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MEMOIR 415

PRECAMBRIAN GEOLOGY OF THE HALF WAY HILLS AREA, DISTRICT OF KEEWATIN

F.C. TAYLOR

Canada

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Highly contorted iron formation 250 m east of the Thelon River (GSC 190482)

Critical Reader

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Preface

The first geological work in this part of the barren grounds was by J.B. Tyrrell in 1893 on the first of two remarkably long overland journeys. More than 60 years passed before the area was examined again, this time during one of the first of the Geological Survey's major helicopter-supported reconnaissance operations, which was conducted under the direction of G.M. Wright.

The present report is based on geological mapping at a scale of 1:50 000, carried out to establish the stratigraphy of the Archean basement rocks in the Baker Lake region west of Hudson Bay. A clearly defined stratigraphy was considered important with regard to the location of uranium mineralization associated with the contact between the Dubawnt Group and the basement.

In the past, in District of Keewatin, most of the layered rock units that contain significant amounts of quartzite have been assigned to the Aphebian Hurwitz Group, in this map area these rocks are now considered Archean.

Studies of this kind enable the Geological Survey of Canada to meet one of its objectives, to produce geological maps and reports that help in the exploration for mineral resources. The geological and geochemical data presented in this memoir suggest that future prospecting in the Half Way Hills area should be concentrated in the zone between the greywacke and metavolcanic rocks and within the metavolcanic rocks.

R.A. Price
Director General
Geological Survey of Canada

Préface

Les premiers levés géologiques dans cette partie des terres stériles ont été effectués par M. J.B. Tyrrell en 1893, au cours du premier de deux voyages par voie terrestre d'une longueur remarquable. Il a fallu plus de 60 ans avant que cette région ne fasse l'objet d'une autre étude, soit au cours de l'un des premiers grands projets de reconnaissance par hélicoptère entrepris par la Commission géologique, sous la direction de M. G.M. Wright.

Le présent rapport est basé sur des levés géologiques à 1/50 000 réalisés afin de déterminer la stratigraphie des roches du socle archéen dans la région de Baker Lake, à l'ouest de la baie d'Hudson. On estime qu'il est essentiel de bien définir la stratigraphie afin de pouvoir identifier les zones de minéralisation uranifère associées au contact entre le groupe de Dubawnt et le socle.

Bien que, par le passé, dans le district de Keewatin, la plupart des unités rocheuses stratifiées contenant des quantités importantes de quartzite aient été classées dans le groupe aphébien de Hurwitz, dans le cas de la région à l'étude, ces roches sont maintenant considérées comme appartenant à l'Archéen.

Ce genre d'étude permet à la Commission géologique du Canada de réaliser un de ses objectifs, soit de produire des rapports et des cartes géologiques qui serviront à l'exploration des ressources minérales. Les données géologiques et géochimiques présentées dans le présent mémoire semblent indiquer que les travaux ultérieurs de prospection dans la région des collines Half Way devraient se concentrer dans la zone située entre le grauwacke et les roches métavolcaniques et à l'intérieur de la zone de roches métavolcaniques.

R.A. Price
Le directeur général de la
Commission géologique du Canada

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PRECAMBRIAN GEOLOGY OF THE HALF WAY HILLS AREA, DISTRICT OF KEEWATIN

Abstract

Archean rocks form the basement for strata containing uranium in the Baker Lake district. The stratigraphic sequence of the layered Archean rocks which may have a direct bearing on mineral deposit sites has been established.

A polymictic conglomerate lying nonconformably on a syenite forms the basal layered unit. This conglomerate is overlain by an extensive and probably thick greywacke that underlies 30 per cent of the map area. A zone of varied lithology, consisting of iron formation, slate, dolomite, argillite, siltstone and phyllite, with local small plutons of gabbro, peridotite, and serpentinite, overlies the greywacke. Volcanic rocks, overwhelmingly mafic, and including rare komatiities, conformably overlie the above rock types. A physiographically prominent and thick quartzite unit is interlayered with and succeeds the mafic volcanic rocks. A second mafic volcanic unit overlies the quartzite. Granitic rocks, chiefly granodiorite, postdate the layered rocks.

Aphebian syenite and lamprophyre intrusions, part of the Martell Intrusive Suite (Dubawnt Group) intrude the Archean rocks both as dykes and stocks. A few Neohelikian northeasterly trending diabase dykes are the youngest rocks.

All the Archean rocks are metamorphosed to greenschist grade and close to some of the granitic rocks to amphibolite grade.

Quartzite and volcanic rocks form a major northeast-trending syncline. Major thrust faults, also northeast trending, have displaced strata to the northwest.

Mineral occurrences are rare but geochemical data combined with the geological environment suggest a potential for metal concentrations, especially in the zone of varied lithology.

Résumé

Des roches archéennes forment le socle des couches uranifères dans la région de Baker lake. On a établi la séquence stratigraphique des roches archéennes stratifiées susceptibles d'influer directement sur les lieux des gisements minéraux.

Un conglomérat polygénique reposant en discordance sur une syénite forme l'unité basale stratifiée. Le conglomérat est recouvert par une grauwacke étendue et problement épaisse, elle-même sous-jacente à 30 pour cent de la région cartographique. Une zone à lithologie variée, composée de formation ferrifère, de schiste, de dolomie, d'argillite, de pélite et de phyllite, avec par endroits de petits plutons de gabbro, de péridotite et de serpentinite, recouvre la grauwacke. Des roches volcaniques, presque toutes mafiques, y compris de rares komatiites reposent en concordance sur les roches susmentionnées. Une unité de quartzite, physiographiquement saillante et épaisse, est interstratifiée avec les roches volcaniques mafiques et les suit. Une deuxième unité volcanique mafique recouvre le quartzite. Des roches granitiques, surtout des granodiorites, ont été formées après les roches stratifiées.

Des intrusions aphébiennes de synénite et de lamprophyre, faisant partie de la série intrusive de Martell (groupe de Dubawnt), ont pénétré les roches archéennes sous forme de filons-couches et de petits massifs. Quelques filons de diabase néohélikiens à orientation nord-est représentent les roches les plus récentes.

Toutes les roches archéennes ont été métamorphisées au faciès des schistes verts et, près de certaines roches granitiques, au faciès des amphibolites.

Le quartzite et les roches volcaniques forment un grand synclinal à orientation nord-est. D'importantes failles chevauchantes, également à orientation nord-est, ont déplaceé les couches vers le nord-ouest.

Les venues minérales sont rares mais les données géochimiques combinées au milieu géologique semblent indiquer que des concentrations de métaux pourraient y exister, notamment dans la zone à lithologie variée.

INTRODUCTION

The stratigraphy of the basement rocks in the Baker Lake region has not been clearly defined to the present. As this knowledge may be significant with regard to the location of uranium mineralization associated with the contact between Dubawnt Group and basement, it was decided to map an area in sufficient detail to establish the basement rock sequence. It was also anticipated that a greater knowledge of the basement stratigraphy would assist in regional correlation of the major layered rock units, such as the Hurwitz Group, that are commonly dominated by thick quartzite accumulations. The Half Way Hills map area was selected for this study as earlier reconnaissance surveys by Wright (1955, 1967) and Donaldson (1966) indicated that outcrop was sufficiently adequate to determine the stratigraphic sequence and deformation and metamorphism were slight.

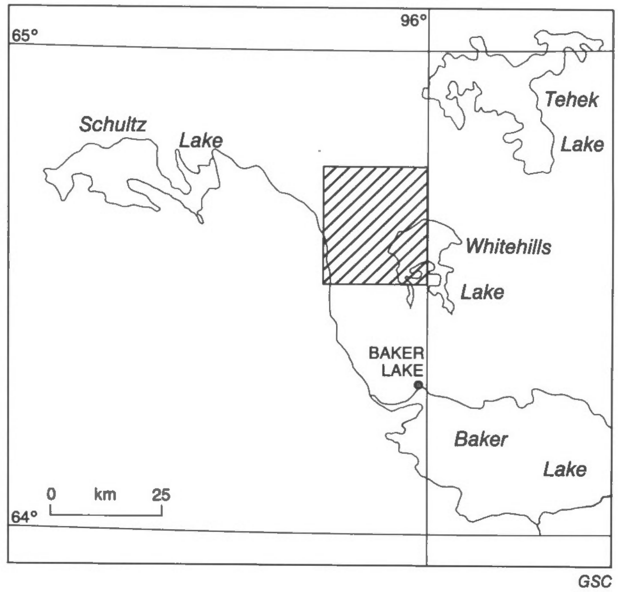

Figure 1. Location of Half Way Hills map area.

Location and access

The Half Way Hills map area lies 20 km north of Baker Lake settlement (Fig. 1) between 64°30' and 64°45'N and 96°00' and 96°15'W. Whereas access to the southwestern part of the area is available along the Thelon River, the remainder requires the use of aircraft as other rivers into the area are too shallow for navigation. Within the map area Whitehills Lake provides ready water access to most of the southeast and some of the central parts and the large lake to the northwest of Whitehills Lake, much of the remainder. The south-central part has ready access only by aircraft.

Operations

Camp supplies and personnel were moved by helicopter to a camp site on the northwest side of Whitehills Lake in mid-June, 1980. A fly camp was established on the Thelon River which was ice free in early July prior to breakup of the lakes, which are ice covered until late July. Helicopter set-outs of traversing parties into areas not readily accessible by water greatly facilitated the work, especially during the breakup period. Traversing by helicopter was limited to the northeast corner where outcrop is scarce.

Groceries and other camp supplies were obtained in Churchill, Manitoba and Baker Lake, N.W.T., and flown by helicopter to the camp site on Whitehills Lake from the latter settlement. Baker Lake has frequent commercial air service from Churchill, Manitoba and other coastal settlements.

Climate

The summers in the Half Way Hills map area are cool and short. Average daily high and low temperatures in °C recorded at Whitehills Lake in 1980 are as follows:

June 19-30		July 1-15		July 16-31		August 1-14	
17.5	2.1	15.9	5.1	16.6	4.3	20.5	5.3

Whitehills Lake was ice free on July 21 but the smaller lakes were ice free a week to 10 days earlier. High winds, chiefly from the northwest to north-northwest can restrict operations, particularly by boat, and sometimes by aircraft.

Previous work

J.B. Tyrrell (1898) was the first geologist to pass through the map area via the Thelon River. He described a 100 foot high hill of green chlorite gneiss cut by veins of red granite and several dykes of red mica trap occurring 8 miles upstream from Baker Lake. This is possibly the volcanic outcrop on the west side of the Thelon River at the west boundary of the map area, although it is about 33 km from Baker Lake. The map area was not examined for more than 50 years when helicopter reconnaissance surveys were undertaken over a large region, which included the Half Way Hills map area (Wright, 1955, 1967). A more detailed survey by Donaldson (1966) of the 1:250 000 scale Schultz Lake map area outlined the general extent of the supracrustal rocks. An aeromagnetic map of the map area was published in 1973 (Geological Survey of Canada, 1973) and led to the staking over several high anomalies.

Physiography and Pleistocene geology

The physiography of the area is dominated by the Half Way Hills and Whitehills Lake. The former are up to 232.6 m above mean sea level whereas the latter is at 73.1 m. Maximum relief is about 201.2 m but local relief is chiefly between 30 and 75 m. A prominent scarp extending along the northwest side of the Half Way Hills diminishes gradually from southwest to northeast. Islands in Whitehills Lake, cored by igneous rocks of the Dubawnt Group, form a distinctive conical silhouette when viewed from lake level in contrast to other islands that are low lying. Except for the Thelon River that runs near the west boundary, drainage channels are poorly developed. The entire area was glaciated during the Pleistocene. As noted by Fyles (in Wright, 1955), the map area lies along an ice divide, later named by Lee et al. (1957) the Keewatin Ice Divide. However, ice flow appears to have been dominantly northward as huge quartzite boulders, some of over 100 tonnes, have been moved north of any quartzite outcrops. Similarly, granitic boulders, probably from the southern part of the area, are present in the northern part which is underlain by layered rocks.

Postglacial, abandoned, marine, boulder shorelines up to about 120 m above mean sea level (Fyles, in Wright, 1955) are scattered throughout the area. Marine shells were found at three localities, one east of the Thelon River, and the others on the shore of, and on an island in, the large lake draining into Whitehills Lake. None of these are near the marine limit discovered by Fyles (in Wright, 1955), which is at least 129 m.

Acknowledgments

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GENERAL GEOLOGY

The Half Way Hills map area lies within the Armit Lake Block of the Churchill Structural Province (Heywood and Schau, 1978) and all the rocks are Precambrian. The age of the sedimentary and volcanic rock units and some of the intrusive rocks has not been established with certainty but they are probably Archean. A small area of syenite predates the layered rocks and hence is also Archean. The layered rocks are intruded by granitic rocks, at which time they were deformed and metamorphosed. Posttectonic emplacement of Dubawnt Group intrusive rocks in the form of stocks and dykes occurred during the Late Aphebian. A few northeast-trending diabase dykes, probably Neohelikian, cut the older rocks.

