowyak Lake the two units occur in proximity but are always separated by major faults. The lithology of the lower part of unit 19 and that of unit 16 are similar in that both are composed of impure quartzites or protoquartzites. Both units also contain carbonate beds, but in quantity the stratigraphically thin section in the uppermost part of unit 16 is not comparable with the thick dolomite–argillite section in the upper part of unit 19. It is noteworthy that no Hurwitz Group rocks have been located west of the major northeast-trending zone of faulting in which rocks of unit 19 are preserved in down-dropped blocks.

About 200 miles southeast of Kognak River, in northern Manitoba, Taylor (1958) described the Great Island Group of sedimentary rocks. The lithology of this group resembles that of unit 19 in many respects. According to Taylor (pers. com.), red to pink dolomites containing gritty quartz grains occur in the Great Island Group as they do in some sections of unit 19. However, it seems unlikely that the two units could be correlatives.

Granite, Quartz Monzonite, Granodiorite

The large pluton south and southeast of Bate Lake is chiefly granite to quartz monzonite with local granodiorite zones. Typically, the rock is massive, pink, medium to coarse grained, with a low (3 to 6 per cent) mafic content, normally biotite partly altered to chlorite. Muscovite is present in some places, but it is not an essential constituent. Feldspar is commonly antiperthite with graphic intergrowths. Magnetite is the only common accessory mineral. The central core of the pluton is granite to quartz monzonite, and toward the margins of the pluton the composition is chiefly quartz monzonite. In the central granite core, dark grey to smoky or black quartz is a distinctive feature. Pink granite pegmatite stringers and dykes containing muscovite and biotite are associated with the pluton and cut the granite and quartz monzonite. The pink pegmatite is cut by younger, grey to white, quartz-rich pegmatite containing abundant dark coloured quartz. The pink pegmatite is commonly sheared and deformed, whereas the younger grey dykes are undeformed.

Contacts of the pluton with adjoining gneiss units (6, 6a, 7) are gradational, with intimate mixing of the quartz monzonite in the gneisses. Thin lenses or remnants of grey gneiss are scattered through the quartz monzonite.

North of Bernier Lake, dolomite (14) and greywacke (15) show marked contact metamorphism, although they are not in contact with the quartz monzonite to granite (20). Stringers of pegmatite and a single small granodiorite dyke cutting the Hurwitz Group rocks are believed to be associated with the granite to quartz monzonite (20).

The pluton is thought to be a composite intrusion consisting of an earlier phase, chiefly quartz monzonite in composition, with associated pink pegmatite and a younger, central core phase, chiefly granite in composition, with associated grey to white, quartz-rich pegmatite. Radiometric age determination on specimens from the pluton, to be discussed in a later section, do not show any age distinction in the phases.

Porphyritic Granite

Coarse-grained porphyritic pink granite (unit 21), commonly fluorite-bearing, is confined to the southwest corner of the map-area. The rock has been informally named the Nueltin Lake granite by Wright (1967). In Kognak River area the occurrence of the granite is in the northeastern part of a larger pluton, as shown by Wright (1967). Forty to fifty per cent of the rock is composed of pink microcline and microcline–perthite phenocrysts, the remainder being microcline, dark grey quartz, oligoclase, and biotite; purple fluorite, apatite, and magnetite form the accessory minerals. The fluorite, in grains up to $\frac{1}{8}$ inch, is widely disseminated. Near the contacts of the pluton, the rock is medium to coarse grained and contains fewer feldspar phenocrysts. A small isolated area of these rocks south of Hawk Hill Lake, lying between the volcanics (1) and orthoquartzite (12), is not typical of the unit in that phenocrysts are less abundant, the groundmass is greyer, biotite-rich inclusions are abundant, and fluorite is scarce.

The fluorite-bearing porphyritic granite is similar to that described in areas to the south by Lord (1953), Fraser (1962), Davison (1963), and Wright (1967). Lord suggested that the granite may be younger than orthoquartzite (12). From field work the age relations of granite (21) and orthoquartzite (12) are not known, as the only observed contact is a shear zone. However, later field work in areas to the south (Eade, 1971, 1973) shows that the Nueltin Lake granite intrudes Hurwitz Group rocks and transects the structure associated with the Hudsonian orogeny. As discussed in a following section, radiometric age determinations also give a late Aphebian or early Helikian age for the granite.

Gabbro and Diabase Dykes

Northwest-trending gabbro and diabase dykes (unit 22), the most continuous and most prominent dykes in the area, are also the freshest and youngest rocks. Two of these dykes are particularly prominent, one east of Griffin Lake and Mountain Lake, the other east of Bray Lake. Segments of dykes with this trend are scattered throughout the area, for example, north of North Henik Lake and southwest of Imikula Lake.

The dykes range from 80 to 150 feet wide, have an apparent vertical dip, and are medium grained with fine-grained chilled margins. Normally they are grey to greenish grey on fresh surfaces, with reddish brown weathered surfaces. Locally, pink to red, feldspar-rich granophyre containing some quartz forms segregations in the gabbro. The dykes are typical plagioclase (labradorite to andesine)—augite gabbro, with minor biotite; commonly apatite and some magnetite are accessory minerals. Feldspar is partly altered to sericite and clinozoisite, and the augite and biotite to chlorite. Diabasic texture is present here and there in all the dykes. Parts of dykes may be porphyritic with prominent plagioclase phenocrysts up to 2 inches long. Jointing, normal to the trend of the dyke, is commonly prominent, but there is little or no shearing in these rocks with the exception of one dyke in the north-central part of the area, west of Imikula Lake, with a slightly different west-northwest trend. This dyke is sheared and slightly metamorphosed. Contact effects due to these dykes are slight. In granodiorite and gneiss a slight reddening of the country rock for about one foot from the contact is apparent, but Hurwitz Group rocks, with the exception of dolomite (14), are unaffected. At dolomite–dyke contacts actinolite is commonly developed, and this type of metamorphism is pronounced northwest of Bray Lake. These dykes typically show a good response on the aeromagnetic maps.

Dykes with a northwest trend elsewhere in the Churchill Structural Province have been dated at approximately 1315 m.y. (Fahrig and Wanless, 1963). Dykes in the area with this trend are considered to belong to the same swarm and to be of similar age.

Biotite Lamprophyre Sills

Minor sills of biotite lamprophyre (22a) occur in dolomite (14) east of Cullaton Lake. At least three sills, 8 to 15 feet thick, at this locality occur along the crest of a small anticline. The dark grey to black rock, light greenish grey on weathered surface, is fine grained to very fine grained with abundant dark phenocrysts, which weather out, scattered through the groundmass. The groundmass consists of a matte of biotite, feldspar, and minor quartz, and the phenocrysts are composed of a matte of tiny calcite grains surrounded by a rim of biotite. In the lamprophyre dykes (9a) the phenocrysts are composed of biotite only.

Summary and Interpretation of Depositional Environment of the Hurwitz Group and Unit 19

The Hurwitz Group was deposited in a major north- to northeast-trending Aphebian geosyncline, the former extent of which is not known. Basal conglomerate occurs locally as thin lenses or rarely as a thick lens deposited in a local basin. Most commonly the basal unit is orthoquartzite, extremely thick (4,000+ feet) in the northeast but thinning to 400 feet in the west and north, with a suggestion that it is absent altogether just north of the area. The great thickness of orthoquartzite in some parts is difficult to explain and differential upward and downward movements of the foreland must have occurred. Pebble horizons are common throughout the orthoquartzite and it is abundantly ripple-marked, although crossbeds are rare. The source of material for the orthoquartzite, probably a mature terrain as suggested by the extreme purity of the quartzite, is believed to have been a craton to the east with direction of transport west to northwest. The unit was probably laid down in an on-lapping sea advancing from west to east. If the two westernmost observations on ripple-mark asymmetry (Fig. 2) are significant, then there may have been some transport of material from the west, perhaps a local high providing a source of material.

The shale–slate–siltstone–greywacke unit overlying the orthoquartzite shows some lateral change; the unit appears to be thicker in the east and northeast, disappearing entirely in the north around Imikula Lake, and to the west it is thinner and coarser as greywacke is more abundant. In the extreme west, around Griffin Lake, dolomite occurs immediately over the orthoquartzite, with some slate above the dolomite beds. The coarser material in the western part of this unit is possibly another indication of a local, western source of material. The abundant black slates in this unit in the eastern part of the area suggest that there may have locally been a semiclosed basin, partly separated from the open, deeper water to the west.

Dolomite–argillite overlying orthoquartzite and slate is a commonly recognized facies, and the carbonate–argillaceous beds are indicative of stable conditions and deposition in quieter, deeper waters of the sedimentary basin. In the southeast part of the area the unit seems to be thinner, with greywacke of the overlying unit thicker than elsewhere. Everywhere in unit 14 carbonate is predominant in the lower part and argillite most abundant in the upper part.

Greywacke, overlying the dolomite–argillite, is thickest in the central and southern parts of the area and elsewhere appears to form lenses of varying thickness. In the north part of the area the unit is thin, 100 to 150 feet, forming a transitional zone between dolomite–argillite and impure quartzite. The greywacke is indicative of changing conditions in the sedimentary basin, the influx of poorly sorted clastic material reflecting relative uplift of the source area, with more rapid erosion under unstable conditions and deposition in a shallow basin. The greywacke unit as a whole may be regarded as a transitional phase to the overlying impure quartzite unit, a protoquartzite in which ripple-marks and crossbeds indicate relatively shallow waters of deposition and the composition of the rock suggests a rejuvenated source area. Carbonate beds in the upper part of the impure quartzite suggest a return to deposition in less turbulent, deeper waters. It is possible that a regional disconformity exists within the greywacke–impure quartzite units or at the upper boundary of the dolomite–argillite. Nowhere, however, is there any evidence of an angular unconformity within the Hurwitz Group. Sparse conglomerate beds in the upper part of the impure quartzite unit do indicate a local break in deposition.

Nowhere in the area do units 13–16 lie unconformably on the older rocks, units 1–10; that is, there is no overlap.

The possibility that igneous flows or sills were formerly present in the upper part of the Hurwitz Group in this area must be considered, although the evidence is tenuous. Bell (1968) reported volcanic rocks in the upper part of the Hurwitz Group in an area to the east, and 150 miles to the southwest, near Kasba Lake, thin volcanic flows and tuff occur within subgreywacke, overlying dolomite of the Hurwitz Group (Eade, 1971). Thus, it is possible that local centres of volcanism were present in the basin at several localities during the final stages of deposition of the group. The intrusion of the gabbro sills may be related to such igneous activity.

The relationship of unit 19 and the Hurwitz Group remains uncertain, although it seems likely that both originated in the same basin of deposition. Lithologically, the lower quartzitic part of unit 19 is similar to the impure quartzite 16, as both are essentially protoquartzites. However, it is possible that unit 19a, rather than being a lateral equivalent of unit 16, may be equivalent to orthoquartzite (12) as in some places unit 19 has basal conglomeratic beds and rests on the old basement rocks. The upper part of unit 19, intercalated dolomite, argillite, and quartzite, could be equivalent to the uppermost part of unit 16, in which carbonate beds are interbedded with quartzite, or it may be the lateral equivalent of units 13–16, that is, all the Hurwitz Group overlying the orthoquartzite. Rocks of unit 19 may be close to the western margin of the sedimentary basin. Movements on the postulated major zone of faulting in the northwest part of the area, which would be close to such a suggested western margin, may have resulted in uplift and a local western source area for the clastic sediments of unit 19.

Metamorphism

As the metamorphic rocks in the Kognak River area have been described on previous pages, this section summarizes the data on regional, contact, and dynamic metamorphism.

Regional Metamorphism

Nearly all rocks of the area, with the exception of the younger igneous rocks, have been affected by slight to moderate regional metamorphism, but at the present scale of mapping it is only readily detectable in certain units. In part of the western half of the region the progression of regional metamorphism can be traced in the clastic rocks of unit 2, but elsewhere only comments can be made on the grade of metamorphism. Two main regional metamorphic events, a pre-Hurwitz Group event and a post-Hurwitz Group event, are recognized, although in the pre-Hurwitz Group rocks it is difficult to distinguish the effects of the two events. In the Hurwitz Group rocks there is some difficulty in distinguishing low-grade regional metamorphism and dynamic metamorphism related to intense folding.

Greenschist facies—quartz–albite–muscovite–chlorite subfacies in pre-Hurwitz Group rocks. Greywacke, slate, and some tuff of unit 2 between the west arm of Ducker Lake and Mountain Lake are in the lowest subfacies of the greenschist facies of metamorphism (Turner and Verhoogen, 1960). The slates tend to be phyllitic and are characterized by a very fine grained aggregate of chlorite and sericite, with some quartz, feldspar, and minor, opaque accessory minerals. The subgreywacke or lithic greywacke accompanying the slates is essentially of the same composition but in different proportions, with quartz, feldspar, and rock fragment grains set in a fine matrix of chlorite and sericite. On the accompanying geological map, the biotite isograd outlines this area in which no biotite is developed. A similar area of low metamorphic grade is outlined on the west side of South Henik Lake. Equivalent low-grade metamorphic zones exist in the basic volcanic rocks of unit 1, but lack of petrological detail precludes outlining them. Basic volcanic rocks in these zones contain few or no primary minerals and are characterized by chlorite.

Greenschist facies—quartz–albite–epidote–biotite subfacies in pre-Hurwitz Group rocks. Biotite marks the boundary between this subfacies and the lower quartz–albite–muscovite–chlorite subfacies; hence the biotite isograd is the boundary between these subfacies. The biotite appears gradually but eventually it and muscovite completely replace the chlorite and sericite in the clastic rocks. The greater part of unit 2 in the area is in the quartz–albite–epidote–biotite subfacies, and unless otherwise indicated on the map, these rocks can be considered to be in this subfacies. An exception is the area of tuff with some greywacke north of Montgomery Lake and south of Oftedal Lake which seems to be almost at the boundary of this subfacies and the lower subfacies, as the minerals present vary almost from outcrop to outcrop, with no possibility of indicating a boundary between the subfacies. In the basic volcanic rocks associated with this subfacies, actinolite, rather than chlorite, is a major constituent.

Greenschist facies—quartz–albite–epidote–almandine subfacies in pre-Hurwitz Group rocks. West of Bernier Lake, the garnet isograd in rocks of unit 2, as indicated on the map, is the boundary of this subfacies. Almandine garnet and albite feldspar are the characteristic minerals in the clastic rocks (unit 2). In the associated basic volcanic rocks, hornblende occurs with the actinolite. Iron-formation (3) occurring in this subfacies contains some hematite.

Almandine–amphibolite facies in pre-Hurwitz Group rocks. The boundary between the almandine–amphibolite facies and the greenschist facies in the clastic rocks of unit 2 is marked by the change in composition of the plagioclase from albite, in the greenschist facies, to oligoclase to andesine, in the almandine–amphibolite facies. It is not possible to mark this boundary on the accompanying map. Schists and gneisses of units 5, 6, and 7 are principally in this facies and are characterized by the assemblage plagioclase (An $_{25\text{-}40}$), blue-green hornblende, biotite, quartz, epidote, and sphene. Commonly there is evidence of retrograde metamorphism with hornblende almost completely altered to chlorite. The iron-formation (3) in this zone of metamorphism seems to be characterized by the presence of grunerite–cummingtonite or blue-green hornblende, and by the absence of hematite.

Hurwitz Group. Greenschist facies metamorphism affecting the Hurwitz Group is most evident in the slates (13), argillite (14), and greywacke–slate (15). Other sedimentary rocks of the group, rather than clear-cut evidence of metamorphic grade, show some increase in the amount of secondary minerals and some degree of textural modification. In the slate, argillite, and greywacke, the presence of chlorite and sericite in the fine-grained matrix is indicative of lower greenschist grade metamorphism. Locally, biotite appears, indicating that middle greenschist facies may be reached. Difficulty exists in differentiating biotite and muscovite developed by regional metamorphism and the same minerals resulting from dynamic metamorphism.

The presence of sericite in the matrix of the orthoquartzite (12) and impure quartzite (16) may indicate lower greenschist grade metamorphism, although it may, in part, be detrital. Calcareous rocks of unit 14 show no more than recrystallization, as a result of the low-grade regional metamorphism.

Evidence of two separate metamorphic events is present west of Bernier Lake where greywacke (2) is in the upper greenschist facies due to the earlier metamorphic event, but greywacke (15) of essentially similar composition is in the lowest greenschist facies, the result of the later metamorphic event.

Contact Metamorphism

Northwest of Bernier Lake, a zone of contact metamorphism has been outlined, the metamorphism being attributed to the young granite (20). In the contact zone cordierite and andalusite are extensively developed in the schists and gneisses of unit 6, tremolite in the dolomite of unit 14, and garnets in the greywacke of unit 15. In the same area iron-formation (3) shows magnetite recrystallization and development of blue-green hornblende and grunerite.

Slate (13) adjacent to gabbro sills (17) is converted to hornfels for a distance of 1 foot to 2 feet and dolomite (14) is slightly tremolitized adjacent to gabbro dykes (22), but both these examples of contact metamorphism are of extremely limited areal extent.

The composite stock (8, 8b, 8c) southeast of Hawk Hill Lake has had little contact effect on adjacent greywacke (2), with the exception of some recrystallization and a slight increase in the development of biotite over and above that due to regional metamorphism. Similarly, in the northwestern part of the area where granodiorite (8) and hornblende–biotite quartz diorite (8a) plutons intrude volcanic rocks (1), metamorphic effects are limited to development of epidote.

Dynamic Metamorphism

Effects of dynamic metamorphism are probably present in nearly all the regionally metamorphosed rocks, but it is only readily apparent in certain of them. Quartz–sericite schist (15), abundant in parts of the impure quartzite, results from intense axial plane cleavage related to folding. Greywacke (14) affected by the same cleavage has much biotite developed along the cleavage planes.

The area of quartz–feldspar–mica schist and quartz–mica schist (2b) at South Henik Lake probably results from dynamic metamorphism, although it could be, in part, due to contact metamorphism related to the granodiorite (8) pluton to the south.

Age Determinations

All presently available results of potassium–argon age determinations on specimens from this area are listed in Table I. Some strontium–rubidium determinations have been made (Wanless, pers. com.) and, although the detailed results are as yet unpublished, the values are discussed in this section.

TABLE I | *Potassium–argon age determinations, Kognak River area*

Determination No.	GSC Reference	Rock Type	Mineral	Age m.y.
GSC 61-106	Paper 62-17	granodiorite gneiss (7)	biotite	1735
GSC 64-70	Paper 65-17	granodiorite (8)	biotite	1760 ± 60
GSC 64-71	Paper 65-17	gabbro (17)	biotite	1685 ± 120
GSC 65-71	Paper 66-17	pegmatite (20)	muscovite	1665 ± 55
GSC 65-72	Paper 66-17	pegmatite (20)	biotite	1355 ± 50
GSC 66-91	Paper 67-2 Part A	quartz–sericite schist (16)	sericite	1480 ± 50

Most of the potassium–argon age determinations give ages related to the Hudsonian orogeny. The determination (GSC 66-91) on sericite from quartz–sericite schist (16) from the north shore of Ducker Lake indicates an age of 1480 ± 50 m.y., which is younger than most of the others. This schist results from intense cleavage related to the northeast-trending folds in the Hurwitz Group rocks. As this deformation is related to the Hudsonian orogeny, it must be assumed the young age is the result of argon loss due to deformation. The other young age, (GSC 65-72) 1355 ± 50 m.y. is on biotite of a muscovite–biotite pair from a slightly deformed pegmatite related to the quartz monzonite (20). The muscovite from this dyke (GSC 65-71) gives an age of 1665 ± 55 m.y. and it can only be assumed that there was argon loss from the biotite.

The age 1685 ± 120 m.y. determined on biotite from the gabbro sill in the Hurwitz Group, just south of Griffin Lake (GSC 64-71) could possibly represent the age of crystallization of the sill but it seems more probable, in light of the alteration of the gabbro, the age is that of the Hudsonian orogeny.

The two oldest potassium–argon ages are 1735 m.y. (GSC 61-106) on granodiorite gneiss (7) from south of Nowyak Lake, and 1760 ± 60 m.y. (GSC 64-70) on granodiorite (8) from the north shore of Ameto Lake. Stockwell (1963), in discussing the 1735 m.y. age, stated that it may be either that of primary crystallization or of metamorphism. Recent strontium–rubidium age determinations indicate that both are the age of the metamorphism associated with the Hudsonian orogeny. Suites of samples from granodiorite gneiss (7) south of Nowyak Lake and of granodiorite (8) from east of North Henik Lake give isochrons that

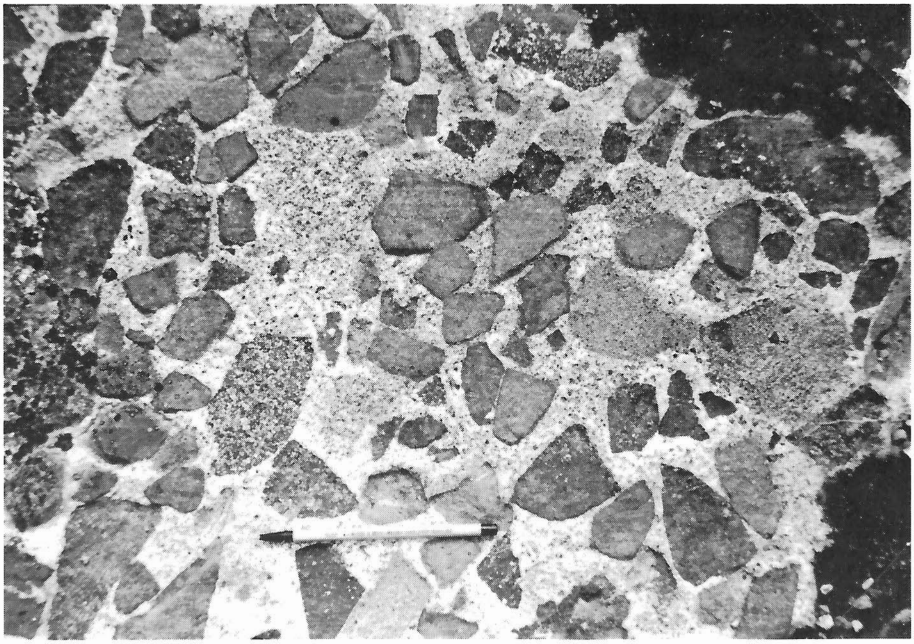

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PLATE I. Breccia dyke (8d) in granodiorite (8) north of Ameto Lake (61°43′N, 97°17′W).