Archean

Syenite (Asy)

The oldest rocks may be a few small outcrops of syenite about 650 m north of Whitehills Lake. There a pale reddish brown, pale red to greyish red, rarely greyish orange-pink, medium grained, massive to brecciated syenite is overlain by conglomerate. At the base of the conglomerate locally, fragments of syenite 2 to 10 mm in diameter lie directly on the syenite. Elsewhere, red syenite cobbles and boulders up to 1 m in greatest dimension, as close as 5 cm apart, overlie the syenite. Some are angular, cemented to the syenite outcrop by fine grained granite detritus, and others are enclosed in a chloritic detritus. Close to the syenite in some places syenite cobbles and boulders are the sole rock type, whereas elsewhere syenite cobbles are rare or absent from the overlying rock. A few tiny pebbles of syenite and quartz pebbles up to 1 cm are imbedded in the weathered syenite, which may be a regolithic surface. The syenite is locally porous and the same is true of some syenite boulders. The matrix surrounding the syenite boulders immediately above the basement is chiefly chloritic, in part granitic, with rare pyrite.

The only other rocks in the immediate vicinity occur on the southwest end of the small lake 650 m north of Whitehills Lake where slate and argillite with rare quartz-feldspar grains along joint planes lie to the north of the syenite. The contact with the syenite is drift covered, hence the age relationship is unknown. Topography suggests a fault may extend through and parallel to this small lake, but shearing is not evident in the slate and argillite.

The above evidence suggests a very thin regolith and almost no transport of the syenite clasts prior to deposition.

Microscopic examination of the syenite shows it to consist of approximately 75 per cent of string and bleb type perthitic potassium feldspar, 20 per cent plagioclase (An_8), and variable amounts of calcite, quartz, chlorite and rare pyrite. Fractures in the brecciated rock are filled with plagioclase and calcite. Calcite also occurs interstitially. Quartz and calcite fill miarolitic-like cavities in the syenite and euhedral crystals of quartz are present in some cavities. Thin sections of syenite cobbles from the overlying conglomerate display similar mineralogy but in some samples plagioclase content exceeds potassium feldspar content, probably because the cobbles are highly fractured and the plagioclase is filling fractures. The matrix around the syenite cobbles from immediately above the syenite consists of angular to rounded feldspar and syenite fragments, rare calcite and quartz, and a few angular muscovite grains that may be detrital. Chlorite is abundant and less commonly white mica and very finely divided feldspar are interstitial to the obviously detrital fraction. Hematite stain is commonplace and partially pseudomorphous after magnetite in one sample. The conglomerate overlies the syenite and there seems little question that it is derived from syenite.

The absolute age of this syenite is unknown. It differs petrographically from syenite in the Amer Lake map area to the north (Heywood, personal communication, 1982) but is similar to syenite in the Baker Lake map area to the east. There, south of Tehek Lake, an extensive exposure of syenite is considered by Heywood and Schau (1981) to postdate the Tehek granitic rocks which intrude metasedimentary strata. Hence correlation with those syenites is unlikely. It is considered Archean as it is overlain by layered rocks of probable Archean age.

Conglomerate (Acg)

Polymictic conglomerate forms a well defined but narrow map unit along the north and west shores of Whitehills Lake. Another isolated and thin (up to 25 m) conglomerate horizon is also present at the east end of the large lake northwest of Whitehills Lake. The major conglomerate unit is up to 425 m thick on the north end of Whitehills Lake and 225 m thick on the west. These thicknesses include thin arenaceous and argillaceous beds that are intercalated. The eastern limit of the conglomerate is not exposed on the west side of the lake. The thickness of the conglomerate is variable as only 1.7 km east of the thickest part, at the north end of Whitehills Lake, it is absent, and elsewhere outcrop distribution suggests a pinching and swelling and interfingering with slate.

The conglomerate along the west shore of Whitehills Lake is characterized by well rounded cobbles and boulders up to 1 m long. The larger boulders are chiefly granite, but boulders up to 15 cm include many of quartzite and few of dolomite. Where the matrix is dark grey and fine grained, especially in from the water's edge, boulders are scarce, widely spaced and predominantly granite and dolomite. Where the matrix is lighter grey and coarser grained clasts of all sizes are present and in great numbers.

Clasts are undeformed for the most part but locally, such as along the lake shore, a moderate to strong elongation is developed in the plane of the schistosity. This elongation is more marked in the sedimentary clasts than in the igneous ones.

A 15 m thick horizon of gritty pebble conglomerate is present along the western side of the largest outcrop area. This same rock forms much thinner bands in the greywacke to the west. Only rare boulders occur in this rock.

Bedding is obscure, especially distant from the water-washed shoreline outcrops.

Quantitatively the clasts are predominantly a fine to medium dark grey, medium grained, massive quartzite, some of which contain biotite and many discrete, well rounded quartz grains. A dark grey, fine- to medium-grained greywacke locally displaying moderate reddish-orange feldspars is well represented. Clasts of medium grained, massive, equigranular, moderate orange-pink granite are common also, particularly amongst the larger clasts. Clasts of a second massive, medium grained granite show moderate reddish-orange feldspars in a dark grey chloritic matrix. A few pale red and moderate reddish-orange granite clasts are also present. None of the granitic rocks contain megascopically significant amounts of either hornblende or biotite and hence are highly felsic. Light olive-grey weathering dolomite clasts, up to 25 cm long, are widely scattered. This medium grey, fine grained, massive rock locally is transected by quartz veins and generally weathers below the general outcrop surface. Rare clasts of greyish-red aplite, vein quartz, and pinkish-grey feldspathic quartzite are also present. A single small boulder of medium- to coarse-grained, massive, dark bluish-grey anorthosite containing a few grains of pyrite and chalcopyrite, was also located.

A 1 m long boulder of pinkish-grey and medium dark grey, equigranular granite was sampled for a zircon age analysis. This rock consists approximately of 45% microcline, 35% quartz, 15% plagioclase, and small amounts of muscovite, chlorite, pyrite, hematite, calcite and zircon. It is dissimilar to rocks currently exposed.

Clasts of subangular, yellowish-grey muscovite-quartz schist and medium dark grey slate occur erratically. These are chiefly in the pebble to small cobble range.

The matrix is primarily a fine- to medium-grained, medium grey greywacke and locally, as previously mentioned, a gritty pebble conglomerate.

Bedding is poorly defined and sorting of clasts nonexistent. Faint grain gradation in the matrix suggests tops to the east.

The conglomerate at the north end of Whitehills Lake is similar to that on the west, with a few exceptions. The main difference is the presence of red granite and syenite clasts. Graded bedding is locally well preserved, indicating tops to the southeast. A light grey to medium grey slate horizon is present within the conglomerate unit. At one place, in the northeast part of this conglomerate outcrop area, cobbles of light grey to white quartzite, lithologically similar to the quartzite (Aqz) forming Half Way Hills and other large quartzite areas, are present. None of these are known to occur on the west side of Whitehills Lake. In general there is a decrease in the size of the clasts from the southeast to the northwest, except near the nonconformity with the red syenite.

The small occurrence of conglomerate at the east end of the large lake northwest of Whitehills Lake consists primarily of subrounded to rounded cobbles and boulders of vein quartz, quartzite, limestone and leucogranite, all of which are medium grained rocks. The largest boulders are up to 40 cm in greatest dimension and all the boulder-sized clasts are invariably granitic. Many clasts contain carbonate and a few are extensively carbonatized. Rare angular fragments of yellowish-grey, fine grained mica-quartz schist with disseminated hematite are also present. The matrix consists of a fine- to medium-grained, dark grey, slightly schistose, feldspathic quartzite. Tiny well rounded grains of quartz and less commonly, plagioclase, are sporadically distributed in a matrix of quartz, chlorite, muscovite and calcite. The relationship of this outcrop to those bordering Whitehills Lake is unknown.

Greywacke (Agk)

Greywacke comprises the major rock type underlying about 30 per cent of the map area. Although the stratigraphic sequence has not been determined unequivocally the greywacke (Agk) probably overlies conglomerate (Acg).

This greywacke is characterized by its lithological uniformity and a dearth of primary structures. Only rarely throughout areas of generally good outcrop is bedding visible, hence the structure or thickness of this unit is unknown. Secondary structures consist primarily of a moderate but persistent foliation, generally in an east-northeast to east direction with steep southerly dips. A few drag folds are widely distributed. If it is assumed there is no repetition of beds due to folding or faulting, over 9000 m of greywacke is present between the north boundary and the slates and volcanic rocks which presumably overlie it on the south. This great thickness alone suggests this greywacke unit is considerably thickened by structural processes.

Typically this greywacke is equigranular, fine- to medium-grained, shades of medium grey and moderately foliated, and commonly displays bright vitreous quartz 'eyes'. Although dominantly shades of grey, locally light to dark greenish-grey and olive-grey hues are present, particularly along the southern perimeter of the greywacke outcrop area. Rarely, a few coarse grained elements are present and it grades into pebble and coarse conglomerate locally (Agcg). East of the Thelon River at the west boundary well-rounded cobbles and boulders, up to 8 cm in greatest dimension, of very light to pinkish grey, fine grained quartzite are widely scattered in the greywacke. The clasts are so widely scattered that nowhere do they form discrete beds.

Several slate horizons are intercalated with the greywacke about 3.5 km west of the east boundary of the map area. There is no consistency in the slate:greywacke ratio and a short distance both to the east and west slate is scarce or absent. Slate-greywacke contacts dip consistently steeply south in this area but tops are unknown.

Almost all samples of greywacke contain some carbonate (Act). Near the southern limits of the greywacke, carbonate content commonly is greater than normal and a few carbonate-rich horizons are present, especially north of the large lake northwest of Whitehills Lake. The carbonate is readily recognizeable by its light brown weathering. These carbonate-rich zones are up to 10 m wide.

Foliation is marked by alignment of muscovite and, less commonly, chlorite. Bedding is extremely rare. In an outcrop 6.8 km east of where the Thelon River enters the map area, bedding ranges from 0.5 to 1 m thick but north of volcanic rocks and 3.2 km west of the east boundary bedding, marked by fine grained horizons, is less than 0.25 m. Bedding is also marked in a few places by the existence of rare quartzite beds within the greywacke. For example, in the northeast corner two 0.6 m thick quartzite beds, each of which grades into greywacke, define bedding. Similar rare quartzite beds occur elsewhere but particularly toward the southern margin of the greywacke. Where bedding is discernible, foliation is parallel or nearly parallel with it.

Microscopic examination shows subangular to rounded, rarely angular fragments composed chiefly of quartz, plagioclase, and quartzite, with lesser amounts of potassium feldspar and granitic rock. Detrital grains of zircon, apatite, epidote and muscovite, in order of decreasing abundance, occur rarely. Detrital grains are generally 0.25 to 0.50 mm in diameter, but locally some grains up to 2 mm in greatest dimension are present.

The matrix consists of quartz, untwinned plagioclase, chlorite, muscovite and carbonate, with some samples containing small amounts of epidote, biotite, pyrite, sphene, tourmaline, hematite and magnetite. Secondary pyrite crystals, commonly euhedral and locally up to 1 cm on crystal faces, occur widely dispersed in this matrix.

Detrital feldspars are variously fresh to highly altered, chiefly to sericite.

Hornfels (Ahf)

Hornfels is confined to those islands in Whitehills Lake that are the site of intrusions of Dubawnt Group Martell syenite. There it forms haloes about the intrusions up to 200 m wide. These haloes are of variable width as in some places, such as on the southwest shore of the second largest island, greywacke, quartzite and slate occur within 50 m of the syenite. The width of the hornfels zone is in part related to the size of the intrusion, as on the small islands in the northeast part of Whitehills Lake where syenite forms dykes, the hornfels is only a few metres wide. As the intrusions are probably near vertical, size may be the chief reason for variation in the width of the hornfels zones. At the northwest end of the second largest island a zone of breccia, about 30 by 10 m, is present within the hornfels. There, well banded hornfels fragments lie in a massive hornfels matrix. This breccia may be due to an explosive event.

The formation of the hornfels has accentuated the banding, which is undoubtedly bedding, so that it is readily visible. Bedding is rarely displayed by the same rocks outside the hornfels zone.

A very fine grained to aphanitic, medium light grey to dark grey rock is typical. A conchoidal fracture is characteristic. The hornfels is variously well banded to massive. Some outcrops are characterized by a weak gossan that is formed by the weathering of tiny, randomly distributed pyrite veins and weakly disseminated pyrite.

Microscopically some samples show original grain boundaries for the detrital minerals and rock fragments, others show the detrital fraction distorted or only vague outlines, and others are chiefly recrystallized. Detrital grains consist of quartz, plagioclase, quartzite and granitic rock. The matrix, which is chiefly quartz and feldspar, also displays chlorite, muscovite, biotite and rarer epidote, calcite, magnetite, zircon and apatite. Muscovite and chlorite grains are larger than those present in rocks remote from the syenite contact zone.

Slate, siltstone, argillite and phyllite (Asl, Asn, Aal, Apt)

These argillaceous rocks are confined in general to a zone at and near the top of the greywacke unit and to the north shore of Whitehills Lake and on some of the nearby islands. Thin beds are present adjacent to areas underlain by iron formation but are commonly only represented by highly frost-fractured rubble.

Only in the northeastern part of the map area do these rocks attain any great thickness and there their thickness is variable as they tend to form wedge-shaped units in the uppermost part of the greywacke. The greatest thickness, assuming no structural repetition, is 225 m about 3 km west of the east boundary.

Argillite, siltstone, slate and phyllite are chiefly shades of grey ranging from medium light grey to medium dark grey with rare light grey and greenish-grey shades. Even rarer black, carbonaceous slate occurs locally, chiefly near the iron formation. Bedding ranges from a few millimetres to about 1 cm thick but is rarely discernible as secondary structures, particularly cleavage, are much more prominent. Hence, slate is the commonest of these rock types as cleavage is well developed in many places. Cleavage and bedding are parallel or nearly parallel in several places. Phyllite is confined to a poorly exposed area bordering iron formation 6.1 km east of the west boundary at latitude 64°40'N and in or near fault zones. Unlike the greywacke, these rocks contain only small amounts of carbonate, although carbonate is locally present in fractures.

Iron formation (Aif)

Iron formation occurs intermittently across the map area from the Thelon River to near the east boundary. The largest gap in the iron formation is from near the west end of the large lake north of Whitehills Lake to the east end of the same lake. Aeromagnetic data (Geological Survey of Canada, 1973) suggest this gap, except for one or possibly two small occurrences, is real and that the lake does not cover much additional iron formation. Most of the iron formation lies close to the upper part of the greywacke and below most of the volcanic rocks. However, in the east-central part of the area iron formation occurs within the volcanic rocks, although it extends only about 750 m along strike.

The thickness of the iron formation is indefinite because of the intricate folding that is prevalent in most outcrops (Fig. 2). This folding is probably a primary structure as it is chaotic and unrelated to postdepositional deformation which is not manifested internally in the iron formation. Near the Thelon River and to the east, about 150 m of iron formation are present and in some places additional thin bands occur in the sedimentary rocks overlying the main iron formation horizon. On an island in the western end of the large lake northwest of Whitehills Lake, iron formation is 25 m thick and 150 m laterally. In the eastern part of the map area the iron formation is only 65 m thick at the maximum and in most places it is between 40 and 50 m thick. The band of iron formation within the volcanic rocks is 15 to 30 m thick, including some chert in the thicker parts.

This iron formation is well banded or bedded with bands ranging from 1 mm to 1.5 cm. Where the iron formation is thick, beds are commonly contorted and/or broken and disturbed. These are considered to be primary structures. Where bodies are thin and intercalated with arenaceous rocks bedding is more uniform. Greyish-red, dusky red and very dark red beds intercalated with medium light grey to dark grey beds are most typical. However, where magnetite content is high and hematite low or absent, a medium to dark grey rock with light grey interbeds is characteristic. Rare, white cherty beds occur in a few places. In others, near massive patches of dark to dusky red hematite with irregular blotchy areas of medium to dark grey magnetic arenite are present.

Both quartz-hematite iron formation and quartz-magnetite iron formation are represented and in most outcrops both are present, although hematite iron formation is probably more abundant. A few cubes of pyrite are present in some places. Hematite and/or magnetite content typically

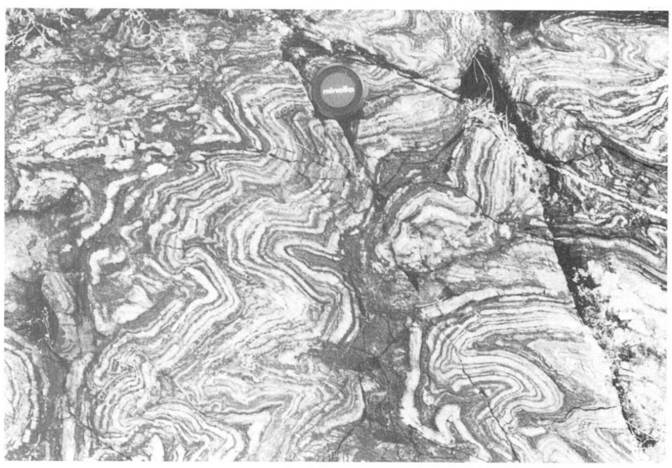

Figure 2. *Highly contorted iron formation (Aif) 250 m east of the Thelon River (GSC 190-482).*

Table 1. Analyses of selected mafic volcanic rocks

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SiO_2	56.4	55.0	55.2	47.4	54.9	53.8	53.0	57.3	52.8	53.3	51.5	54.2	46.4	62.4	55.8
TiO_2	.89	1.54	1.00	1.76	2.10	.84	1.53	1.60	2.47	2.20	2.39	2.09	1.01	.20	1.55
Al_2O_3	13.6	14.2	14.0	12.4	13.4	14.7	13.3	14.5	12.6	13.5	13.0	13.0	15.5	11.2	13.9
Cr_2O_3													.07		
Fe_2O_3	1.8	8.1	2.3	3.9	8.0	2.3	4.9	4.9	6.8	5.3	12.0	9.4	1.6	4.4	7.8
FeO	7.7	4.5	8.8	12.6	5.6	8.1	7.7	7.0	6.9	5.8	3.5	4.4	8.8	11.8	4.6
MnO	.15	.14	.18	.21	.14	.18	.12	.15	.20	.10	.17	.15	.22	.03	.15
MgO	5.43	2.39	5.04	5.17	2.44	5.52	4.08	2.26	3.30	3.26	3.33	2.53	7.92	1.68	2.22
CaO	4.36	5.63	7.35	8.10	5.81	6.91	3.51	2.52	6.05	4.33	3.75	5.14	7.55	.23	5.57
Na_2O	4.0	4.5	3.0	1.0	3.9	4.2	5.2	5.2	2.7	4.4	3.7	3.8	4.8	2.1	3.6
K_2O	.99	1.57	1.02	.09	1.87	.88	3.10	1.28	1.45	2.23	2.56	1.71	.25	1.11	1.68
H_2OT	2.9	2.2	2.3	4.5	2.1	2.2	2.3	2.7	2.7	2.3	2.9	2.3	3.5	3.3	2.2
CO_2	1.4	.2	.2	3.2	.1	.1	1.7	.5	.5	1.9	.2	.2	2.1	.2	.1
P_2O_5	.13	.17	.12	.16	.24	.10	.20	.18	.35	.23	.24	.25	.10	.10	.19
S	.03	.04	.03	.11	.03	.04	.05	.03	.03	.03	.04	.03	.03	.06	.04
Ba	.029	.027	.036	.018	.049	.019	.051	.060	.042	.076	.048	.03	.014	.020	.038
Rb	.005	.005	.006	0.000		.007	.015	.004		.007		.007	.005	.006	.005
Zn	.010	.013	.011	.013	.014	.010	.016	.013	.015	.021	.017	.014	.013	.008	.015
Total	99.8	100.4	100.6	100.6	100.7	99.9	100.9	100.3	99.0	99.0	99.6	99.4	99.9	98.9	99.6

All analysis of XRF fused, except FeO, H_2OT, CO_2, S by rapid chemical

1, 3, 6 and 13 are typical mafic volcanic rocks;
2, 5, 7-12, 14 and 15 are biotite-rich mafic volcanic rocks;
4 is a tuff

is in the 10 to 20 per cent range but in a few outcrops it is much greater. For example, 650 m from the east boundary, magnetite, in bands ranging from 2 to 10 mm thick, forms up to 50 per cent. Whereas some of the hematite is unquestionably the result of oxidation, as it can be seen developed along fractures, in other places it may be of primary origin.

Dolomite (Adm)

Dolomite is commonest in a narrow zone between the greywacke outcrop area and the major outcrop area of basic volcanic rocks east of the Thelon River. Dolomite is scarce east of longitude 96°18'W. Nowhere is it well exposed and much of the outcrop is frost heaved but it may occur in the large lake northwest of Whitehills Lake. Areas along strike between outcrops are low-lying ground or swamp with widely scattered dolomite boulders.

The thickness of the dolomite is determinable only within wide limits as it is extensively deformed and crumpled. Although outcrop width at one place is about 100 m, it rarely exceeds 50 m. It is absent in parts of its general outcrop area as it is probably lensoid.

This rock is characterized by a distinctive weathered surface that is primarily moderate brown but locally moderate reddish brown or moderate yellowish brown. A rough surface is typical as tiny quartz veins and irregularly-shaped quartz blebs project above the carbonate surface. Fresh rock is fine- to medium-grained, medium light grey to greenish grey, massive to schistose, and locally brecciated. The latter has pinkish-grey carbonate veins forming the matrix. Although dominantly dolomite, a minor amount of calcite (less than 10 per cent) is commonly present along with rare quartz. A brilliant green mica, possibly fuchsite, occurs along fractures in some samples.

Bedding is not discernible and if ever present was probably destroyed by deformation.

The dolomite overlies greywacke in several places and grades into it in some of them. East of the Thelon River, 500 m of schistose greywacke grades into a schistose dolomitic greywacke that in turn grades into dolomite. On the southwest the dolomite is overlain by iron formation. Farther east dolomite lies to the south of the iron formation, whereas a carbonaceous slate lies between the iron formation and greywacke. It is evident that dolomite is not confined to one place in the stratigraphic column and its variable position shows conditions suitable for carbonate deposition were not uniformly distributed in time and place.

Metavolcanic Rocks (Age, Avb, Abv, Atf, Act)

Metavolcanic rocks form two discrete broad outcrop areas, one extending from the Thelon River in the west east-northeastwards to the east boundary, the other a few kilometres to the south, roughly parallel to the first but ending in a fold 5 km west of Whitehills Lake. They are locally intercalated with quartzite and less commonly with argillaceous rocks and iron formation.

These metavolcanic rocks are characterized by a dearth of primary structures. The only primary structures suitable for top determinations are rare pillows present near the east boundary. Locally, breccia zones and amygdules are present but ill-preserved and unsuitable for top determinations. A weak but persistent foliation is present throughout these rocks and coupled with low grade metamorphism, accompanied in many places by extensive carbonatization (Act), has undoubtedly destroyed the primary characteristics.

Typically these mafic metavolcanic rocks are fine grained, greenish grey to dark greenish grey, and weakly foliated (Age). A few display various other shades such as light olive grey, yellowish grey, and greenish black. A pronounced slaty cleavage is locally present. Microscopically most samples are seen to be completely recrystallized. A subophitic texture is present in a few and others show scattered plagioclase phenocrysts and amygdules. Plagioclase is chiefly altered to albite but a few grains show anorthite contents ranging from 32 to 42. Amphibole present is a pale actinolite that is altered in some samples, partly or completely, to chlorite. The latter mineral is also common in the matrix. Epidote is present in almost all samples examined, forming as much as 40 per cent, but comprising chiefly less than 5 per cent. Sphene is common in accessory amounts. Many samples contain small amounts of carbonate and some samples, particularly those from the western end of the lake northwest of Whitehills Lake, are composed of over 50 per cent carbonate (Act). Small amounts of quartz, biotite, ilmenite, magnetite, pyrite and apatite are scattered throughout the matrix.

Intermixed with the above metavolcanic rocks are a few massive to schistose, locally amygdaloidal, dark moderate brown weathering (significantly darker than the other rocks) biotite-rich metavolcanic rocks (Abv). These rocks are olive grey to olive black and very fine grained to fine grained and equigranular. Locally, scattered subhedral phenocrysts of plagioclase, up to 2 cm, are present. These rocks form discrete horizons or grade into the associated metavolcanic rocks. On the bulbous peninsula on the west side of Whitehills Lake this rock grades into the common metavolcanic rock over approximately 1 m with no apparent break. Elsewhere, such as northwest of Whitehills Lake, this rock is intercalated with quartzite bands.

Compositionally the biotite-rich metavolcanics are characterized by abundant brown biotite and chlorite. The former forms 15 to 40 per cent and the latter 10 to 30 per cent. In some samples biotite is extensively altered to chlorite, whereas in others it is fresh. Plagioclase, where determinable, notably in the phenocrysts, is andesine, but some in the matrix is albitic. Sphene and epidote are common, comprising up to 5 per cent each. Actinolite is present in only half the samples examined microscopically and forms up to 5 per cent. Small amounts of calcite, ilmenite and magnetite complete the mineralogy.

Where volcanic rocks display primary breccia zones they are indicated Avb. These breccias consist of volcanic fragments, chiefly in the range of 2 to 10 cm, in a fine grained matrix that commonly grades into massive greenstone. Carbonatization, primarily associated with secondary brecciation but also including some pervasive carbonatization, is shown as Act. This carbonatization is characterized by a moderate to dark reddish brown weathered surface.

Fifteen samples of volcanic rocks were analyzed using XRF in the laboratory of the Geological Survey of Canada (Table 1). Ten of these samples are from high biotite, dark, moderate brown-weathering rocks, four are typical mafic volcanic rocks, and one is probably a metatuff. These analyses show that overall all these rocks are subalkaline (see Fig. 4). The four typical mafic rocks lie on the calc-alkaline side of the tholeiite-calc-alkaline line and 9 of 11 of the other samples on the tholeiitic side on the AFM diagram (see Fig. 3). However, on a weight percent Al_2O_3 versus normative plagioclase composition curve no clear division is apparent but the typical mafic volcanic rocks all lie in the calc-alkaline field. Although all metamorphosed and containing calcite, they fall into the andesite classification. One sample (no. 13) includes carbonate amygdules and hence is anomalous on that account, but the very low silica content is unexplained.