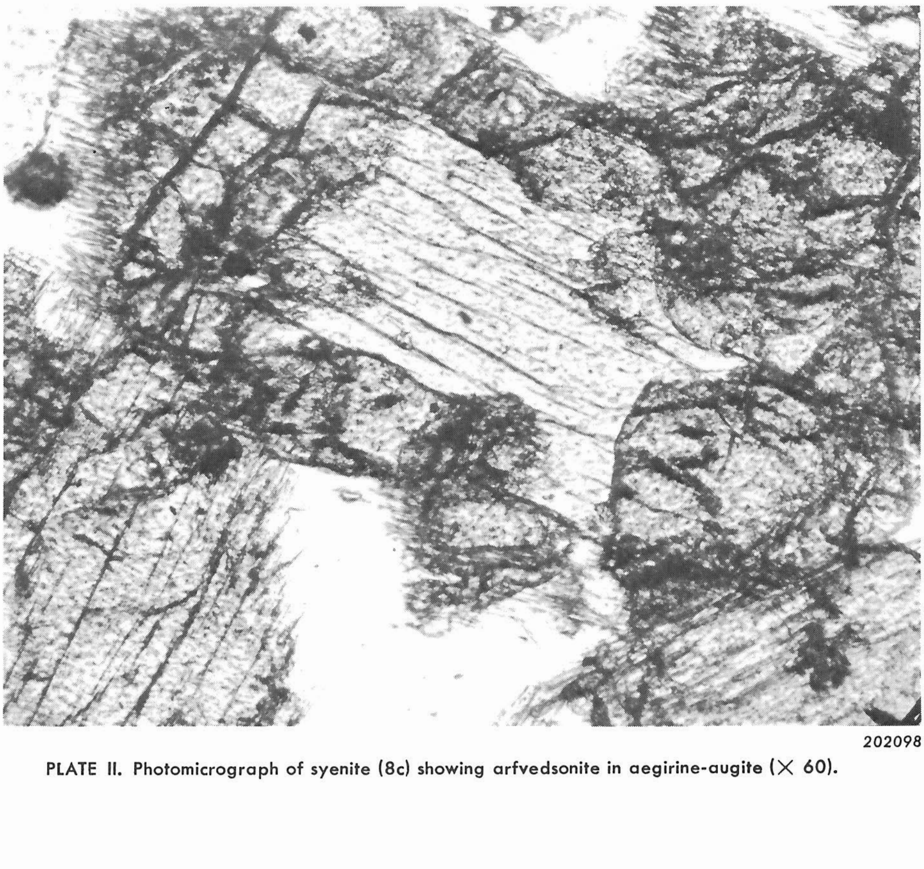

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PLATE II. Photomicrograph of syenite (8c) showing arfvedsonite in aegirine-augite (× 60).

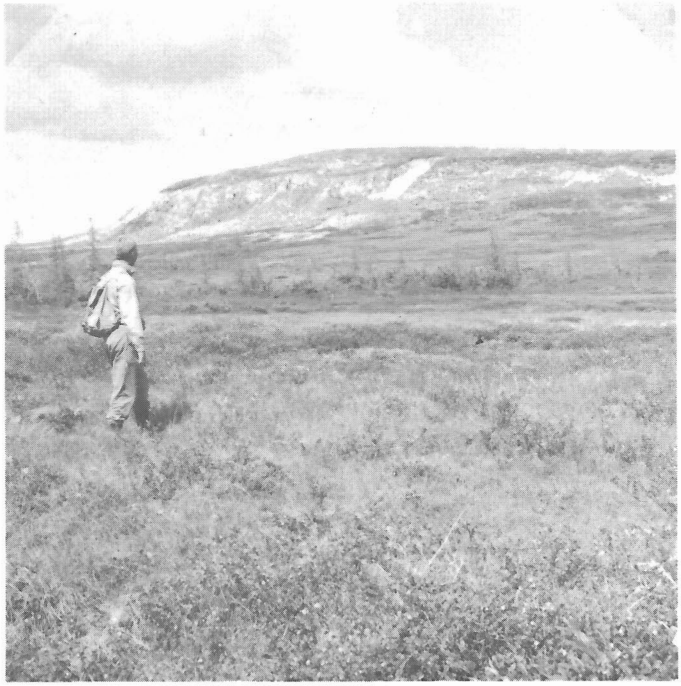

PLATE III

Typical ridge topography of Hurwitz Group orthoquartzite (12) near the northeast corner of Hawk Hill Lake.

132351

PLATE IV

Quartz-pebble conglomerate in Hurwitz Group orthoquartzite (12) south of North Henik Lake.

115737

132336

PLATE V. Typical ripple-marks in Hurwitz Group orthoquartzite (12) east of Otter Lake.

132339

PLATE VI. Ripple-marks in Hurwitz Group orthoquartzite (12) with sharp crests and troughs, southwest side of the northwest arm of Ducker Lake.

115731

PLATE VII. Superimposed ripple-marks in Hurwitz Group orthoquartzite (12), north side of Ameto Lake.

132362

PLATE VIII. Brecciated and recemented Hurwitz Group orthoquartzite (12) at the nose of a small fold, southeast of Otter Lake.

115724

PLATE IX

Bleach spots in Hurwitz Group orthoquartzite (12), north of Ameto Lake.

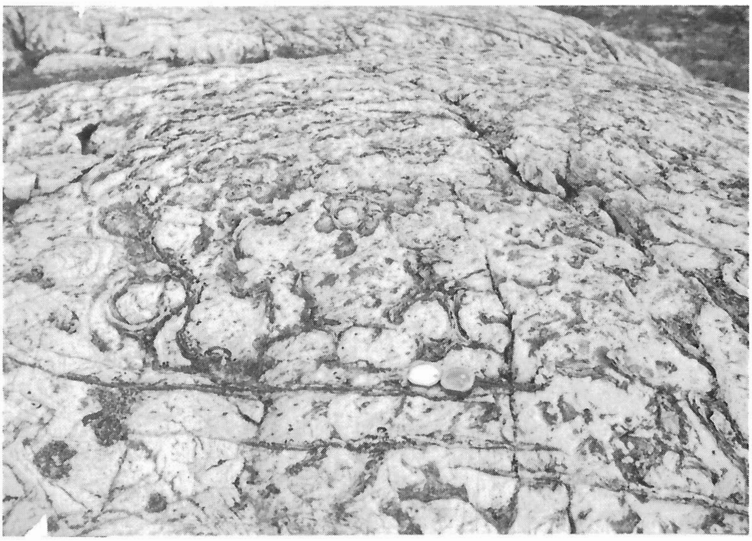

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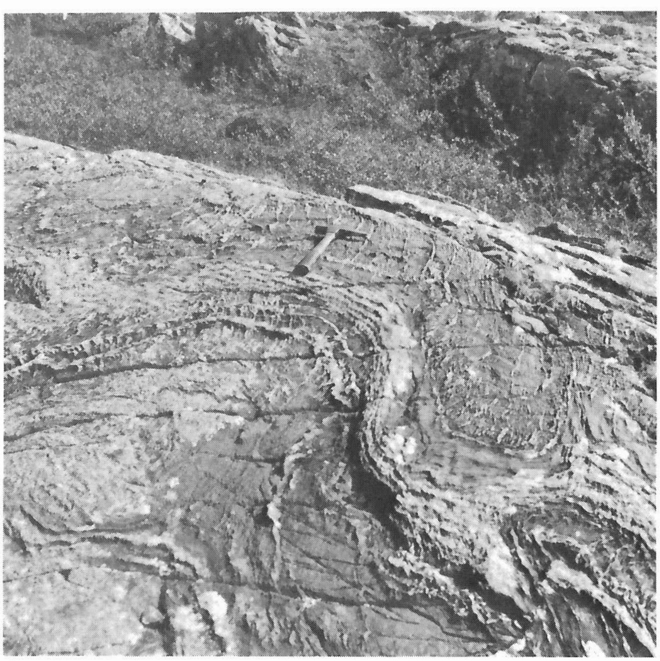
PLATE X

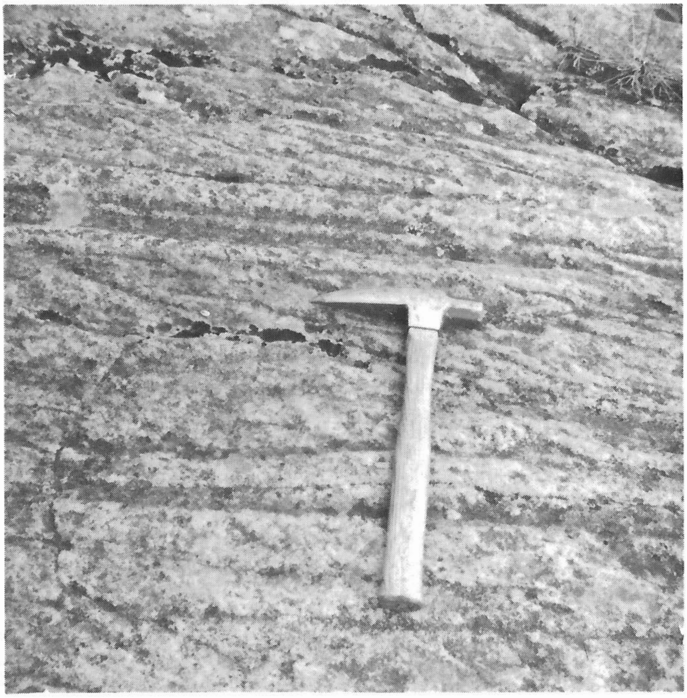
Stromatolites in Hurwitz Group dolomite (14), southeast of Bray Lake.