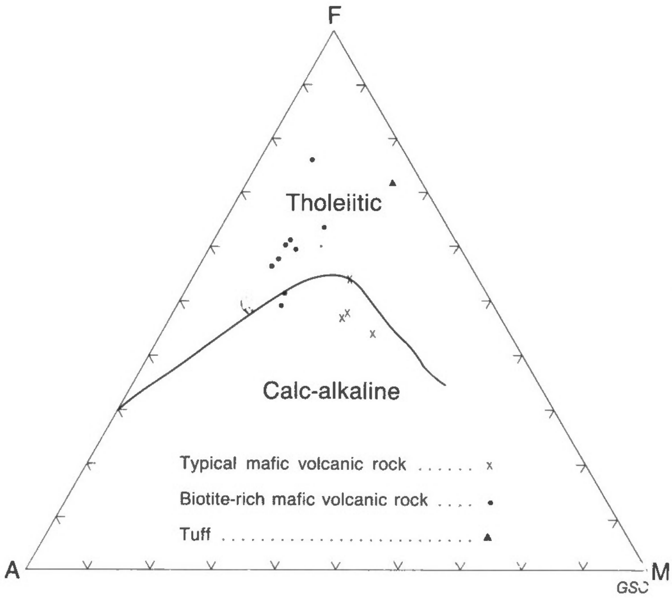

Figure 3. *AFM plot of mafic volcanic rocks.*

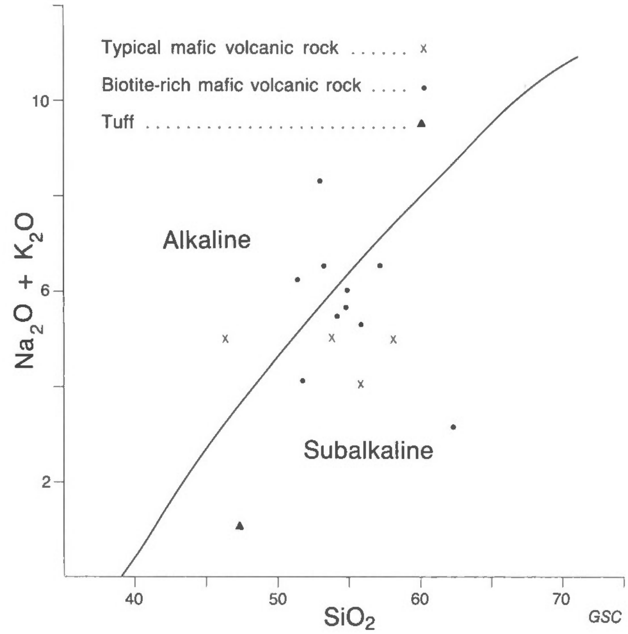

Figure 4. *$Na_2O + K_2O$ vs. SiO_2 plot of mafic volcanic rocks.*

The high silica content in sample no. 14 is due to the presence of tiny anhedral quartz grains scattered throughout the matrix and microscopic chlorite-biotite-quartz veinlets. A 1 cm quartz vein is present in the hand specimen of this sample.

The major chemical differences are that the mica-rich volcanic rocks have over twice the K_2O of the typical mafic volcanic rocks (1.85 vs. 0.78) and less MgO (2.74 vs. 5.97) and more TiO_2 (1.76 vs. 0.93).

As the dark weathering rocks are known to grade into the typical mafic volcanic rocks, their genesis is obscure. As all the rocks have been metamorphosed it is unlikely that a metamorphic origin is justified unless an extreme example of metamorphic differentiation is called upon. The difference is probably deuteric alteration and may be due to a hydrothermal process, possibly shortly after deposition.

Komatiite (Akt)

Komatiite, which was first recognized in this map area by W.W. Heywood, is limited to a few small outcrops in the northeast where it lies near or at the base of the major mafic volcanic zone.

The westernmost outcrop consists in part of a flow 12 to 14 m thick lying on a fine grained, light grey quartzite with minor rusty slate beds. The top of this flow is marked by rounded spinifex textured komatiite fragments (up to 30 cm in diameter and averaging 10 cm) that lie in a limestone matrix. This limy zone is roughly 3 m thick. In part, along the river bank, this spinifex textured komatiite is sheared parallel with the regional trend. Slightly farther west the same 18 m thick spinifex textured horizon is bounded by a brown weathering serpentinite on the north and a yellowish-grey weathering serpentinite on the south.

However, the eastern komatiite exposure is best displayed on a small peninsula where 35 m of excellently spinifex textured rock forms a prominent ridge. The north boundary is drift covered but the south is marked by a serpentinite sill. Some of the southern part of the komatiite is extensively brecciated close to the serpentinite. Possibly several flows are present in this exposure, with a weak rubbly zone of cumulate and excellent spinifex needles, locally up to 25 cm in the central parts. A few flow lines are present near the top of the cumulate zone and these are roughly normal to the spinifex grains. The cumulate zone in general weathers a darker brown than the spinifex zone. Tops to the south are suggested by a progressive decrease in the length of the spinifex needles in that direction. Poorly developed pillows and a faint polyhedral jointing are present in parts of the outcrop devoid of spinifex texture. The easternmost outcrop exposes 20 m of spinifex textured komatiite bounded on both sides by mafic volcanic rocks.

The komatiite is a moderate brown weathering rock that is dark greenish grey on fresh surfaces. Spinifex needles, which are up to 25 cm long but chiefly in the 2 to 5 cm range, lie in an aphanitic matrix. Microscopic examination shows that all primary minerals have been replaced. Spinifex needles, probably originally olivine, consist of serpentine and the matrix of tremolite. Small amounts of calcite occur in the cores of some of the serpentine and magnetite and pyrite are present in both the matrix and spinifex grains.

Felsic volcanic rocks (Afv, Arl)

Felsic volcanic rocks comprise a small part of the volcanic terrane and form only one significant outcrop area toward the east end of the large lake northwest of Whitehills Lake. East of the Thelon River small occurrences are present, chiefly within the mafic volcanics where locally they form up to 20 per cent of the rock. The felsite (Afl) outcropping west of the granitic dome may be related to these rocks.

Typically the felsic volcanic rocks are interlayered with mafic volcanic strata forming bands up to 30 m thick, but more commonly 1 to 2 m thick. Individual bands rarely extend more than 25 m. East of the Thelon River many of the felsic rocks occur as highly irregular dykes about 1 m thick. Clearly defined flows are scarce in this part of the map area.

The largest outcrop area of felsic volcanic rocks consists of a medium grey, fine grained, schistose rock. Microscopically it is seen to be composed chiefly of equigranular, untwinned, indeterminate sodic plagioclase. Quartz, locally with calcite, occurs chiefly as well defined streaks but also is present in the matrix. Potassium feldspar is not known to occur. Tiny chlorite grains are disseminated throughout the matrix. Rare epidote and pyrite complete the mineralogy.

The felsic volcanics near the Thelon River are more siliceous than the above rocks and locally are rhyolite. A pinkish-grey to very light grey, very fine grained to aphanitic rock is typical. Microscopic examination reveals scattered subhedral phenocrysts of plagioclase, quartz and potassium feldspar in a matrix of quartz, muscovite and chlorite. Some phenocrysts display cuspate outlines, suggesting that some may be of crystal tuff derivation.

Schist (Asc)

Rocks of this unit are well represented along the western flank of the major quartzite exposures east of the Thelon River. There a yellowish-grey schist up to 550 m wide and possibly 500 m thick is present. However, this schist zone is poorly exposed on the whole and undoubtedly pinches and swells as 3.5 km to the southwest it may be absent or 50 m thick at the maximum. In part it is cut off by the major north-northeast-striking fault. An 8 m thick schistose mafic volcanic band with prominent pyrite cubes is present within it near the southernmost outcrops. Massive quartzite beds, up to 5 cm thick in this schist, have been intepreted as bedding. At this occurrence, schist ranging from 8 to 15 m thick is interbedded with quartzite and 400 m to the east a 75 m thick band of schist is present between quartzite and the mafic volcanic rocks.

These schists are fine- to medium-grained, variously yellowish grey to light olive grey, greenish grey, very light and medium grey. Schistosity is well but coarsely developed. Crinkles and small open folds normal to the schistosity are well developed locally with a wave length from submegascopic to about 6 cm. Typically this rock is a muscovite-quartz schist. In general, recrystallization is complete but locally, such as near Whitehills Lake, detrital quartz and quartzite grains are well preserved. Whereas the bulk of this unit is composed solely of quartz and muscovite, a minor amount of pyrite, hematite, goethite, plagioclase, and chlorite occurs in some places.

Quartzite (Aqz)

Quartzite is the major rock unit in a broad arc from near the southwest corner to south of the northeast corner. Topographically it forms the Half Way Hills, the highest landform in the map area, and a major topographic feature in the district. Only a few small occurrences of quartzite are present outside of the main outcrop area.

The thickness of this unit is not established with certainty as structural data within and adjacent to it are scarce. To the southwest, if there is no repetition of strata, about 1800 m is exposed. In the area northwest of Whitehills Lake there is 2700 m of quartzite and in the northeast 1500 m. Although most of this quartzite occurs in thick units in some places, thin quartzite bands, interlayered with mafic metavolcanic rocks are present, such as northwest of Whitehills Lake.

This quartzite in general is massive and only rarely are any primary structures discernible. In only a few places are bedding, crossbedding and symmetrical ripple marks present (Fig. 5). Where bedding is present it ranges from 1 to 20 cm. Ripple marks are a product of wave action and display a wave length of about 25 cm and an amplitude of 5 cm. These are so widely spaced that it is structurally unreliable to project top determinations from them for any great distances. Similarly, secondary structures are also rare, with only a few drag folds apparent, such as on the large peninsula on the west side of Whitehills Lake.

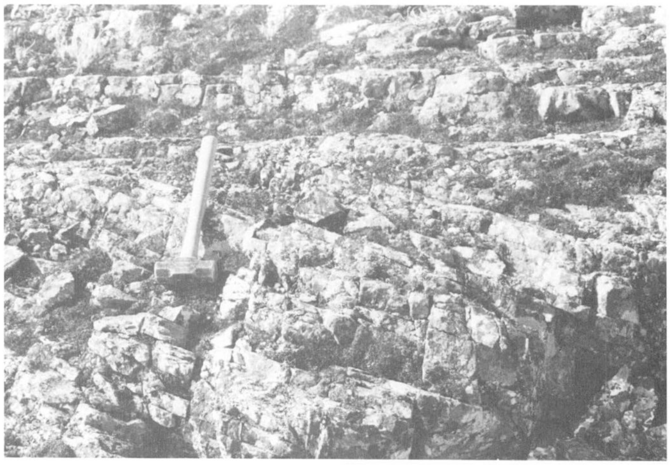

Figure 5. *Well bedded and crossbedded quartzite (Aqz) west of Whitehills Lake (GSC 190-467).*

The major characteristic of this quartzite is its purity. Only in a few places are small amounts of muscovite, pyrite and hematite present in this yellowish-grey, light olive-grey, light to medium grey, rarely white, fine- to medium-grained rock. The quartzite consists chiefly of subrounded to locally rounded detrital quartz and quartzite grains up to 0.6 mm in diameter and averaging about 0.2 mm in a finer grained quartz matrix. The degree of recrystallization is variable but in most samples a few detrital grains are visible.

Interlayered schist or slate are present near the boundaries of the quartzite and rarely within it.

A few conglomerate zones (Aqcg) occur erratically. These contain pebble-sized quartzite clasts that do not form well defined beds. An exceptionally coarse grained conglomerate, with well rounded quartzite boulders up to 40 cm in diameter, occurs in the quartzite in the south-central part of the map area. There, also, bedding is poorly defined but is suggested by elongation of the boulders.

In a few places, such as along the narrows between the two lakes north of Whitehills Lake, this quartzite grades into pale to dark red, moderately hematitic iron formation. A similar hematite-rich rock is common in many of the cross faults in the quartzite. This low grade iron formation is up to 8 m thick and 40 m long, but lacks any great continuity and is inclined to be patchy.

Serpentinite and peridotite (Ase, Apd)

Small plutons of peridotite (Apd) and serpentinite (Ase) occur sporadically along the southern limit of the greywacke in the same general zones as the iron formation and dolomite. A small quantity of these rocks also occur higher in the section, some also near iron formation and other lens-shaped plutons near the east boundary within the mafic volcanic rocks. They form small, ovoid and lensoid stocks, up to 300 m long and 100 m wide, and sills up to 700 m long and 45 m thick. Some of these rocks east of the Thelon River have been extensively carbonatized, probably along a shear zone.

The small ultrabasic pluton roughly 30 m wide on the island in the large lake northwest of Whitehills Lake is characterized by a breccia consisting of subrounded fragments of serpentinite up to 40 cm in longest dimension, in a serpentinite matrix. It is strongly sheared, with inconsistent foliation trends.

These rocks are variously moderate brown or light greenish grey on weathered surfaces and greenish black to olive black, dark greenish grey on fresh surfaces. A fine grained massive rock is typical, but in some places shearing is prominent and slip surfaces common. A single veinlet of chrysotile was present in one outcrop. Where extensively carbonatized, a pale yellowish-brown to greyish-orange or olive-grey rock is characteristic.

Microscopic examination showed that all primary minerals have been serpentinized. In some samples excellent olivine outlines are apparent. Carbonate is a common constituent and in some places, where carbonatization is extensive, forms over 90 per cent of the rock. Tiny subhedral to euhedral grains of chromite, pyrite and magnetite occur in accessory amounts.

Gabbro (Agb)

Most gabbro plutons are small and tend to be equidimensional, but some are tabular. Gabbro is more widely distributed than the ultrabasic rocks although most commonly it too occurs in the zone above the greywacke and associated with iron formation and dolomite. However, some gabbro is present within the mafic volcanic rocks and quartzite, such as the stock on the large peninsula in Whitehills Lake.

Contacts are rarely exposed and those that are, commonly are shear zones with bordering rocks. For example, the gabbro 4.5 km east of the Thelon River has sheared dolomite on the south contact and sheared dolomite and mafic volcanic rocks on the north. The stock on the large peninsula in Whitehills Lake is primarily a felsic quartz gabbro but there are zones of amphibolite within it along with some mafic volcanic rocks. A small part of this outcrop consists of gabbro breccia. Late, tiny granitic veinlets are present locally.

Near the southeast corner a sill of weakly foliated gabbro with diorite phases is associated with metavolcanic rocks in a generally granitic terrane. Although age relationships are not established with certainty, this sill-like pluton probably predates the granitic rocks and postdates the volcanic rocks.

The gabbro is typically a greenish-grey to dark greenish-grey, massive to weakly schistose, equigranular, fine- to medium-grained rock. Locally, a bluish-grey or mottled rock is representative and some medium- to coarse-grained rocks exist. A light coloured quartz gabbro also occurs in a few places. The diorite is mixed yellowish grey and dark greenish grey, medium grained, equigranular and moderately foliated. As some gabbro is lithologically similar to some crystalline mafic volcanic rocks, isolated outcrops may be misidentified.

Commonly the gabbros weather darker shades, in places brown, than the volcanic rocks.

In thin section the gabbro is seen to be composed of plagioclase and ferromagnesian minerals, the former variously fresh to entirely altered to sericite and epidote. Some of the highly altered plagioclase consists of a nearly opaque mixture of sericite and epidote. Where fresh or only partly altered, the plagioclase ranges from An_{30} to An_{38}. Ferromagnesian minerals are chiefly a colourless to pale green clinoamphibole that in a few samples contains cores of common green hornblende. Less common is hornblende altered to chlorite. None of these rocks examined microscopically contain pyroxene. Anhedral to subhedral epidote occurs in the matrix as well as an alteration of the plagioclase. Calcite forms up to 5 per cent, being subhedral in some samples. Small amounts of biotite, chiefly altered to chlorite, sphene, apatite, muscovite, ilmenite and pyrite, occur sporadically. Quartz is present locally and rarely as much as 10 per cent, as in the quartz gabbro on the large peninsula in Whitehills Lake.

Granitic rocks (Agr, Agd, Atl, Adr, App, Aap, Apm, Afl, Agg, Agga, Aggp)

Granite (Agr) plutons occupy most of the southeast and southwest parts, extending northeasterly from the latter to the centre of the map area. Whereas the major areas are of batholithic proportions, the northern extremities are well defined stocks. Small dykes of porphyry (App), aplite (Aap) and felsite (Afl) occur sporadically, a few well beyond the main granitic outcrop areas. The contacts with the layered rocks are in general abrupt, but in a few places gradational over a few metres. Inclusions of the layered rocks are locally common and in the southeast extensive areas of layered rocks can be interpreted as roof pendants. Apophyses of the granitic rocks extend into the layered rocks in some places, such as northwest of Whitehills Lake, clearly cutting across the strata. These granitic rocks unquestionably postdate all the layered rocks.

The granitic rocks are chiefly medium grained, equigranular, foliated (Agg), and are mottled pinkish grey and dark grey green. Less commonly they are fine-or coarse-grained, massive and various colours, ranging from greyish orange pink to greenish or yellowish grey. Rarely they display augen or porphyritic feldspars.

Granite, granodiorite, tonalite (Agr, Agd, Atl) and very rarely syenite, are represented in the major areas underlain by granitic rocks, but mappable units in general do not exist as they grade into one another over short distances. Locally, west of Whitehills Lake, discrete areas of massive granite have been distinguished in a dominantly gneissic granodiorite terrane. Granodiorite is the major rock type, with lesser amounts of granite and tonalite. As previously noted, porphyry, aplite and felsite occur as dykes.

Potassium feldspar, which ranges from less than 5 to 50 per cent, is chiefly fresh, weakly to moderately perthitic orthoclase with lesser amounts of local microcline. Plagioclase (An_{6-27}) is zoned in part, variously fresh to highly altered to sericite with minor amounts of epidote. Quartz content is highly variable, ranging from 5 to 30 per cent. Varietal minerals only comprise a small part of these rocks, rarely more than 5 per cent. Chlorite is by far the commonest and is present in almost all the granitic rocks. Muscovite content ranges from a trace to 5 per cent. A minor amount of calcite is present in most specimens. Accessory amounts of apatite, epidote, zircon, pyrite, sphene, ilmenite, and magnetite, occur. Scarce purple fluorite was located in a very fine grained, massive granite on the bulbous peninsula in Whitehills Lake 2.1 km north of the south boundary. It also occurs 150 m south of the south boundary at longitude 96°26'W.

The porphyry dykes (App), of which one 3 m thick dyke north of Whitehills Lake is typical, are massive, and pale reddish brown with quartz and plagioclase phenocrysts to 1 mm in a very fine grained matrix. The phenocrysts are variously anhedral and euhedral, with both discrete and mixed grains. The plagioclase (An_{11}) is slightly sericitized. The matrix consists of 70 per cent plagioclase, probably albite, with the remainder quartz, except for trace amounts of muscovite, biotite, limonite and hematite.

Aplite dykes (Aap) are greyish pink to pale red, equigranular and massive. Trace amounts of biotite, and where fractured, epidote, are present with potassium feldspar and quartz.

An aphanitic, intrusive rock, commonly with a conchoidal fracture, is mapped as felsite (Afl). It forms narrow dykes and irregular patches chiefly within the areas underlain by granitic rocks, but the largest exposure lies west of the oval granodiorite stock in the north-central part of the map area. Whereas most of the felsite is massive, some in this latter area is well banded due to abnormally high biotite content. A pale red colour is typical, but olive grey, white and pinkish grey hues also occur. Quartz and sodic plagioclase comprise over 95 per cent in all samples except the banded rock. Trace amounts of chlorite, calcite, muscovite, epidote, pyrite and hematite are common.

Where inclusions of amphibolite or paragneiss are abundant in the gneissic granitic rocks they are shown as Agga and Aggp respectively.

Amphibolite (Aab)

Amphibolite is chiefly equigranular, fine- to medium-grained, foliated, and greenish grey to greenish black. In a few places bands or laminae of hornblende in plagioclase, probably the result of metamorphic segregation, are prominent. Actinolite, locally altered in part to chlorite, forms up to 60 per cent. Sodic plagioclase, variously fresh to sericitic, is the only other essential mineral. Quartz, epidote, biotite, chlorite, apatite, calcite, sphene and pyrite, are present in small amounts.

Paragneiss (Apg)

Paragneiss occurs chiefly in the southeastern part of the map area within the granitic terrane. Outcrop distribution suggests that the paragneiss and amphibolite with which it is commonly associated form roof pendants within the granitic rocks. Small occurrences of paragneiss are also present in a similar environment near the Thelon River.

This paragneiss is a fine- to medium-grained, foliate to schistose, rarely crenulated rock that is dominantly grey but with yellowish and greenish shades. A distinct layering or banding is present as well as mineral foliation. Plagioclase (An_{32}; 40-50 per cent) and quartz (10-25 per cent) are dominant. Varietal minerals include hornblende, in part entirely altered to uralite, brown biotite, in part altered to chlorite, and less commonly, muscovite. One sample contains a colourless amphibole that is possibly cummingtonite. Accessory amounts of calcite, pyrite, apatite, sphene, epidote and iddingsite are also present.

A sample from 200 m south of the map area contains fresh, anhedral andalusite, but none is known within the map area.

Aphebian

Dubawnt Group

Martell Intrusive Suite (AMsy, AMgr, AMlp)

Posttectonic intrusive rocks, in the form of dykes and stocks, occur throughout the map area. The stocks, which are prominent topographically, all outcrop on islands in Whitehills Lake, with the largest being 1.2 by 0.6 km. The second largest and most northern stock generates a weak magnetic anomaly (Geological Survey of Canada, 1973) but none of the other plutons have a magnetic signature. A sample from the northernmost island contains much more magnetite and mafic minerals than samples from the others.

Syenite (AMsy) on the largest island consists predominantly of a well jointed, medium- to coarse-grained, equigranular, massive, olive-grey rock that near its periphery locally grades into a fine grained, porphyritic, massive, light brownish-grey rock. Phenocrysts in the latter rock consist of phlogopite and altered clinopyroxene up to 4 mm long. The syenite, and less commonly the country rock, is intruded by very pale orange, medium grained, equigranular, massive granite. Dykes of this granite up to 4 m thick occur in the syenite and a sill 4 m thick is present in the surrounding hornfels.

A few subangular to rounded cobble to boulder sized inclusions of quartzite up to 1 m, but chiefly 15 cm or less, are present in the syenite at the southeast end of the island. A single, well rounded, 10 cm cobble of medium grained red granite is present near the south end.

Microscopically the major part of this syenite is seen to consist essentially of clinopyroxene, micas and potassium feldspar. The clinopyroxene is anhedral to subhedral augite and variously fresh to entirely altered. A few crystals are terminated by bright green aegirine. Some pseudomorphic grains contain intergrowths of very pale actinolite or chlorite and others consist of chlorite, epidote, fibrous riebeckite, and biotite. A few grains have an outer zone of chlorite enclosing epidote primarily. A few highly altered grains have augite cores and more rarely include some aegirine.

The mica is chiefly phlogopite but it is extensively mixed with biotite. The potassium feldspar, some with Carlsbad twins, includes minor amounts of perthite and rare fresh plagioclase, probably albite. Some grains now composed of talc, calcite, chlorite and/or serpentinite are possibly olivine pseudomorphs. Similarly, some riebeckite-chlorite grains are possibly olivine pseudomorphs.

Tiny subhedral to euhedral apatite crystals are disseminated throughout the rock and comprise 1 to 2 per cent. Accessory magnetite and calcite also are present. The porphyritic zone has a much greater potassium feldspar content (70 per cent); the micas are chiefly altered to chlorite and only very minor amounts of completely altered clinopyroxene (now chlorite and very pale actinolite) are present. Some grains consisting of a mixture of two chlorites and carbonate may be pseudomorphous after pyroxene. Approximately 5 per cent quartz, 2 per cent magnetite, and accessory apatite are also present.

The granite intrusives (AMgr), which form dykes on the largest island, consist of 50 per cent weakly perthitic potassium feldspar, 25 per cent plagioclase (An_{10}) and 20 per cent quartz with minor reddish-brown biotite almost entirely altered to chlorite, calcite, zircon and apatite.

The second largest syenite stock, on the northernmost island, is similar to that previously described and it too contains quartzite fragments up to 30 cm in diameter. At the contact this syenite has a well developed aphanitic chill zone. Joints dip inward at low angles (10 to 40°). As previously noted, this stock contains much more magnetite than other syenite plutons. At the north end a light olive-grey, fine grained, massive granite occurs along the contact between the hornfels and the syenite and is in sharp contact with both. It occupies an area 40 by 50 m. Except for the grain size and that it contains very minor amounts of muscovite instead of biotite, this rock is similar in composition and texture to the granite dykes on the largest island.

The syenite outcropping on the two islands near the east boundary is in general megascopically similar to that previously described. The more northern of the two contains inclusions of hornfels and although it is similar to the finer grained phases of the syenite on the largest island there are microscopic differences.

Augite grains, variously anhedral to euhedral, are fresh, show thin compositional zoning, and are commonly twinned. Potassium feldspar grains are small compared to the augite, cloudy, and display Carlsbad twins. Mica consists of a brown to reddish-brown anhedral biotite and a very fine grained felt-like light brown biotite that in a few places grades into a green biotite. This fine grained biotite appears to be later than the reddish-brown type and also later than clinoamphibole. Riebeckite locally borders the augite but does not replace it, and also forms euhedral grains commonly mixed in or associated with the very fine grained biotite. Trace amounts of apatite and magnetite also are present.

On the southern island the syenite displays a medium dark grey, fine grained border zone that grades into an olive-grey, medium grained rock, which in turn grades into a coarse grained rock with dark greenish-grey mafic minerals and greyish-orange pink feldspars. All these rocks are equigranular and massive.

The fine grained rock consists of subhedral to euhedral, in part twinned and zoned, fresh augite, locally containing biotite and very rarely olivine inclusions. Some of the smaller augite grains are rimmed with magnetite. Brown biotite, variously granular or fibrous, is partly altered to chlorite. A few biotite grains contain streaks of phlogopite. Subhedral to slightly rounded olivine, with 2V close to 90° (12 mol % Fe_2SiO_4), is commonly rimmed with a thick magnetite halo. Whereas most of the olivine is fresh, some grains are partly, and a few are entirely, serpentinized. Potassium feldspar, showing extensive Carlsbad twinning, is finer grained than the ferromagnesian minerals and has the appearance of flowing around them.