132360

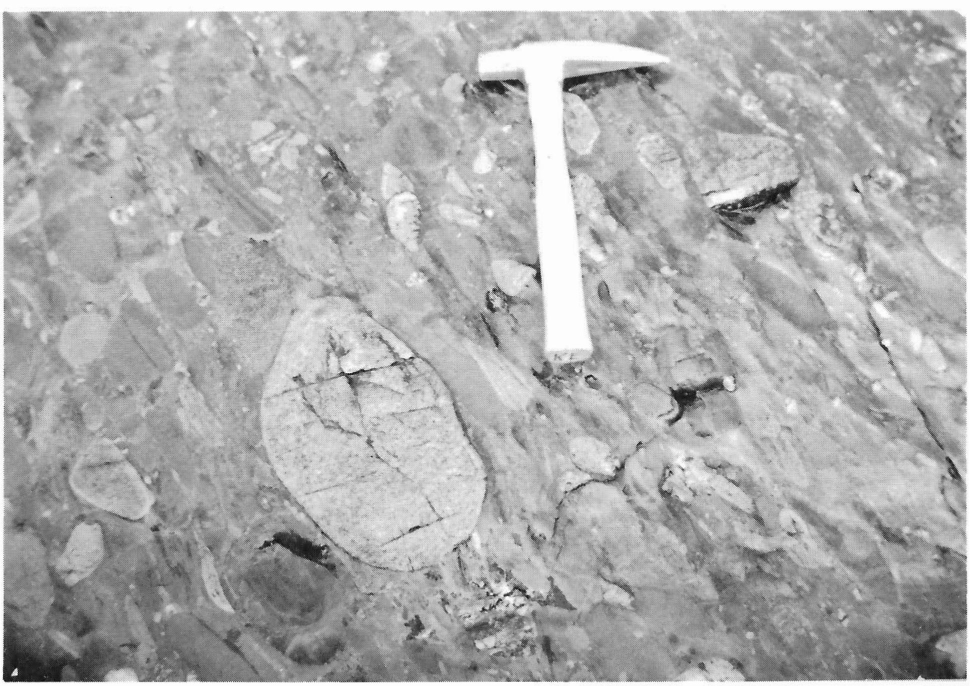
PLATE XI

Folded quartz or chert segregations and stringers in Hurwitz Group dolomite (14), south of Bernier Lake.



115785

PLATE XII. Crossbedding in Hurwitz Group impure quartzite (16), north of North Henik Lake.



115770

PLATE XIII. Basal conglomerate (10a) of the Montgomery Lake Group, east shore of Montgomery Lake.

indicate ages of 2404 ± 184 m.y. and 2512 ± 112 m.y. respectively, that is, probable Archean ages. These are believed to be the ages of metamorphism and crystallization, respectively, and potassium–argon ages on the same rock-units represent the overprint of the Hudsonian orogeny.

A suite of samples of quartz monzonite (20) gave a strontium–rubidium isochron that indicates an age of 1772 ± 22 m.y. This is believed to be the age of crystallization of the pluton and the potassium–argon age of 1665 ± 55 m.y. on pegmatite cutting the quartz monzonite is too young. As this pluton is considered to be a synorogenic intrusion associated with the Hudsonian orogeny, 1772 ± 22 m.y. is the date of the orogeny in this area and the potassium–argon ages are all slightly young.

A strontium–rubidium isochron based on a suite of samples of the coarse-grained, porphyritic, fluorite-bearing granite (21) indicates an age of 1700 ± 16 m.y. Field observations on plutons of these rocks in areas to the south (Eade, 1971, 1973) showed that they are post-orogenic intrusions and transect structures associated with the Hudsonian orogeny. Hence, these rocks are Paleohelikian. Therefore, in this region the Aphebian–Helikian boundary is between 1684 and 1794 m.y.

All the above rubidium–strontium ages are based on a ^{87}Rb decay constant of 1.47×10^{-11} yr^{-1} (Wanless, pers. com.).

Zircons extracted from granodiorite gneiss (7) samples from 10 miles north of Griffin Lake, and 2 miles from the contact with the quartz monzonite (20) pluton, proved to be discordant but provided a $Pb^{207/206}$ age of 2335 m.y.

Aeromagnetic Data

All the Kognak River area is covered by aeromagnetic series maps, scale 1 inch = 1 mile, as shown on the Index Map, Figure 3. Unfortunately, these maps were not available when the geological mapping was being done, nevertheless, they have been a useful aid in interpreting the field data. In this section, some observations and comments are made on the aeromagnetic response of rock types in the various units and on some features of the structural geology. Volcanic rocks of unit 1 show two markedly different responses on the maps, being characterized by either crowded, closing contours in roughly circular patterns or rather dispersed open contours. The best illustrations of these features are in the area north of North Henik Lake where the southern part of the unit shows the former pattern and the northern part, the latter pattern. North of Griffin Lake, an area of circular, close contours is indicated by field observations to be a possible volcanic neck. Volcanic rocks near the south border of the area, southeast of Hawk Hill Lake, show such dispersed contours so lacking in pattern, as to be considered atypical. Large amounts of tuff may be interlayered with the flow rocks, resulting in this uncharacteristic response.

Clastic rocks of unit 2 differ from place to place in the response shown on the maps, from widely spaced, meandering contours, lacking any pattern, to widely spread contours with linear parallelism. In general, the least metamorphosed rocks show the former pattern, whereas more metamorphosed clastic rocks, commonly adjacent to schists or gneisses, show parallel linear contours. In all rocks of this unit, the contours tend to be widely spaced, except where iron-formation is interbedded. West of South Henik Lake, schists (2b) have closer parallel linear contours than do the adjacent clastic rocks (2). The contact between (2) and (2b) in this locality is marked on the aeromagnetic map by differences in trend and spacing of contours, suggesting the possibility of a fault contact, although none was recognized in the field. The area of tuff and greywacke (2a) north of Montgomery Lake shows a different pattern of closely spaced, parallel linear contours.

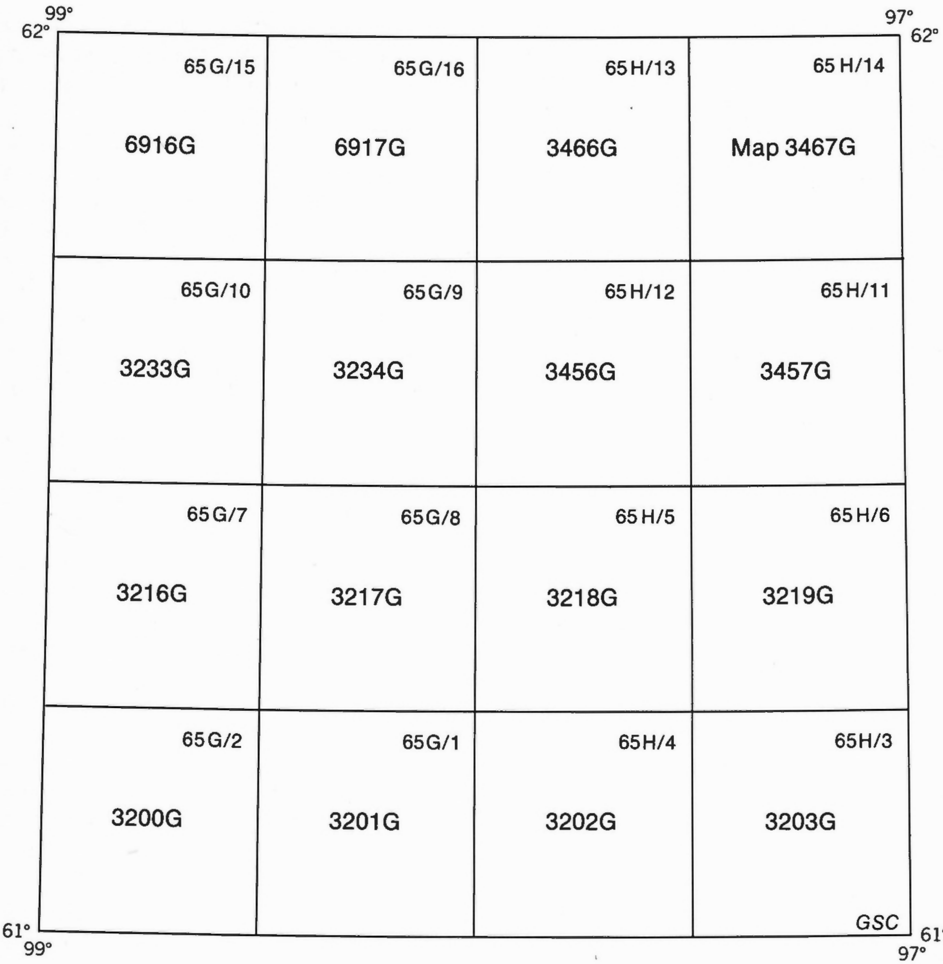


FIGURE 3. Index map of Geological Survey of Canada aeromagnetic series maps, scale 1 inch=1 mile, for Kognak River area.

Iron-formation (3) normally gives very high magnetic readings and shows crowded, closing, linear contours. The only exception is some of the low-grade iron-formation west and southwest of Cullaton Lake which shows only slight response. Magnetism of the iron-formation apparently increases with increasing metamorphism, undoubtedly due to conversion of hematite to magnetite. The aeromagnetic maps suggest that more iron-formation is present beneath the drift.

Basic schist and gneiss (5) produce a typical pattern of long, closely spaced, parallel linear contours that show a few closures. On the other hand, schists and gneisses of units 6 and 7 show variations from area to area in their response, perhaps reflecting the variation in composition of these rocks. Contours normally have a linear pattern but may be either widely or closely spaced. Closing contours resulting in a pattern of egg-shaped figures are typical in some localities underlain by these rocks.

Igneous rocks of unit 8 produce widely spaced, meandering, patternless contours. Within the composite stock (8, 8c, 8d) southeast of Hawk Hill Lake, the contours roughly parallel the outline of the stock. Rocks of unit 8 west of Hawk Hill and Griffin lakes give contours more closely spaced and with more closures than is normal for rocks of this unit. Quartz monzonite to granite (20) shows widely spaced, generally patternless contours, but vague parallelism of the contours with the outline of the pluton does exist. Porphyritic fluorite-bearing granite (21) in the southwest corner of the map-area results in widely spaced, distinctly parallel contours, a pattern different from that in (8) or (20). Within part of this mass a band of closely spaced contours is perhaps an indication of a differentiation band within the pluton.

Montgomery Lake Group rocks (10) apparently have little magnetic effect and the contours on areas underlain by these rocks are probably a reflection of the underlying rocks. This is particularly true where the iron-formation (3) band is overlain by the Montgomery Lake Group.

With certain exceptions rocks of the Hurwitz Group (11–18) give little magnetic response, so that contours are linear, patternless, and widely spaced. In many places any pattern is probably due to the underlying rocks. An exception seems to be the greywacke (15), which results in a pattern of rather closely spaced linear contours. Another minor exception is the dolomite east of Cullaton Lake containing disseminated magnetite crystals, which shows as a magnetic high with closely spaced linear contours on the aeromagnetic map. Gabbro (17) lacks magnetic response so that the extent and shape of these sills is not determinable.

The Hurwitz Group is considered to be thin because it seems to have little or no effect on magnetic intensities.