Trace amounts of apatite and quartz are also present. The coarse grained rock shows markedly different mineralogy and texture than the finer grained one. The potassium feldspars are large, cloudy, commonly perthitic, display local Carlsbad twins, and thin rims of plagioclase. The latter (An_5), which is generally clearer than the potassium feldspar, also occurs interstitially. Unlike the finer grained rock the ferromagnesian minerals are chiefly smaller than the potassium feldspars with only a few mixed phlogopite-biotite grains equal in size to the feldspar. Phlogopite is similar to that previously described, in that it has thin biotite rims and some grains include very minor amounts of chlorite. Small brown biotite grains are also present throughout. Olivine or pseudomorphs of it do not exist. Subhedral clinopyroxene, chiefly augite, is rarely fresh and contains much biotite and calcite and in a few places only pseudomorphs of augite exist. Zoning and twinning are both rare. Some augite grains are terminated with aegirine-augite and it also forms scattered discrete grains. Clinoamphibole is present as overgrowths on aegirine-augite where it chiefly forms tiny needles, but also as rare, subhedral grains equal in size to the augite where it shows excellent amphibole cleavage. The clinoamphibole is dominantly riebeckite but small amounts of a colourless amphibole, possibly tremolite, are also present.

The small island north of the large peninsula in Whitehills Lake is about half underlain by a dark grey, massive syenite and half by an intrusive breccia. Both rocks are cut by fine grained to aphanitic felsite or rhyolite dykes. The syenite at the north end contains rare angular and rounded quartzite and quartz fragments up to 10 cm long. The felsite and rhyolite dykes that intrude this syenite contain numerous quartzite and felsite fragments, angular and well rounded, up to 30 cm long and also rare hornfels fragments.

The breccia on the south end of the island consists of quartzite and hornfels fragments in a matrix of very fine grained felsite.

This syenite consists of subhedral phenocrysts of phlogopite, up to 4 mm, and clinopyroxene in a very fine grained matrix of potassium feldspar and biotite. The phlogopite is in part zoned and some shows thin biotite rims. The clinopyroxene is completely altered to calcite, chlorite, biotite and tremolite. A few rice-shaped grains consisting of carbonate, chlorite and magnetite may be olivine pseudomorphs. Small amounts of pyrite, sphene, albite, calcite, epidote and chlorite, occur erratically in the matrix. Rare miarolitic cavities are partially filled with calcite, chlorite, pyrite, sphene and euhedral quartz.

Dykes belonging to the Martell Intrusive Suite are oriented primarily between 060 and 090° azimuth but range from 010 to 165°. They range from less than 1 to 30 m thick but most commonly are about 3 m. Few of these dykes are known to be more than 20 m long but one, 3 m thick, near the northwest extremity of Whitehills Lake was traced for 180 m. Dykes are known to intrude the granitic rocks (Agr, Agd, etc.) and are assumed to be intruded by diabase (Ndb).

A few of the lamprophyre dykes (AMlp) contain rounded to well rounded pebble and cobble sized inclusions of massive, medium grained, equigranular, greyish-orange pink granite. This granite is lithologically dissimilar to much of the granite currently exposed within the map area but may be derived from it nevertheless. Most of these fragments are 10 cm in diameter or less, but in a dyke in granite 5.5 km east of the Thelon River a few are up to 20 cm. These lamprophyres variously intrude mafic volcanic rocks, greywacke and granitic rocks.

The syenite and lamprophyre dykes are randomly distributed. In some places the two rock types outcrop close to one another but none are known to intersect.

The breakdown of the dyke rocks into lamprophyre and syenite has been based primarily on field observation and in general those rocks with well defined mica phenocrysts have been termed lamprophyres and those either with small amounts or no mica, syenite. There is evidently a gradation between rocks here classified as lamprophyre and syenite.

The lamprophyres are medium dark grey to dark greenish-grey (commonly olive-grey), rarely greenish-red, fine- to medium-grained massive rocks that display small dark mica phenocrysts up to 1 cm in diameter, with the majority about 2 to 4 mm.

The syenite dykes are chiefly fine grained, massive, dominantly pale to greyish-red rocks. Medium dark grey and rare brownish-grey varieties are also represented.

Microscopic examination shows both the lamprophyre and syenite to be mineralogically complex. Some minerals are common to both rock types but some minerals are restricted or much more abundant in one or the other. For example, both have, in general, high potassium feldspar contents ranging from 55-80 per cent. One syenite examined has about 30 per cent plagioclase (An_{10-46}) and in this sample potassium feldspar forms only 40 per cent. Potassium feldspar is variously fresh, although cloudy, to highly altered to talc. Carlsbad twins are common and very thin rims of clear sodic plagioclase (albite) are present bordering many grains. A syenite dyke north of Whitehills Lake shows both potassium feldspar and plagioclase phenocrysts, the former perthitic in part. The occurrence of both feldspars together is uncommon.

The lamprophyres are characterized by the presence of abundant subhedral mica (10-30 per cent), chiefly phlogopite with only minor amounts of biotite, but in a few dykes biotite alone. Phlogopite forms up to 30 per cent and biotite from trace amounts to 15 per cent. Phlogopite grains are commonly rimmed by narrow biotite zones and most uncommonly phlogopite has a core of biotite. In a few lamprophyres chlorite partly replaces the micas and extremely rarely, replacement is complete.

Clinopyroxene is present in 15 per cent of the syenites and 60 per cent of the lamprophyres examined. In the syenites, where it forms approximately 20 per cent where present, clinopyroxene consists of subhedral and partly twinned augite that is locally partially to entirely altered to chlorite. In the lamprophyres, augite is partly twinned subhedral to euhedral, and in some rocks shows two size fractions. Alteration, where present, is chiefly to chlorite with scarcer calcite and epidote. In a few lamprophyres some augite has aegirine overgrowths on crystal ends. In other lamprophyres aegirine forms discrete tiny grains disseminated throughout the feldspar matrix. In these latter rocks augite is absent.

Amphiboles are rare in the syenites. Only a trace of common hornblende is present in one sample. However, in the lamprophyres amphibole forms up to 15 per cent, although absent in some rocks. Subhedral, fresh, green, common hornblende is present in a few rocks, whereas in others strongly pleochroic soda amphiboles in places after aegirine but also as separate crystals, are present. The soda amphiboles form small, subhedral or less commonly sheaf-like grains. Whereas most of the soda amphiboles are probably arfvedsonite with dusky yellow to light olive pleochroism, one specimen shows two amphiboles, the second, with pleochroism from greyish purple to pale greenish yellow, probably riebeckite. This latter occurs as overgrowths on the former.

Chlorite comprises a significant part of the syenites (5-20 per cent) but it is absent or in trace amounts in most of the lamprophyres. Epidote in the syenites occurs interstitially and also as an alteration of clinopyroxene, but in the few lamprophyres where it is common, it is an alteration of the micas.

Rarely, talc with variable amounts of chlorite and calcite, forms what are probably pseudomorphs of olivine. These also include tremolite and magnetite in some places. Unaltered olivine is not known to be present.

Calcite is present in almost all dykes and commonly comprises from 3 to 10 per cent. It occurs disseminated throughout the matrix and also fills miarolitic cavities or vesicles. As previously mentioned, it also occurs as an alteration product of clinopyroxenes and olivine.

Although rare or absent in most dykes, epidote forms about 10 per cent in one lamprophyre. In another, where it comprises only 3 per cent, it forms subhedral, pleochroic, twinned and zoned crystals.

Neohelikian

Diabase (Ndb)

Sparsely distributed, vertical or nearly vertical diabase dykes are the youngest rock type. Linear magnetic anomalies (Geological Survey of Canada, 1973) in the north quarter of the map area are produced by these dykes. The major representatives of this unit trend east-northeast but narrower and shorter dykes are variously oriented from north-northeast to east. The longest dyke extends, with breaks, for about 9.5 km through the greywacke terrane and one within the volcanic rocks, also including breaks, is 1.1 km long. These dykes show a great range of thicknesses from a few centimetres to 100 m, the latter located close to the north boundary at longitude 96°10'W. The longest dyke is variously 5 to 15 m thick and the one in the volcanic rocks is 5 to 10 m thick.

This rock is a very fine- to medium-grained, massive, olive to greenish-black, less commonly dark grey, diabase. Locally, anhedral plagioclase phenocrysts up to 5 cm in diameter are present, particularly near the dyke margins. All the larger dykes display well defined chill zones and joint sets normal and parallel to the contacts.

Thin sections of a small dyke near the west boundary show this diabase to have a good ophitic texture with fresh plagioclase (An_{46}), clinopyroxene and olivine, the latter entirely altered to serpentine, talc, chlorite and magnetite. Trace amounts of pyrite are also present.

STRATIGRAPHY

The stratigraphy of the layered rocks is not established unequivocally, however, a general sequence has been determined. The dearth of top determinations and horizon markers, coupled with structural disturbances, leaves room for more than one interpretation. Representative stratigraphic sections are shown in Figure 6 (in pocket).

The oldest layered rock unit is the polymictic conglomerate that outcrops on the north and west sides of Whitehills Lake. Evidence for this stratigraphic assignment is not, however, absolute. For example, the outcrop north of the lake contains a few white quartzite boulders lithologically similar to the quartzites outcropping to the north and west. On this evidence alone the conglomerate could be considered to be younger than the quartzite. Similarly, the outcrop to the west of the lake contains rare dolomite boulders lithologically similar to the dolomite exposed to the north and west, reinforcing a younger age for the conglomerate. However, the majority of the larger clasts in the conglomerate in both outcrop areas are granitic rocks, all of which are dissimilar to those currently exposed within the map area. The absence of metavolcanic rock clasts is also significant. Considering the volume of metavolcanic rocks to the north and west it is reasonable to expect clasts of metavolcanic rocks to also be present if the dolomite and quartzite in the conglomerate were derived from the same general source. The absence of iron formation clasts, which are much more erosionally durable than the dolomite, is also noteworthy. Therefore on compositional grounds the conglomerate is considered to predate the quartzite, dolomite and metavolcanic rocks.

Structurally, only on the north side of the lake is there any datum as to the stratigraphic position of the conglomerate. There it lies nonconformably on syenite with bedding that displays rare southward facing tops, parallel to the regional trend. To the south the conglomerate passes into a terrane dominated by greywacke that is locally hornfelsed, with small amounts of slate, argillite and siltstone. This suggests that the conglomerate forms the basal unit of the layered rocks and that the greywacke lies conformably above it.

The conglomerate, including intercalated arenaceous and argillaceous beds, is up to 425 m thick.

The greywacke, which is well exposed in the north, typically shows an increase in carbonate content in the upper portion, and in a couple of places north of the large lake northwest of Whitehills Lake carbonate-rich zones 5 to 10 m wide are present. Where metavolcanic rocks lie directly on greywacke, a few carbonate laminae are commonly present. Near the Thelon River widely scattered, rounded quartzite clasts are erratically distributed in the greywacke near the top. Greywacke is intercalated with slate near its upper limit in the northeastern part of the map area, but elsewhere is conformably overlain variously by metavolcanic rocks, dolomite, iron formation and slate.

The sequence in the east part of the map area close to the east boundary is greywacke, slate, iron formation, greywacke, quartzite, slate and metavolcanic rocks, whereas 1.3 km west it is greywacke, iron formation, slate, metavolcanic rocks, and 2.8 km farther west, greywacke, slate, iron formation, metavolcanic rocks. In the western part of the map area greywacke is commonly overlain by dolomite. Near the Thelon River the sequence is greywacke, dolomite, slate, iron formation, slate, dolomite, metavolcanic rocks, whereas farther northeast it is greywacke, dolomite, quartzite, iron formation, intermixed iron formation and greywacke, and metavolcanic rocks. In some places this zone between the greywacke and metavolcanic rocks is the site of small plutons of peridotite and gabbro, and locally these lie adjacent to the greywacke. The dolomite is extensively sheared and bedding highly distorted or destroyed throughout this zone; however, it is probably conformable.

The thickness of the greywacke is unknown.

As can be seen in Figure 6, the zone immediately above the greywacke is characterized by diversity with the various rock types occupying different places in the stratigraphic sequence from place to place, and in some places being absent. However, all are considered to be conformable and throughout a conformable sequence of metavolcanic rocks is present, whether separated from greywacke by slate, iron formation or dolomite, or lying directly on greywacke. Included in the metavolcanic member are interbedded greywacke, and less commonly, slate horizons, and in one place an iron formation, slate, quartzite and greywacke horizon. The volcanic rocks are possibly up to 1300 m until they give way to quartzite.

The contact between the metavolcanic rocks and quartzite in the western and central parts is characterized by an interlayering of the two rock types. The scale of interlayering ranges from as little as 3 to 20 m, the former consisting of an individual flow, and the latter of several flows. In the easternmost part this interlayering does not exist and the transition from volcanic rocks to quartzite is abrupt. This quartzite horizon is possibly up to 2700 m thick.

Overlying the quartzite is a second metavolcanic member of variable thickness that may be as much as 400 m thick. Locally some interlayering with quartzite occurs, but elsewhere the break between the two rock types is sudden. This second metavolcanic unit is the highest stratigraphic unit. As far as is known, the two metavolcanic members are similar both lithologically and chemically. Of the 15 analyses in Table 1, 9 are from the lower member, 8 of which are biotite-rich rocks, and 6 are from the upper member, 3 of which are biotite-rich rocks.

STRUCTURE

The structure of the Half Way Hills map area is poorly understood in detail because of a dearth of primary structures, including bedding, throughout the layered rock sequence. Only 16 crossbeds, 5 graded beds, and 2 ripple marked surfaces were located in the sedimentary rocks and 7 areas of useful pillows in the metavolcanic rocks. Secondary structures in the form of drag folds, crenulations, clast elongations and crinkles are more common, and 90 of these were noted.

On a smaller scale the map area lies within the Armit Lake block, a structural unit considered by Heywood and Schau (1978) to be an intermediate to deep level crustal derivative. Within the map area two prominent strike faults, one on each side of the Half Way Hills, divide the area into three blocks. In the northwest the rocks are mixed sedimentary, volcanic and plutonic, in the centre chiefly quartzite and volcanic, and in the southeast mixed sedimentary, volcanic and plutonic, the latter including the only major occurrences of the Martell Intrusive Suite. The central block contains a major syncline, the sole clearly defined macroscopic fold.

Faults

Faults fall into two groups, strike faults and cross faults. The former trend east to northeast, whereas the latter trend primarily north to northwest, with a few easterly. The strike faults are reverse faults and probably thrusts. For example, the major fault that forms the west and northwest limit of the central block, is probably a thrust fault that pushed the central block over the northwestern one. In general, drift covers this fault plane, but where exposed it cuts both layered and granitic rocks and is characterized by mylonitized granitic rocks, micaceous quartzite schist, and locally, phyllitic schist. Crenulations in the schist plunge east-southeasterly between 30 and 60°. North of latitude 97°37'N this fault is less prominent and either dies out or breaks into several splays that are wholly within the quartzite in some places. Similarly, the major strike fault on the southeast side of the central block is probably also a thrust. It lies north of the conglomerate (Acg) and syenite (Asy) on the north side of Whitehills Lake, extends across the northwest end of the lake, along the valley wall of the bulbous peninsula on the west side of the lake, and probably extends to the south boundary. In the south it forms most of the contact between quartzite and granitic rocks. Extremely rare kinks and crenulations in sedimentary rocks show plunges of 45 to 75° to the south and southeast near this fault line. This fault is assumed to have thrust syenite (Asy) and conglomerate (Acg) onto the younger quartzite on the north side of the lake. A branch of this fault probably lies in the drift west of the conglomerate (Acg) on the west side of Whitehills Lake.

Other strike faults occur within the stratigraphic sequence, chiefly in quartzite and metavolcanic rocks. For example, metavolcanic rocks along the river entering the large lake northwest of Whitehills Lake are in part in fault contact with greywacke, and this too is probably a reverse or thrust fault. The small area of polymictic conglomerate (Acg) 8.5 km north of Whitehills Lake may also have been emplaced by thrusting along a line now defined by a prominent valley running east-northeast and along the large lake to the west. The amount of displacement on the strike faults is unknown but it is chiefly dip-slip with thrusting from the southeast.

Cross faults, chiefly vertical or nearly vertical, offset the strike faults and hence postdate them. They are particularly common in the central quartzite-volcanic block. Strike separations range from a few metres to 1000 m or possibly more. Conspicuous hematite occurrences occur along many of the cross faults in the quartzite. For example, a 3 m wide zone of quartz-hematite breccia is present in the quartzite 600 m east of the Thelon River and 800 m north of the south boundary along an east-southeast-trending cross fault. Similar hematite-rich zones are present in several places within the quartzite northwest of Whitehills Lake. Cross faults in the metavolcanic rocks are commonly characterized by extensive carbonatization. This is particularly prevalent on islands and on the hook-shaped peninsula in the large lake northwest of Whitehills Lake. Moderate reddish-brown weathering carbonate zones up to 2 m wide and bordered by extensively carbonatized metavolcanic rocks are typical.

All faults postdate the emplacement of the granitic rocks but their relationship to the Dubawnt Group is unknown. No faults are known in the major outcrop areas of the Martell Intrusive Suite and its intrusion may be post-faulting.

Folds

The only major fold defined is in the central block. Undoubtedly, small folds are present within the larger structure, as suggested by local reversals in dip, in the quartzite in particular. The only two top determinations on the southeast limb of the major fold are southeast facing and these also probably form parts of smaller folds. However, none are defined due to heavy lichen cover and dearth of bedding data.

The fold in the central block is an inclined, partly isoclinal, syncline extending northeast from near the southwest corner of the map area. Its nose is 1.5 km farther south. The location of the trace of the axial surface of this fold is poorly demarcated, particularly in the northeast, due to tight closure plus offsets by cross faults. The majority of the crenulations and minor folds in the quartzite and metavolcanic rocks show plunges to the southwest between 15 and 70° and average about 30°, suggesting a similar plunge for this major fold.

METAMORPHISM

All the rocks of the Half Way Hills map area are metamorphosed except for the Martell Intrusive Suite and diabase dykes. The entire area is in the regional greenschist facies with minor local contact metamorphism adjacent to some of the intrusive rocks. The following mineral assemblages are characteristic of the greenschist facies:

Pelitic rocks:
- quartz-albite-muscovite-chlorite (-epidote-calcite)
- quartz-albite-biotite-muscovite-chlorite

Quartzofeldspathic rocks:
- quartz-albite-chlorite-calcite-sphene
- quartz-albite-biotite-muscovite-chlorite (-epidote-calcite-tourmaline)
- quartz-albite-muscovite-chlorite-calcite (-epidote)
- quartz-albite-muscovite-calcite (-epidote-tourmaline)
- quartz-albite-chlorite-calcite (-epidote-sphene)

Basic rocks:
- albite-epidote-chlorite (-biotite-sphene-calcite)
- albite-epidote-actinolite (-biotite-chlorite-sphene)
- albite-epidote-actinolite-chlorite-sphene-calcite
- albite-chlorite-biotite (-sphene-calcite)
- albite-actinolite-chlorite-sphene-calcite

As none of these rocks contain garnet or hornblende, the temperature and pressure conditions never rise above the lower to middle portion of the greenschist metamorphic zone.

Contact metamorphism is most prominent on the islands in Whitehills Lake cored by Martell Intrusive rocks and along the contact zone with some of the granitic rocks. The hornfels at Whitehills Lake mineral assemblage is quartz-albite-biotite-muscovite-chlorite, which is characteristic of the albite-epidote-hornfels facies.

Metasedimentary and metavolcanic rocks, particularly in the southeast, display hornblende hornfels grade contact metamorphism. These rocks are characterized by assemblages with andesine, hornblende, biotite and rare andalusite, and cummingtonite. Most of these rocks show some retrograde effects with chlorite and epidote.

CORRELATION AND AGE OF LAYERED ROCKS

The correlation of the layered rocks with others in the District of Keewatin must be established before a meaningful interpretation or synthesis is possible. In the past most of the layered rock units containing significant amounts of quartzite have been assigned to the Aphebian Hurwitz Group. The rocks in the present map area have been so assigned by Wright (1967) and Donaldson (1966). However, this correlation is rather tenuous, as Wright recognized. When making his correlation he considered the bulk of the volcanic rocks in the Half Way Hills area, now known to be interlayered with the quartzite, to be older than the quartzite. Donaldson reported some volcanics to be interlayered with quartzite but did not assign them to the Hurwitz Group. Wright also assigned an extensive area of quartzite and other sedimentary rocks in the Amer Lake area (66H), north-northwest of the present map area, to the Hurwitz Group, so that a distance of 500 km separated the type region, the Kognak River area (Eade, 1974), from the northernmost representatives. How valid is this correlation?

The type region of the Hurwitz Group mapped by Eade (1974) is dominated by up to over 1220 m of orthoquartzite, which is commonly the basal unit. In a few places a polymictic conglomerate forms the base. A shale-slate-siltstone-greywacke unit overlies the quartzite. Whereas carbonate in places overlies the orthoquartzite, in most other places a carbonate-argillite member with very minor iron formation overlies the shale-slate-siltstone-greywacke. The dolomite-argillite unit is followed by greywacke, which in turn gives way to impure quartzite that contains some carbonate in the upper part. A few gabbro sills occur in the slates overlying the orthoquartzite. Volcanic rocks are not present in the type region but a few are known in the upper part of the group elsewhere (Bell, 1970; Eade, 1971; Eade and Chandler, 1975). The uppermost Hurwitz Group consists of greywacke, siltstone, argillite and dolomite, which is overlain by a feldspathic, dolomitic arenite with minor siltstone and shale.

In the Amer Lake map area layered sedimentary rocks, informally named the Amer group by Heywood (1977) consist of quartzite, feldspathic sandstone, conglomerate, slate, carbonate rocks and derived schist and phyllite. Tippett and Heywood (1978) show a stratigraphic column for the group. Unlike the sequence in the Half Way Hills map area, there are no volcanic rocks in their column. More recently, Patterson (1981 and personal communication) considered a minimum of 300 m of mafic volcanics to occur in the core of a syncline near the top of the Amer sequence. The rocks mapped by Patterson are not deemed to form part of the Amer group by Heywood (personal communication, 1982) and Tella (personal communication, 1982). Most of the volcanic rocks in the Amer Lake map area form part of the basement for the unconformably overlying Amer group. The carbonate rocks, unlike the present sequence in the Half Way Hills area, overlie the quartzite.

Table 2. Analyses of iron formation

	Ag ppm	Au ppm	As ppm
A61	<0.1	<5	< 2
A105	<0.1	<5	3
TA59C	<0.1	<5	3
TA94C	<0.1	<5	2
TA97	0.3	<5	20
TA114	<0.1	<5	10
TA155	<0.1	<5	4
TA161A	<0.1	<5	< 2
TA190	<0.1	<5	20

Bondar-Clegg and Company Limited Analysts

Table 3. Analyses of till samples

Sample No	Cu ppm	Pb corr ppm	Zn ppm	Mo ppm	Co corr ppm	Ni corr ppm	Cr ppm	Mn ppm	Fe %	U ppm
1	115	37	115	6	27	70	55	625	6.46	4.3
2	97	31	81	7	19	45	52	475	5.61	6.2
3	107	33	131	10	26	54	65	745	6.90	5.8
4	109	44	87	6	32	68	53	735	5.59	5.3
5	118	35	120	5	21	66	71	685	6.41	4.5
6	126	34	145	5	30	73	88	720	6.32	4.3
7	106	48	124	7	27	57	63	545	6.05	5.8
8	110	46	137	11	21	48	68	475	7.14	7.7
9	112	68	118	10	18	47	62	415	7.49	4.4
10	132	27	134	2	34	60	105	645	6.82	3.1
11	108	47	77	11	14	35	56	355	6.95	3.0
12	129	42	96	10	19	47	66	475	6.98	6.5
13	200	29	163	7	35	85	118	975	7.82	1.3
14	130	29	137	6	25	76	82	880	6.48	4.2
15	103	34	111	6	20	51	61	430	6.03	5.3
16	161	31	127	7	25	74	86	670	6.88	4.0
17	123	37	148	5	35	72	86	725	6.50	5.6
18	116	29	125	10	27	58	68	549	6.45	5.4
19	203	25	80	9	16	40	53	355	7.40	5.8
20	166	31	82	9	21	42	62	488	7.41	7.3
21	133	34	180	5	43	73	96	1030	6.82	5.8
22	138	32	181	6	31	84	105	973	6.92	5.5
23	157	43	127	4	45	49	73	1650	8.50	3.0
24	119	40	213	7	53	108	67	828	6.49	4.3
25	194	25	128	5	41	365	477	1280	8.15	2.1
26	67	34	73	3	15	30	73	600	5.55	2.0
27	103	36	128	4	24	56	91	795	6.35	3.3
28	93	37	128	4	23	60	91	885	5.21	2.7
29	92	28	128	5	21	54	91	1060	6.29	2.2
30	147	33	93	5	23	34	73	1480	6.60	2.2
31	126	31	126	4	19	64	92	783	6.40	6.2
32	139	23	124	5	19	67	84	602	6.30	3.3
33	83	36	105	6	20	45	70	905	6.64	2.8
34	104	45	103	6	22	50	64	649	7.65	3.2
35	138	46	152	6	23	64	82	910	6.58	5.0
36	130	44	111	5	36	47	74	1440	7.50	3.1
37	162	54	131	7	23	61	96	845	6.75	4.0
38	114	31	113	8	27	79	67	540	6.02	5.6
39	117	39	137	4	37	67	114	1040	7.52	2.2
40	154	26	138	3	24	74	88	685	6.58	1.4
41	120	27	143	4	27	71	84	875	5.42	1.8
42	198	47	174	3	40	142	159	920	6.75	4.1
43	108	27	98	3	33	56	75	815	5.07	2.7
44	144	39	187	8	31	78	108	845	6.75	17.8
45	172	35	161	4	40	86	108	1025	6.60	5.7
46	145	41	138	5	46	86	133	1330	6.35	3.6
47	88	30	106	8	29	53	82	779	6.18	5.5
48	104	43	136	4	24	55	68	770	6.27	1.6
49	112	54	147	4	31	54	67	905	6.42	6.4
50	149	5	276	7	225	1550	2400	1260	7.30	ND
51	169	58	180	5	42	82	86	915	6.52	3.7
52	115	31	113	4	26	51	76	725	6.75	2.6
53	89	28	98	5	27	48	85	925	6.99	3.5
54	96	30	123	4	23	51	98	435	6.13	3.6
55	107	41	134	4	29	58	94	1090	6.31	2.3
56	124	45	147	4	25	65	90	1010	6.09	2.2
57	281	68	163	6	41	73	99	1610	7.70	6.3
58	56	31	117	2	16	38	75	365	4.35	3.3
59	129	53	135	3	25	59	82	950	5.80	2.0
60	109	39	98	5	25	46	75	760	6.60	2.9
61	121	36	130	3	22	53	79	840	6.30	5.3
62	97	37	113	6	29	37	65	1100	6.30	3.6
63	94	45	116	4	29	48	91	1290	6.35	2.2
64	71	25	57	9	14	29	49	285	6.85	3.0
65	169	77	82	8	17	36	62	415	7.65	3.7
66	120	22	95	5	25	55	76	548	5.56	6.3

Table 3 (cont.)