The rocks of unit 19b northeast of Bate Lake result in parallel linear contours throughout, widely spaced in the lower part of the unit but closely spaced in the upper part.

As mentioned previously, northwest-trending gabbro dykes (22) give a pronounced magnetic response consisting of linear magnetic highs, whereas dykes of other trends do not.

Many faults on the geological map can be recognized on the aeromagnetic maps by marked breaks in trends of contours or in some of them, particularly the reverse faults, by a definite change in the pattern on either side of the fault.

North of Bray Lake, in the area underlain by Hurwitz Group rocks in a synclinal structure, contours on the aeromagnetic map show a marked change from a closed to spreading fan pattern. This may indicate a change in the form of the syncline from a closed to open fold, although underlying older rocks may control the pattern.

Several pronounced anomalies on the aeromagnetic maps remain unexplained. For example, the extremely high anomaly near the south end of Mountain Lake may be due to iron-formation, although the circular pattern of the contours is not typical of iron-formation elsewhere. North of Oftedal Lake, an anomaly in the area underlain by Hurwitz Group rocks, with a roughly circular pattern, must be due to rocks beneath the Hurwitz. Several other anomalies in this general locality are in drift-covered areas.

STRUCTURAL GEOLOGY

The regional structural geology of this part of the Churchill Structural Province (Stockwell, 1961) is little known. The Tectonic Map of Canada (Geol. Surv. Can. Map 1251A) shows a northeast regional trend for both Archean and Proterozoic rocks throughout southern District of Keewatin. Within the area, structures in the old volcanic and sedimentary rocks are difficult to determine at this scale of mapping because of the lack of recognizable marker beds. Further, the interfingering of rock types complicates local interpretation of the structure. Over restricted areas the contact of the volcanic and sedimentary rocks is a useful horizon. The orthoquartzite at or near the base of the Hurwitz Group, a distinctive rock that outcrops in many places, is the most useful rock-unit defining the deformation of the Aphebian rocks.

Folding

Early, pre-Hurwitz Group deformation is difficult to recognize in the older rock, as it is masked by the younger deformation related to the Hudsonian orogeny. There is evidence in a few places, however, of early, north-trending folds. The trend of the younger folding differs from place to place due to differences in lithology within the Hurwitz Group and the underlying rocks. The variation in lithology introduces disharmonic folding and results in minor structures not having a constant style or intensity over wide areas. Nevertheless, two main phases are clearly recognizable, an episode of folding with north- to northeast-trending axes and one with northwest- to west-trending axes. Although the former may be earlier, it seems that a close genetic relationship existed between the two and deformation was continuous from one phase to the next.

A large antiform south of Nowyak Lake in schists, gneisses, and granodiorite gneiss (units 5, 6, and 7) is considered to be the result of early, pre-Hurwitz Group deformation. The axis of the fold trends north and plunges 15 to 30 degrees north, as indicated by prominent lineations. Other pre-Hurwitz Group rocks elsewhere in the area have cleavage and lineation apparently related to this deformation but, for the most part, the structures related to later deformation are more pronounced and obscure the old features.

The folds trending north-northeast to north in Hurwitz Group rocks are probably the result of the earliest deformation in the younger rocks. These folds result in prominent axial plane cleavage, not only in the Hurwitz Group, but in the older rocks as well. In the older rocks it is difficult to distinguish this cleavage from pre-Hurwitz Group cleavage which is similar in trend. Attitude of the cleavage suggests that, in general, axial planes of the folds dip steeply, although in a few places, for example, southeast of Bernier Lake, minor folds with the same trend have axial planes dipping gently southeast, indicating almost recumbent folding to the northwest. Normally these folds plunge to the northeast, but reversals of plunge are known. Primarily these folds are simple and open. The Henik Group rocks (1–4) and the Montgomery Group rocks (10) were folded with the Hurwitz Group rocks, for both cleavage and lineations are congruent.

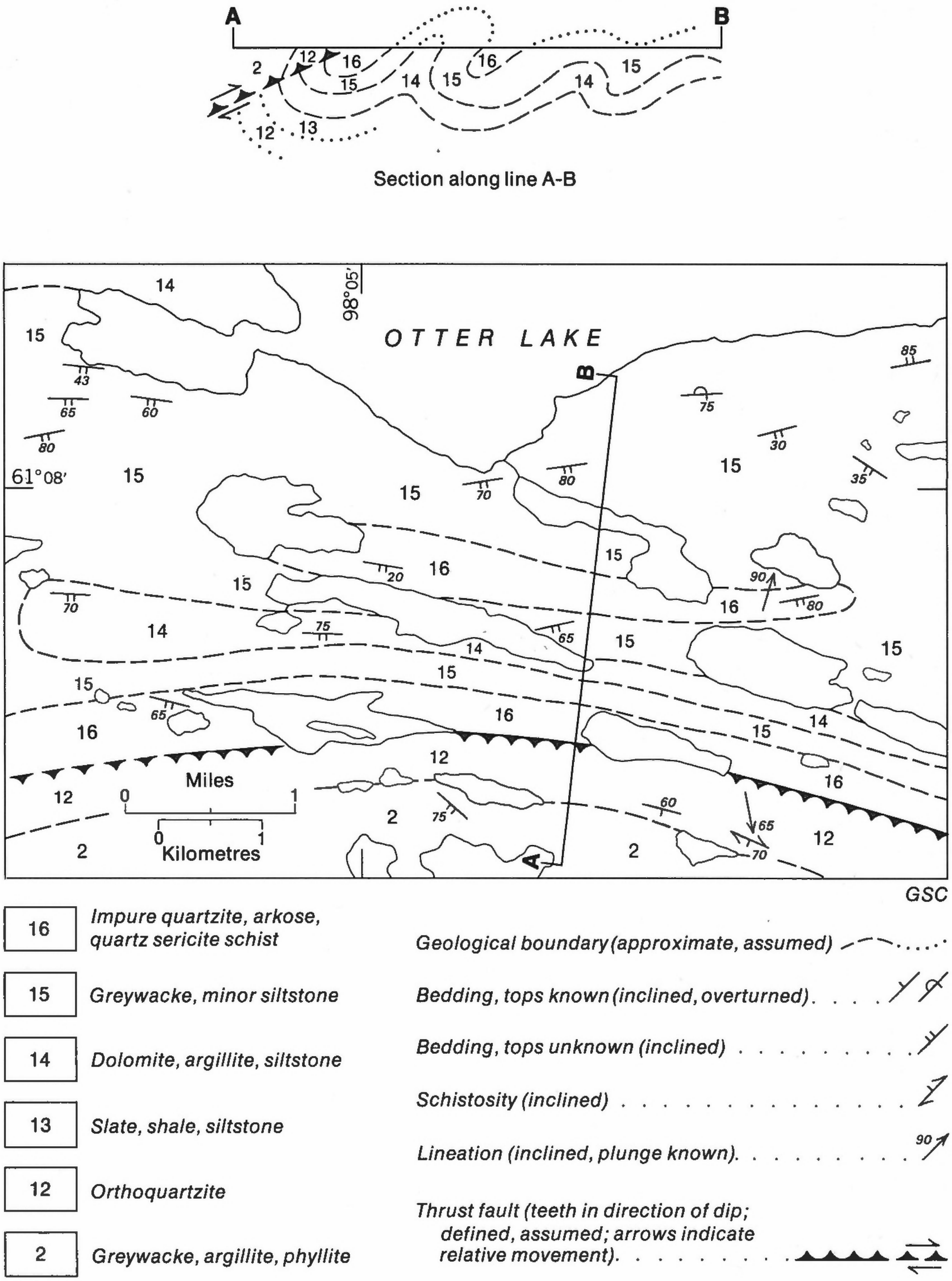
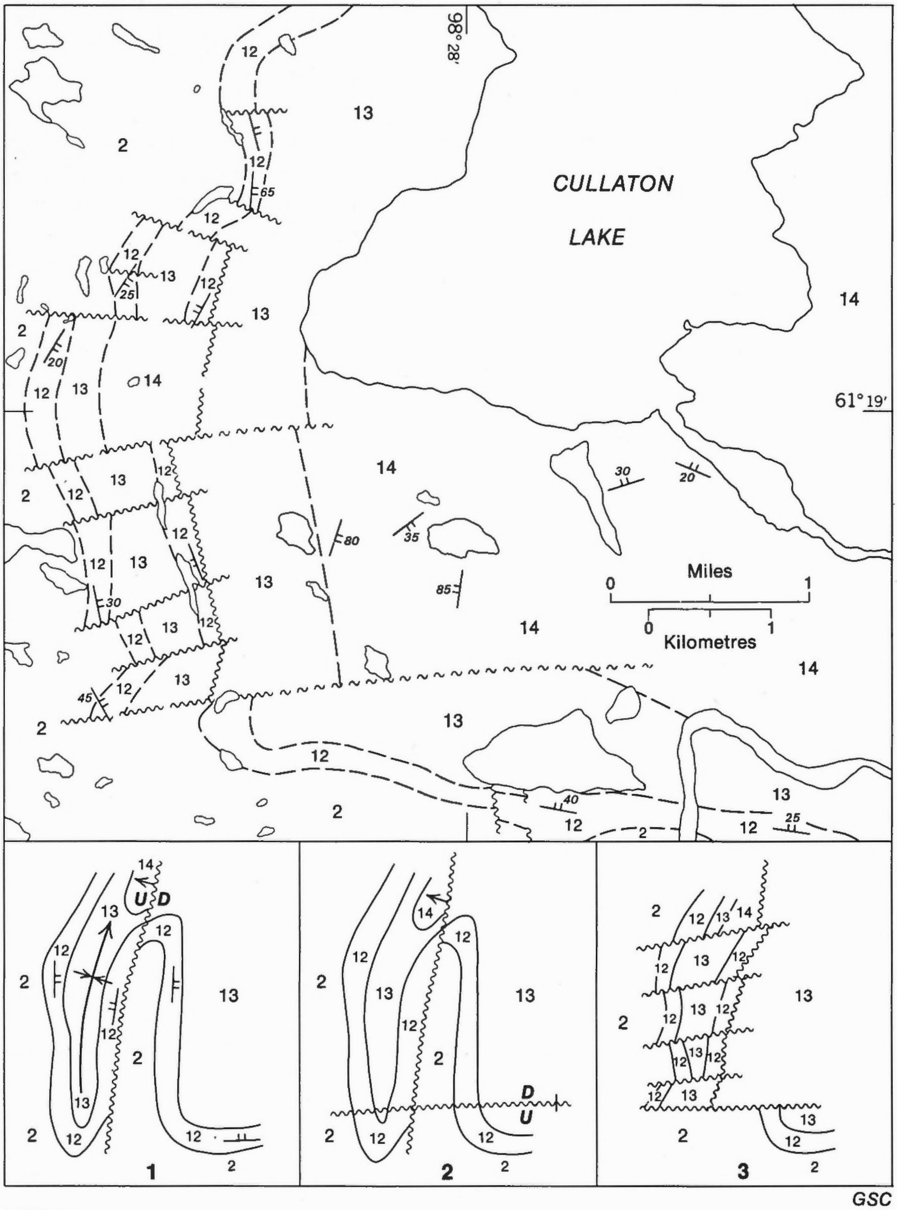


FIGURE 4. Plan and schematic section of the geology south of Otter Lake.

A

B



14	*Dolomite, argillite, siltstone*
13	*Slate, shale, siltstone*
12	*Orthoquartzite*
2	*Greywacke, argillite, phyllite*

Geological boundary (defined, approximate).

Bedding, tops unknown (inclined).

Fault (defined, assumed; arrow indicates direction of dip; relative movement: U-up, D-down)

Syncline (arrow indicates plunge).

FIGURE 5. A. Details of geology southwest of Cullaton Lake.
B. Probable sequence of events.
1. Folding and reverse faulting, west side up.
2. Normal vertical fault, south side up.
3. Normal cross-faults with rotation and dislocation of blocks.

A second, probably younger, deformation affecting Hurwitz Group rocks results in folds trending northwest to west. This may be a later phase of the same major deformation. Cleavage and lineations related to the northwest- to west-trending folds are present in the Hurwitz Group rocks, particularly in the area east of Cullaton Lake and Bernier Lake, although this cleavage is not pronounced. This cleavage occurs only rarely in the older rocks, units 1–4. It is suggested that the stresses producing this deformation were of a near-surface type with most effect on the cover rocks. Many folds of this trend are simple and open and plunge west with steeply dipping axial planes. South of Otter Lake, folds trending west are overturned to the north and a thrust fault cuts off the folds to the south as illustrated in Figure 4, a schematic section of this locality.

Folds with a northwest trend are most common in the southwest part of the area. The Hurwitz Group rocks in the northeast part of the area have only a few minor folds with the west to northwest trend. At the southeast end of Ducker Lake, closed folds trending northwest are overturned to the northeast, but to the north they are cut off by a reverse fault. Southwest of Cullaton Lake, a portion of a much-faulted fold in Hurwitz Group rocks is preserved and Figure 5 illustrates some details of the structure there. Small north- to northeast-trending folds, probably on the flank of a larger fold, are almost horizontal as shown by dragfolds. A fault, parallel to the trend of the folding, lies just east of the east limb of the syncline and appears to be a reverse fault dipping 40 to 50 degrees west, with movement west side up relative to the east side. A number of late vertical normal faults, trending just north of east, crosscut the faulted fold.

A number of south-plunging folds, trending northwest, occur in the Hurwitz Group rocks east of Bernier and Cullaton lakes. Numerous faults parallel the axial planes of the folds and later cross-faults cut and offset the folds.

Faults

Faults of definite pre-Hurwitz Group age cannot be identified, but it is probable that some early faults were reactivated during later deformation and have affected Hurwitz rocks. The north-trending fault south of Oftedal Lake and the fault trending slightly west of north occurring 4 miles east of Bernier Lake, both along limbs of anticlines, are considered to be related to the deformation that results in the northeast-trending folds. A similar north-trending fault, along the limb of a syncline north of North Henik Lake, is complicated by crosscutting northeast- and northwest-trending faults.

Some of the northeast-trending normal faults cutting the Hurwitz Group rocks probably developed during the late stages of the deformation that results in folds of this trend.

Thrust or reverse faults, trending east to slightly north of east, are related to the deformation that produced the west- to northwest-trending folds. The most northerly of these, here named the Ameto Lake fault, trends approximately east, although its trace is not straight. A second, smaller thrust fault to the north is associated with it. The Ameto Lake fault occurs along the north limb of an east-trending syncline of Hurwitz Group rocks and all but a very small portion of the south limb of the syncline is thrust-faulted out. The small area of orthoquartzite (12) and Montgomery Lake Group quartzite (10b) at the east boundary of the area and south of the Ameto Lake fault is part of the south limb of this syncline. Another part of the south limb occurs on the south shore of North Henik Lake. This east-trending syncline, of which only remnants are preserved, appears originally to have joined two northeast-trending synclines, one in North Henik Lake and the other east of the east boundary of the area (Bell, 1971). A northeast-trending normal fault at the west end of Ameto Lake postdates the Ameto Lake fault and it terminates there.

The thrust fault north of Montgomery Lake trends east and dips south, and lies along the north limb of an east-trending syncline with the south limb of the syncline thrust-faulted out. This fault also is probably related to deformation that produced the west- to northwest-trending folds. The extension of this fault on the east side of South Henik Lake cuts the old clastic rocks of unit 2 in which there is evidence of dynamic metamorphism associated with the fault. Aeromagnetic maps indicate the presence of this fault in the older rocks, as the contours show a marked break along the postulated trace of the fault. Only east of South Henik Lake does evidence exist of the extension of a thrust fault into the older rocks. The fault cannot be traced west from the south end of Bray Lake. It possibly cuts the north-trending syncline of Hurwitz Group rocks and continues west, north of Bernier Lake, to join, still farther west, the fault on the south side of the orthoquartzite band north of Griffin Lake.

South of Otter Lake an east-trending thrust fault, dipping south, thrusts an overturned limb of orthoquartzite (12) into contact with impure quartzite (16), as illustrated in Figure 4. Its westward and eastward extensions are unknown. This fault is associated with overturned folds and shortening is indicated.

Two major northeast-trending faults in the northwest part of the map-area are probably related to stresses producing the northeast-trending folds. Lateral movement on these faults are probably small but vertical movement, with the southeast side moving down relative to the northwest side, was considerable. Shearing in the adjacent rocks suggests that these faults dip steeply northwest, so they may be reverse faults. These two faults are believed to be of major proportions and to extend for some distance northeast and southwest of the area. Another fault, 2 miles southeast of the more southeasterly of the two faults mentioned above, is parallel to them. This is a normal fault and forms the southeast contact of the band of sedimentary rocks, unit 19b, extending northeast from Bate Lake. The band of sedimentary rocks is preserved in a down-dropped fault block. Intense shearing and slickensiding of both the sedimentary rocks (19b) and the adjacent schist and gneiss (5) are present along this contact fault. These northeast-trending faults in the northwest part of the area may constitute part of a major regional zone of rupture extending through Ennadai Lake to the southwest and Ferguson Lake to the northeast. Regional aeromagnetic maps indicate the possible existence of such a zone.

Numerous faults cutting Hurwitz Group rocks east of Cullaton and Bernier lakes, related to stresses forming the northwest-trending folds, have resulted in some rotation and tilting of blocks. As described in the section on folding, a number of faults cut folded Hurwitz rocks just southwest of Cullaton Lake, so that a small synclinal remnant is preserved.

Northwest-trending faults are considered to be generally the youngest, cutting, and in part offsetting, earlier faults and folds. These faults perhaps formed during the late relaxation phase of the final deformation. All are steep-dipping, normal faults. The late gabbro dykes (22) are approximately parallel to these faults and were probably intruded along fractures related to them.

ECONOMIC GEOLOGY

Exploratory prospecting in southern District of Keewatin, including this area, was done in 1928 and 1929 by Cyril Knight Prospecting Company, Limited. In the late 1940's Hudson Bay Exploration and Development Company Limited, Kasba Explorations Limited, and D. W. Cameron carried out prospecting and exploration work in the area. In recent years, Selco Exploration Company Limited has done extensive exploration work, including diamond drilling, in this area (Department of Northern Affairs and Natural Resources, 1964a, 1964b; Schiller, 1965; Thorpe, 1966). In 1963 this company opened a 3,000-foot-long airstrip at the southwest corner of Cullaton Lake to facilitate their work.

Kasba Explorations Limited carried out considerable work on their Lowo Group of claims in the volcanic rocks (1) south of Otter Lake. Small amounts of gold are found in small lenses of sugary quartz in narrow shears cutting the andesite. Some pyrite, pyrrhotite, and minor chalcopyrite occur along the walls of the veins. The same company found low gold values in pebble-conglomerate beds in the orthoquartzite (12) east of Ameto Lake.

Selco Exploration Company Limited, in addition to further work on the Lowo Group, has drilled an occurrence of gold in fractured and sheared orthoquartzite (12) southwest of Cullaton Lake. Prospectors of this company have also discovered gold values in iron-formation (3) and greywacke (2) (Selco Exploration Company Limited, pers. com.). Preliminary exploratory work has been done on these occurrences. The gold occurs in quartz stringers in quartz–magnetite iron-formation which commonly contain pyrite, pyrrhotite, and arsenopyrite. Location of gold values appears to be largely controlled by small fold structures (Selco Exploration Company Limited, pers. com.).

It is suggested that gold deposits in the Contwoyto Lake map-area, District of Mackenzie (Tremblay, 1966), may occur in similar rocks but of higher metamorphic grade than those of this area. At Contwoyto Lake, gold with associated pyrrhotite, arsenopyrite, pyrite, and minor chalcopyrite occurs in quartz lenses in garnet–cummingtonite–quartz–sulphide gneiss that commonly contains considerable magnetite. McConnell (1964) has pointed out some similarities between the Contwoyto Lake deposits and the Homestake deposits of South Dakota. The gneiss forming the country rock of the Contwoyto deposits may be derived from low-grade iron-formation by metamorphism, as cummingtonite or grunerite and magnetite are abundant. Some of the iron-formation occurring in the almandine–amphibolite facies of metamorphism in the Kognak River area has similar mineralogy, including quartz, magnetite, cummingtonite, grunerite, garnet, and minor sulphides.

In the Kognak River area no nearby intrusive rocks occur that could be considered a source for hydrothermal solutions introducing sulphides and gold into the iron-formation. It is suggested that the gold may be syngenetic, either detrital, in which case the iron-formation may be a fossil auriferous black sand deposit, or a chemical deposit from colloidal solution at the time of sedimentary deposition. Regional metamorphism and deformation have undoubtedly resulted in some mobilization and redeposition of the gold in favourable locations controlled by structure.

Kasba Explorations Limited discovered slight radioactivity in some of the pebble-conglomerate within the orthoquartzite (12) east of Ameto Lake. About 8 miles to the east of the area, radioactivity has been noted in rocks of the Montgomery Lake Group (Heywood and Roscoe, 1967; Bell, 1968, 1971). Geiger counters were not carried during the course of field work in Kognak River area, but all specimens were tested later by a scintillometer with negative results. However, the pebble-conglomerate lenses in the orthoquartzite are perhaps worth considering as a source of radioactive minerals. Of similar possible economic interest is the quartzite (10b) of the Montgomery Lake Group, with its abundance of disseminated pyrite and scattered pebble lenses.

Although iron-formation is abundant in the area, nowhere has any secondary enrichment been observed. Considering the relatively remote location of the area, it is not conceivable at the present time to consider these iron-formations as a source of iron ore.