Sample No	Cu ppm	Pb corr ppm	Zn ppm	Mo ppm	Co corr ppm	Ni corr ppm	Cr ppm	Mn ppm	Fe %	U ppm
67	229	29	76	5	18	36	64	455	6.41	3.3
68	79	53	159	9	44	88	71	1120	7.45	5.6
69	108	15	67	14	40	148	110	3320	22.1	2.7
70	137	33	130	4	22	58	79	725	5.68	1.9
71	126	46	128	4	34	57	99	1060	6.58	4.0
72	185	84	108	3	42	40	59	1760	6.71	2.7
73	61	28	77	4	17	29	58	515	5.94	1.8
74	130	50	129	3	45	66	90	1690	7.05	2.4
75	122	33	107	5	24	40	71	845	6.05	3.3
76	147	47	105	6	35	55	75	885	7.30	5.3
77	122	34	147	3	25	63	88	805	5.85	2.7
78	149	40	150	5	24	65	84	730	6.10	2.3
79	110	35	91	5	24	49	60	640	5.85	4.7
80	99	25	78	5	20	46	80	455	5.65	4.9
81	109	31	80	6	25	41	73	565	5.85	5.1
82	117	27	114	6	29	60	105	815	6.30	6.4
83	86	72	51	10	6	17	43	210	6.55	2.0
84	91	78	34	11	5	17	30	86	8.45	3.1
85	125	35	128	6	23	64	53	655	6.08	5.3
86	139	31	113	9	26	73	68	595	5.90	7.4
87	149	33	146	3	26	68	82	742	6.00	1.2
88	138	85	136	14	16	23	60	535	7.85	8.8
89	136	27	158	3	27	80	135	785	6.85	6.8
90	127	40	148	10	28	42	72	855	6.18	6.6
91	178	58	74	9	16	26	47	355	8.30	4.0
92	119	46	120	2	30	80	92	740	5.49	4.2
93	143	42	143	9	41	45	66	875	6.21	6.6
94	115	33	127	8	32	73	138	865	6.49	5.1
95	132	36	136	7	36	60	91	1010	6.54	5.3
96	113	35	134	5	23	68	79	610	6.10	3.2
97	144	21	120	2	27	78	83	805	6.25	0.9
98	187	30	97	6	37	63	76	845	6.88	4.4
99	163	24	96	5	39	68	80	1040	6.25	4.0
100	102	35	93	6	27	43	56	655	6.31	2.7
101	528	31	138	4	46	113	200	2090	10.30	3.1
102	152	28	117	4	34	37	76	805	7.05	4.0
103	156	39	123	9	28	67	104	835	6.72	6.8
104	149	34	113	7	20	53	90	605	6.05	5.3
105	136	45	134	6	35	44	66	1390	6.97	2.5
106	176	40	162	4	29	84	144	1160	6.86	3.2
107	139	37	134	4	38	65	147	955	7.28	3.1
108	144	27	121	3	33	55	108	1040	7.20	1.3
109	443	27	133	4	31	58	80	1020	6.49	2.9
110	105	7	118	2	36	48	16	735	4.51	0.5
111	175	25	147	3	28	78	113	785	6.18	1.3
112	211	32	158	4	31	85	115	835	6.60	4.0
113	158	31	108	5	39	68	76	955	6.38	4.6
114	157	40	141	9	45	73	124	1015	8.85	6.6
115	97	33	100	7	23	40	70	575	5.59	3.1
116	136	32	96	8	28	44	83	635	6.39	5.1
117	142	46	91	11	23	42	84	485	7.48	5.3
118	166	33	132	7	31	69	75	630	6.51	5.5
119	150	35	134	6	31	61	69	910	6.52	3.3
120	124	22	84	6	20	46	62	560	5.51	4.1
121	110	28	128	3	23	58	75	660	5.52	1.6
122	238	38	142	10	38	65	91	1360	6.85	2.2
123	135	50	149	3	39	62	59	1010	7.75	4.9
124	51	26	99	5	45	55	67	1490	6.75	2.0
125	146	29	134	4	33	64	84	1000	7.05	6.5
126	140	25	133	10	26	66	88	880	6.35	2.2
127	121	32	86	1	18	37	71	420	6.45	4.9
128	124	29	112	4	28	54	96	635	6.38	2.9
129	136	39	124	9	32	55	91	660	6.91	5.7
130	94	29	104	3	25	50	82	865	5.99	0.9

Note: ND means not detected

Figure 7 (in pocket) shows how the Half Way Hills strata differ conspicuously from the Hurwitz Group and the Amer group, both as to composition and rock type sequence. A great thickness of quartzite is the only common factor. The Amer group is dominantly sedimentary and volcanic rocks are of limited extent in the Hurwitz Group and absent in the type area. Iron formation is much more common in the present area, being of limited extent in the Hurwitz Group and absent, except for a hematite breccia, in the Amer group. There is no sequential correspondence except for a locally developed basal or near basal conglomerate. Correlation of the Half Way Hills strata with the Hurwitz Group is tenuous at best and for the present should be abandoned. Despite the proximity with the Amer group there is no foundation on which to correlate with that group either. It is evident that two distinct supracrustal rock groups are present in the region north of Baker Lake. The presence of a great thickness of volcanic rocks, including a few komatiites, provides a better correlation with the basement rocks in the Amer Lake area than with the Amer group. Ashton (1982) reports that the layered rocks in the map area northwest of Tehek Lake (66H/1) consist of metavolcanic rocks (including komatiites), metagreywacke, iron formation, volcanogenic sedimentary and chemically precipitated rocks, quartzite and rare phyllite. Ashton's map shows the quartzite and greywacke units to be very extensive and that the thickness of quartzite is comparable to that in the present map area. Whereas the sequence of strata is not fully defined, Ashton (1982, p. 157) notes ".....greywacke appears to grade conformably into other metasediments, iron formation and ultimately into metavolcanic rocks...." This is similar to the present sequence. However, Ashton concludes the quartzites are the oldest supracrustal rocks on the basis of quartzite pebbles in greywacke, which does not agree with data in the present map area. However, the dearth of top information in both areas leaves considerable doubt as to the stratigraphic sequence and the existence of more than one quartzite source is likely.

The present rocks are also lithologically similar to those of the Archean Prince Albert Group (Heywood, 1967; Schau, 1975, 1982) which consists of a mixture of quartzite and other clastic sediments, iron formation, and felsic, basic and ultrabasic volcanic rocks.

A zircon age of 2792 Ma was obtained by Heywood on layered basement rocks in the Amer Lake area, demonstrating an Archean age. Hence, the present strata are considered Archean.

The assignment of the layered rocks to the Archean leaves the age of the granitic rocks suspect. Only a single K-Ar biotite age of 1690 Ma (Lowdon, 1960) has been obtained in the district and is too far removed from the present area to be considered. Until such time as suitable dating material can be obtained from the granitic rocks their age is questionable. They are probably Archean.

SYNTHESIS

In the Archean, basement rocks known only to consist of syenite (Asy), were extensively eroded, which was followed by deposition of a coarse polymictic conglomerate. This conglomerate displays a heterogeneous lithology that is probably fairly representative of the rocks then exposed, being chiefly sedimentary and plutonic.

The conglomerate was succeeded by a rapid buildup of a great but indeterminate thickness of greywacke. Presumably, a shallowing of the sea accompanied by minor structural disturbance locally resulted in rare greywacke cobbles in the upper part of the greywacke. Shallower sea conditions can also be inferred from an increase in carbonate content within the greywacke in general, plus local carbonate-rich zones.

Ever decreasing water depth, possibly in part related to an onset of volcanism, ushered in unstable conditions that resulted in the deposition of a variety of rock types, depending upon local conditions. For example, in the northeast, greywacke locally interlayered with argillaceous rock is overlain by iron formation, whereas in the west greywacke is succeeded commonly by dolomite, which in turn is overlain by slate and/or iron formation. Still in other locales, volcanic rocks lie directly on greywacke. Less commonly, quartzite, chert, argillite, siltstone and possibly tuff were deposited in this transition zone at the top of the greywacke.

An intermittent outpouring of submarine volcanic rocks, as indicated by thin intercalated greywacke and other sediment horizons, followed the deposition of the iron formation and dolomite. Early in this volcanic episode rare komatiite flows were extruded. Probably at or close to the same time small ultrabasic and gabbroic stocks and sills were intruded, chiefly within or next to the zone of iron formation and dolomite. The extrusive period gave way to the deposition of a great thickness of remarkably clean quartzite and rare argillaceous rocks, now schist. The change from volcanic rocks to quartzite is abrupt in some places, whereas in others interlayering of these two rock types is typical, presumably the latter being where volcanism was intermittent. The derivation of this great thickness of quartzite, although possibly of second cycle derivation, cannot be demonstrated. A second period of volcanism followed the quartzite deposition.

At this stage in the geological history tectonism and plutonism became the dominant factors. The granitic rocks, also probably Archean, intruded all the previous rock units and probably penecontemporaneous folding occurred. Compression, chiefly from the southeast, folded the volcanics and quartzites into the major syncline and produced the lesser structures also. Continued northwest-southeast compression resulted in the thrusting of southeast blocks over those to the northwest. Numerous cross faults are later than the thrusts as a result of late adjustments. An extensive erosional period probably followed this mountain building as to the north and south Aphebian sedimentary strata overlie the Archean rocks unconformably.

The emplacement of the Martell Intrusive Suite during the Aphebian was apparently quite a passive event in this area, these plutons being the northernmost testimony of the Dubawnt disturbance. The two K-Ar biotite ages shown on the present map are minimum ages. A more reliable age for the Martell Intrusive Suite is provided by a Rb-Sr isochron on volcanic rocks genetically related to the intrusive suite of 1786 ± 26 Ma (Wanless and Loveridge, 1972).

Tensional forces during the Neohelikian permitted the emplacement of the northeasterly trending Mackenzie diabase dykes.

ECONOMIC GEOLOGY

The lithology, metamorphic grade, and structure, provide a suitable environment for metalliferous deposits, although to the present no significant mineralization has been discovered. Donaldson (1966) reported the presence of small amounts of galena in milky vein quartz along the west margin of the granitic stock 6.4 km northwest of Whitehills Lake and a couple of gossans in the metavolcanic rocks. The galena occurrence is in an irregular 6 cm quartz vein at the granite-metavolcanic contact. Mineralization is very sparse and consists of tiny grains of galena and pyrite with chlorite.

The gossans shown by Donaldson are all in zones of intensive carbonatization of the metavolcanic rocks. These and other carbonatized zones examined during the present survey are not mineralized. During the present survey, an 8 cm thick quartz vein, that strikes 135° and dips 65° southwest, was located in a volcanic breccia approximately 2 km north-northeast of the galena mineralization. It is exposed for only 30 cm. This vein contains small amounts of chalcopyrite and pyrite. These are extremely altered to malachite and limonite.

Following publication of air magnetic data in 1973, those areas displaying high magnetic anomalies were staked. All these areas are underlain by iron formation. None of the iron formation is known to be extensive or rich enough to warrant further examination. Nine samples of iron formation were analyzed for silver, gold and arsenic. The results are shown in Table 2. However, despite the general absence of mineralization, the area does have economic potential. A sporadic till survey, during which 130 samples were collected from frost boils covers most of the area underlain by layered rocks. These samples were analyzed for Cu, Pb, Zn, Mo, Co, Ni, Cr, Mn, Fe and U. The analyses are shown in Table 3 and sample locations in Figure 6 (in pocket). Several samples show anomalously high metal contents. For example, 7.2 km east of the Thelon River at latitude 69°37'N a nickel analysis shows 1550 ppm, whereas background readings range from 45 to 86 ppm. This sample is from the dolomite-iron formation-slate zone stratigraphically above the greywacke. Although this zone contains small peridotite stocks to the south of the till sample, peridotite does not outcrop within 1.5 km. Two other soil samples from the same stratigraphic zone show 365 and 148 ppm Ni. In the same general area, chromium, cobalt, manganese, lead, iron and zinc contents are also well above background values.

Predictably, most of the anomalously high copper analyses are from samples collected in areas underlain by metavolcanic rocks. Two samples over 4 times copper background are located at latitude 64°40'N longitude 96°09'30"W, and latitude 64°39'40"N longitude 96°12'36"W. In both places there is extensive shearing in the metavolcanic rocks.

Uranium analyses show consistently low concentrations and confirm scintillometer examination of rock samples which indicated only background amounts.

Geological and geochemical data suggest that future prospecting in the area should be concentrated in the zone between the greywacke and metavolcanic rocks and within the metavolcanic rocks.

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