A number of small occurrences of sulphide mineralization are shown on the accompanying geological map. Many of these are in small shears in basic volcanic rocks, which themselves contain abundant disseminated pyrite. Commonly pyrite and pyrrhotite occur with quartz in the shears in the andesite or in gabbro accompanying the andesite. The fracture fillings may themselves be sheared by later movement. Chalcopyrite is locally present in minor amounts with the iron sulphides. None of these mineralized shear zones have been observed to extend much more than 200 feet. Lord (1953) reported assays on samples from one of these, about 2 miles southwest of the southernmost bay of Griffin Lake, which gave low gold and silver values.

West of Hawk Hill Lake pyrite and minor chalcopyrite is present in a small shear zone in granodiorite, adjacent to folded orthoquartzite. East of South Henik Lake there is pyrite in a gossan zone in the gneisses (7). North of Griffin Lake abundant arsenopyrite occurs in sheared quartz–feldspar–biotite schist or metagreywacke (6). Most occurrences of sulphides, however, are found in the basic volcanic rocks, and it is in them that concentrations of sulphides are most likely to be found.

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APPENDIX

Stratigraphic Sections

The sections that follow are not detailed stratigraphic sections. Most were measured by pace and compass and using the average dip of the beds. In some cases it is possible to check measurements by scaling from the airphotographs and topographic maps. The transitions noted within the orthoquartzite, unit 12, are gradational, so that normally changes can only be measured to the nearest 10 feet. The sections do, however, give an adequate picture of the variations in lithology and their sequence. The localities of the sections are shown on the Index map, Figure 6.

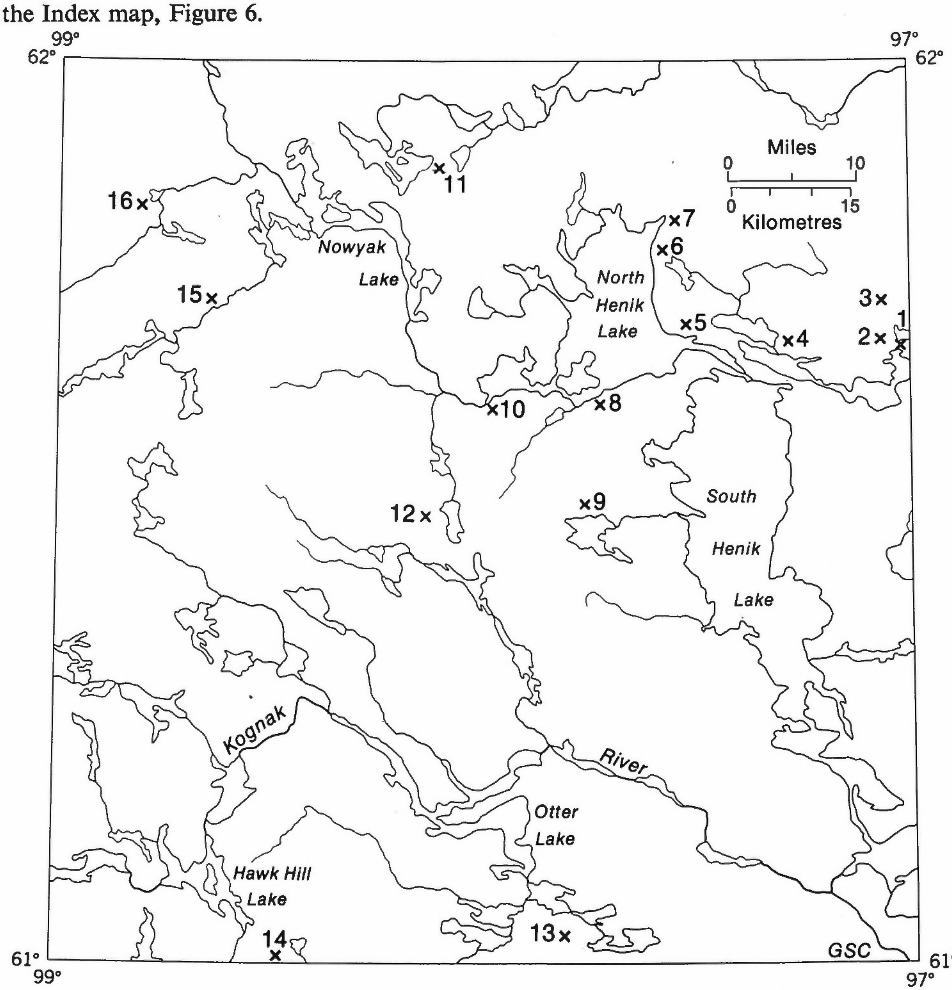

FIGURE 6. Index map of section localities.

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
Loc. 1, near Cabin Lake, Montgomery Lake Group (11), and orthoquartzite (12)			
6	Quartzite, white, fine-grained, thick bedded, no ripples	370	1,870
5	Quartzite, very light greenish grey, thick bedded, fine-grained, no ripples	400	1,500
	Unconformity		
4	Siltstone, brown, and black shale, with interbeds of greenish quartzite	100	1,100
3	Quartzite, reddish to greenish and pebbly	200	1,000
2	Conglomerate, sandstone matrix, well-rounded quartz, quartzite and jasper pebbles	200	800
1	Quartz sandstone, varying to arkose and greywacke, medium-grained, contains much sericite, and scattered quartz-pebbles	600	600
	Contact, acid crystal tuff below		

Loc. 2, east of Ameto Lake, orthoquartzite (12), slate (13), gabbro (17)

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	Fault		
15	Cover	50	6,000
14	Dolomite, grey, fine-grained, thin bedded	100	5,950
13	Cover	90	5,850
12	Gabbro, fine- to medium-grained, dark green to black	50	5,760
11	Cover, much slate detritus	600	5,710
10	Gabbro, medium-grained, dark greenish grey	160	5,110
9	Slate, black, grey, red, minor sandy and silty interbeds	300	4,950
8	Gabbro, fine- to medium-grained, dark green to black	50	4,650
7	Ferruginous slate, red to black, grading upward into sandy slate	500	4,600
6	Interbedded ferruginous slate and ferruginous quartzite	40	4,100
5	Quartzite, white, fine-grained, medium- to thick-bedded, ripples, some ferruginous interbeds in upper 75 feet	1,310	4,060
4	Quartzite, white, fine-grained, thick bedded, no ripples	750	2,750
3	Quartzite, white, fine-grained, thick bedded to massive	250	2,000
2	Quartzite, fine-grained, thick bedded, no ripples	1,285	1,750
1	Sandstone, medium-grained, varies to arkose and greywacke, locally pebbly	465	465
	Contact, deeply weathered andesite or latite (2) below		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
Loc. 3, east of Ameto Lake, orthoquartzite (12)			
6	Slate, red to grey to black, may be ferruginous, sandy in part	380	4,180
5	Quartzite, white, fine-grained, thick bedded, no ripples	200	3,800
4	Quartzite, white, fine-grained, medium- to thick-bedded, no ripples	220	3,600
3	Quartzite, pink to white, fine-grained, poor ripples, abundant closely spaced fractures	180	3,380
2	Quartzite, fine-grained, medium- to thick-bedded, sparse ripples, in part does not outcrop well	3,150	3,200
1	Cover	50	50
	Agglomerate, andesite composition, relatively unweathered		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
Loc. 4, north of Ameto Lake, conglomerate (11), orthoquartzite (12)			
	Fault		
13	Cover	100	6,200
12	Quartzite, white, fine-grained, thick bedded, no ripples	1,000	6,100
11	Quartzite, white, fine-grained, with large-scale low-angle crossbeds	60	5,100
10	Quartzite, pink in lower part varying to white in upper, fine-grained, thin bedded, abundant ripples, some thin grey impure quartzite laminations	660	5,040
9	Cover	260	4,380
	Fault, almost parallel to bedding, stratigraphic separation believed to be small		
8	Cover	70	4,120
7	Quartzite, pink, fine-grained, medium bedded, very abundant ripples	50	4,050
6	Quartzite, white, fine-grained, medium bedded, abundant ripples	600	4,000
5	Quartzite, white, fine-grained, thick bedded, few ripples	800	3,400
4	Quartzite, white, fine-grained, thick bedded, no ripples	1,310	2,600
3	Quartzite, white to grey, fine-grained, very thick bedded to massive, scattered white spheroids (bleach spots?)	290	1,290
2	Quartzite, white, fine-grained, thick bedded, no ripples	780	1,000
1	Greywacke conglomerate in lower part, grading upward to pebbly conglomerate, greywacke, and sandstone	220	220
	Contact, deeply weathered granodiorite below		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
Loc. 5, west of Ameto Lake, orthoquartzite (12)			
	Cover		
6	Quartzite, pink, fine-grained, thin- to medium-bedded, abundant ripples	80	2,400
5	Quartzite, white to faint pink, fine-grained, medium bedded, abundant ripples, locally brecciated	520	2,320
4	Quartzite, white, fine-grained, medium bedded to massive, few ripples	550	1,800
3	Quartzite, white, very sheared	50	1,250
2	Quartzite, white, fine-grained, medium bedded to massive, some shearing, no ripples	750	1,200
1	Quartzite, white to grey, impure in lower part, strongly sheared with much sericite, outcrop broken and poor	450	450
	Contact, andesite, meta-andesite below		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
Loc. 6, east side of North Henik Lake, orthoquartzite (12)			
	Cover		
5	Quartzite, pinkish white, fine-grained, well bedded in thin to medium beds	70	1,520
4	Quartzite, white, thin (4- to 6-inch) pronounced beds	400	1,450
3	Quartzite, white to grey, pronounced thin beds, some crossbeds and torrential crossbeds	200	1,050
2	Quartzite, grey to white, fine- to medium-grained, medium- to thick-bedded, some crossbeds	200	850
1	Cover	650	650
	Hybrid rock, mixed andesite and granodiorite		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	Loc. 7, northeast side of North Henik Lake, orthoquartzite (12)		
	Fault		
5	Cover	180	1,280
4	Quartzite, white, fine-grained, medium bedded, no ripples	100	1,100
3	Quartzite, white, fine-grained, massive	600	1,000
2	Quartzite, white, fine-grained, medium bedded, no ripples	200	400
1	Quartzite, white to grey, very sheared	200	200
	Contact, sheared granodiorite below		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	Loc. 8, southwest of North Henik Lake, orthoquartzite (12), slate (13)		
21	Dolomite, white to pink, fine- to medium-grained, sandy	160	4,600
20	Dolomite, white to pink, interbeds of red, sandy argillite	40	4,440
19	Cover	350	4,400
18	Slate, black, poor outcrop, abundant detritus	350	4,050
17	Slate, dark grey, weathers red, finely bedded	190	3,700
16	Cover	410	3,510
15	Quartzite, pink to red, fine-grained, abundant ripples	100	3,100
14	Quartzite, white to pink, fine-grained, medium bedded, few ripples	200	3,000
13	Quartzite, white to slightly pink, massive, a few magnetite-rich bands	400	2,800
12	Quartzite, white with some pink bands, fine-grained, thin- to medium-bedded, some ripples	200	2,400
11	Quartzite, white, fine-grained, thin bedded, ripples abundant	140	2,200
10	Quartzite, white, fine-grained, medium bedded	90	2,060
9	Quartzite, white, fine-grained, massive	160	1,970
8	Quartzite, pinkish white, fine-grained, massive	110	1,810
7	Quartzite, mauve to grey to white, fine-grained, massive to thick bedded	480	1,700
6	Quartzite, grey to white to pink, conglomeratic, $\frac{1}{2}$- to 1-inch rounded pebbles, mostly white quartz, some iron-formation and greywacke	120	1,220
5	Quartzite, pinkish, gritty, scattered pebbles, minor crossbeds	200	1,100
4	Quartzite, pink, medium- to fine-grained, medium bedded, some ripples	320	900
3	Conglomerate, light grey to brown, sandy matrix, variety of pebbles, white quartz most abundant	180	580
2	Grit, pink, quartzose	200	400
1	Cover	200	200
	Fault		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
Loc. 9, north of Montgomery Lake, orthoquartzite (12), gabbro (17)			
	Fault		
19	Cover	350	5,000
18	Gabbro, dark green to black, medium- to coarse-grained	250	4,650
17	Cover, very abundant detritus, black to reddish slate	1,110	4,400
16	Quartzite, red, brecciated	70	3,290
15	Quartzite, pink, fine-grained, abundant ripples	210	3,220
14	Quartzite, pinkish white, thick bedded	230	3,010
13	Quartzite, white, fine-grained, some ripples	180	2,780
12	Quartzite, pinkish and white, thin bedded	210	2,600
11	Quartzite, white, fine-grained, massive	290	2,390
10	Quartzite, white, massive, scattered pebbles up to ½ inch of white quartz and jasper	120	2,100
9	Quartzite, white, coarse-grained to gritty, scattered quartz and jasper pebbles	180	1,980
8	Quartzite, pink, fine-grained, massive	100	1,800
7	Quartzite, white, fine-grained, medium bedded	120	1,700
6	Quartzite, pink to red, medium- to coarse-grained, gritty	180	1,580
5	Quartzite, white, gritty, thick bedded	200	1,400
4	Quartzite, white, medium- to coarse-grained	370	1,200
3	Quartzite, pink to red, pebbly	340	830
2	Quartzite, pink, sandy, impure	90	490
1	Cover	400	400
	Contact, very sheared tuff, minor ferruginous slate below		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
Loc. 10, southwest of Oftedal Lake, conglomerate (11), orthoquartzite (12)			
	Cover		
8	Quartzite, pink, thin bedded, abundant ripples	100	3,850
7	Quartzite, pink to white, fine-grained, some ripples	400	3,750
6	Quartzite, white, fine-grained, thick bedded to massive	1,000	3,350
5	Cover, conglomerate felsenmeer	100	2,350
4	Conglomerate, minor sandy lenses, light to dark greyish green sandy greywacke matrix, pebbles and cobbles ½- to 6-inch diameter, angular to rounded, of andesite, greywacke, soft green argillite, pinkish quartzite, brownish quartzite, pink granodiorite, jasper, red argillite, outcrop broken, some is felsenmeer	900	2,250
3	Conglomerate, massive, greenish grey to light grey greywacke matrix, variety of pebbles up to 1½-inch diameter, few larger	400	1,350
2	Greywacke and pebble-conglomerate, medium-grained, scattered pebbles, some thick bedding	550	950
1	Cover	400	400
	Contact, very sheared greenish grey tuff and greywacke below		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	Loc. 11, northeast of Nowyak Lake, orthoquartzite (12), dolomite–argillite (14), impure quartzite and dolomite (16)		
	Fault		
7	Dolomite, light brown, fine-grained, thick- to thin-bedded, even textured; interbedded with argillite, dark grey, fine-grained, thin bedded, siliceous	490	6,070
6	Impure quartzite, arkose, siliceous siltstone, grey to greenish grey, fine-grained, massive to thin bedded, with thin micaceous laminae	900	5,580
5	Cover	400	4,680
4	Argillite, light grey, very fine grained, fissile, siliceous, minor impure quartzite; interbedded with dolomite, grey to light brown, contorted bedding, crinkled quartz stringers	1,100	4,280
3	Dolomite, white to pink, massive, abundant quartz stringers, minor fissile argillite laminations	600	3,180
2	Cover	2,100	2,580
1	Quartzite, white, fine-grained, thin- to medium-bedded, abundant ripples	480	480
	Contact, andesite, minor agglomerate below		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
	Loc. 12, west of Bray Lake, orthoquartzite (12), siltstone (13), dolomite–argillite (14), greywacke (15), impure quartzite (16)		
11	Impure quartzite, light to medium green-grey, weathers light grey, fine-grained, beds 3 inches to 2 feet, rare ripples, locally cross-bedded, some thin magnetite-rich laminations	1,450	8,200
10	Cover	1,150	6,750
9	Cover, abundant detritus and felsenmeer of medium-grained, massive to thick bedded greywacke	550	5,600
8	Cover	400	5,050
7	Dolomite, brownish grey or reddish, weathers light brown grey to yellow grey, very fine grained, some silt lenses, abundant cross-cutting veinlets of fine-grained white quartz	1,090	4,650
6	Interbedded dolomitic greywacke and silty dolomite	160	3,560
5	Greywacke to siltstone, dark brown-grey, weathers medium greyish brown, very fine grained, indistinct bedding laminations, prominent cleavage	1,150	3,400
4	Cover	1,100	2,250
3	Subgreywacke to siltstone, quartzose, medium to light grey, locally greenish or pinkish, weathers very light grey or greenish grey, fine-grained to very fine grained, beds 3 inches to 3 feet, thick beds more quartzose	390	1,150
2	Cover	370	760
1	Quartzite, white, locally pink, weathers white to light grey, fine-grained to very fine grained beds 2 inches to 2 feet, abundant ripples, good bedding plane jointing	190	390
	Faint crossbeds in quartzite	30	200
	Scattered ripples, bedding less prominent in beds 1 inch to 3 feet	170	170
	Contact, andesite below		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base
Loc. 13, south of Otter Lake, orthoquartzite (12)			
21	Quartzite, pink to white, poorly bedded	300	1,780
20	Quartzite, white, massive	75	1,480
19	Cover	75	1,405
18	Quartzite, grey, scattered, ½-inch banded purple siltstone pebbles	57	1,330
17	Quartzite, white to grey, mostly massive, few prominent purple beds	223	1,273
16	Quartzite, grey, fine-grained, well bedded, rare, small purple siltstone pebbles	30	1,050
15	Conglomerate, quartzite matrix, well sorted, well rounded siltstone and white quartz pebbles	6	1,020
14	Quartzite, massive, grey, impure	9	1,014
13	Sericite schist, garnetiferous, shear zone	2	1,005
12	Quartzite, grey, massive, impure	13	1,003
11	Pebble-conglomerate, small white quartz pebbles in quartzite	10	990
10	Quartzite, grey to white, massive	15	980
9	Quartzite, grey to white, with pebbly beds 4 to 18 inches thick	5	965
8	Quartzite, grey, and pebble-conglomerate, pebbles of purple to grey banded siltstone and vein quartz	100	960
7	Quartzite, grey, massive	60	860
6	Pebble-conglomerate	90	800
5	Quartzite, white, massive to well bedded, pink and sheared in lower part	410	710
4	Quartzite, grey, impure	20	300
3	Sericite schist, garnetiferous, grey, shear zone	4	280
2	Quartzite, grey, impure, very sheared	96	276
1	Quartzite, grey, impure, very sheared and contorted	180	180
	Fault, greywacke (2), beds dipping away from quartzite on other side		

Loc. 14, southeast of Hawk Hill Lake, (approximate, as much deformation) conglomerate (11), orthoquartzite (12)

	Cover		
5	Quartzite, white, fine-grained, well sorted, ripples abundant with highly variable crest trends	320±	985±
4	Grit, feldspathic, coarse-grained, non-conglomeratic; scattered, completely altered pseudomorphs of large (up to ½-inch) pyrite cubes	90	665
3	Grit or conglomeratic lithic arkose, coarse-grained, interbedded with fissile reddish grey shale; some graded beds; pebbles and cobbles of red quartz-feldspar porphyry, white vein quartz, chlorite schist, quartzite, green shale and red dolomite	140	575
2	Grit or impure quartzite, red, coarse-grained	220	435
1	Greywacke, non-conglomeratic, grey, coarse-grained	215	215
	Contact, sheared rhyolite and acid tuff (2) below		

Unit	Description	Thickness (feet) of unit	Thickness (feet) above base

Loc. 15, southwest of Nowyak Lake, (unit 19), dolomite, phyllite, shale (19b)

	Fault, granodiorite to northwest		
15	Dolomite, buff and grey, fine-grained, siliceous, moderately well bedded	450	7,840
14	Cover	990	7,390
13	Dolomite, buff to grey, some thin interbeds of argillite, some contorted bedding	1,280	6,400
12	Dolomite, pink and grey, siliceous, fine-grained, scattered thin phyllite laminations, cut by quartz veins	350	5,120
11	Cover	1,200	4,770
10	Dolomite, grey, fine- to medium-grained, well bedded	290	3,570
9	Cover	1,200	3,280
8	Shale, black, very finely bedded	130	2,080
7	Dolomite, grey, fine- to medium-grained, very well bedded, thin argillite laminations	300	1,950
6	Cover	390	1,650
5	Dolomite, grey, medium- to fine-grained, massive to moderately bedded	220	1,260
4	Cover	215	1,040
3	Dolomite, grey, siliceous, fine- to medium-grained, moderately well bedded, with grey phyllite interbedded	350	825
2	Phyllite, dark grey, very fine grained, some grey dolomite interbeds	175	475
1	Cover	300	300
	Contact, chlorite schist (5) below		

Loc. 16, west of Nowyak Lake (unit 19), quartzite, dolomite, argillite, greywacke (19a and 19b)

	Dacite and andesite (1)		
	Fault, low-angle, reverse		
8	Greywacke, green to grey, medium- to fine-grained	200	6,300
7	Dolomite, grey to white, fine-grained, scattered interbeds of impure quartzite	550	6,100
6	Interbedded quartzite, impure, greenish, greywacke, green, medium-grained, and shale, red and green, fine-grained	300	5,550
5	Dolomite, red and white, with argillaceous interbeds	550	5,250
4	Quartzite, greenish, impure, fine- to medium-grained	150	4,700
3	Dolomite, sandy red	750	4,550
	Dolomite, brown, siliceous		
	Dolomite, red, with interbedded coarse-grained sandy grit		
2	Quartzite, impure, green to pink	3,500	3,800
	Arkose, arkosic quartzite, very well bedded		
	Quartzite, impure, greenish		
	Quartzite, impure, massive to fissile, minor interbeds of argillaceous dolomite		
1	Cover	300	300
	Contact, andesite, dacite (1) below		

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