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AYLWIN-CAWOOD AREA (PONTIAC AND GATINEAU COUNTIES) - FINAL REPORT

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AYLWIN - CAWOOD AREA

PONTIAC AND GATINEAU COUNTIES

DONALD R. BAKER

FINAL REPORT

Province of Quebec, Canada

DEPARTMENT OF MINES

Geological Surveys Branch

GEOLOGICAL REPORT

AYLWIN-CAWOOD AREA

PONTIAC AND GATINEAU COUNTIES

By

Donald R. Baker

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AYLWIN-CAWOOD AREA

Pontiac and Gatineau Counties

by Donald R. Baker

INTRODUCTION

The Aylwin-Cawood area, which comprises about 210 square miles and is bounded by latitudes $45^{\circ} 45'$ and $46^{\circ} 00'$, a distance of about 18 miles, and longitudes $76^{\circ} 00'$ and $76^{\circ} 15'$, a distance of about 12 miles, was examined and mapped during the summer of 1954. The area includes most of the townships of Low and Aylwin in Gatineau county as well as large portions of the townships of Alleyn, Cawood and Aldfield in Pontiac county. In addition very small portions of Hincks and Masham townships in Gatineau county are included. The center of the area is about 35 miles northwest of Hull.

Highway No. 11 and the Canadian Pacific traverse the northeast corner of the area. The gravel road connecting Kazabazua and Campbells Bay traverses the northern portion in an east-west direction. In addition the area is traversed by several well traveled local roads, other infrequently traveled roads, and numerous bush roads, all of which make the terrain reasonably accessible.

The writer spent about $3\frac{1}{2}$ months during the summer of 1954 in mapping the Aylwin-Cawood area. The base map was the Fort Coulonge Quebec-Ontario topographic sheet (Canada Mines & Technical Surveys, Sheet No. 31 F/N.E.) for which the scale is two miles to one inch and the contour interval is 100 feet. The base map was enlarged four times, so that the field mapping was done on a scale of two inches to one mile. The map proved extremely detailed and accurate even at the enlarged scale. In addition, excellent aerial photographs on a scale only slightly smaller than that of the enlarged base-map were available.

All the field mapping was done by pace and compass traverse. In general, traverses were spaced one-half to three-quarter miles apart and in such a direction that the line of traverse crossed the formations at right angles to their trend.

The writer gratefully acknowledges Mr. Claude Plamondon, who was a very able and helpful field assistant during the summer's work.

No previous detailed work has been done in the Aylwin-Cawood area. However, Wilson (1924) made a general study of the Maniwaki area which included the area under discussion here. Geologic maps and preliminary reports have recently been prepared for several adjacent areas. These include the Denholm-Hincks area, Gatineau county (Mauffette, 1949) which is immediately east of the Aylwin-Cawood area, the Onslow-Masham area, Pontiac and Gatineau counties, (Sabourin, 1954) which is immediately south of the Aylwin-Cawood area, and the Wakefield area, Gatineau county (Beland, 1954) which lies immediately to the southeast of the area described in this report. In addition maps are in preparation for the areas immediately to the southwest and west of the Aylwin-Cawood area. Finally, the Calumet Island area, Pontiac county, which has been mapped in detail by Osborne (1944) lies about thirty miles west-southwest of the Aylwin-Cawood area. Thus the general region surrounding the area under discussion here has been the subject of considerable geologic investigation during the past few years.

PHYSIOGRAPHY

The northern half and most of the southwestern quarter of the area are drained by the Picanoc and Kazabazua rivers which flow eastward into Gatineau river. The southeastern quarter of the area is drained by Venosta, Stag and Blackwater creeks which also flow eastward into Gatineau river. A very small portion of the southwest corner is drained to the west into Quyon river which flows south to Ottawa river. Finally, a small portion of the area in the extreme south drains south into the Lepeche river which flows eastward into the Gatineau river.

Physiographically the area is divided into two parts. The eastern third of the area is essentially a lowlands region or flat plain the elevation of which varies from about 500 to 650 feet, and which is covered by Pleistocene sand and clay. This plain is broken by numerous small hills which rise as much as 200 to 250 feet above the level of the plain. The western two thirds of the area is essentially a highland region. Its terrain is composed of broken hills and some extended ridges. The maximum local relief is about 700 feet. The rivers and streams in the valley bottoms flow at about 600 feet elevation and the highest hill, O'Brien mountain, stands at about 1300 feet elevation. In the valleys and lake areas of the highland region Pleistocene sand deposits are characteristic. In general their elevation is near 700 feet; however, in some restricted areas, such as immediately west of Isabel lake, such sand plains may attain elevations as great as 800 feet. The physiographic boundary between the lowland plain and the highlands corresponds to the geologic boundary between a formation of crystalline limestone, which underlies most of the sand and clay plain, and a formation of more resistant granitic gneisses which outcrops immediately to the west of the lowland-highland boundary. (Plate 1).

The Gatineau river which drains southward and joins the Ottawa river just east of Hull passes through the northeastern corner of the area. Its course in the Aylwin-Cawood area is over bedrock of crystalline limestone and surficial Pleistocene sands. In addition, its course southward through the Denhem-Hincks area (Mauffette, 1949) and the Wakefield area (Beland, 1954) is mostly over crystalline limestones; however, in many places it flows through narrows cut into syenite (Beland, 1954). Well to the north in the Kensington area (de la Rue, 1953) the Gatineau river flows over crystalline limestone. Therefore, it appears evident that the Gatineau river has selected a course over a relative non-resistant crystalline limestone formation which trends more or less north-south from near Hull to beyond Maniwaki.

The Kazabuzua river has its headwaters to the west of the area near the community of Otter Lake, Leslie township. In general the river flows upon Pleistocene sand in both the highland and in the lowland regions. In the highland area the general course of the river is parallel to the structure of the underlying rocks. However, near the community of Danford's Lake the course of the river flows directly across the structural trend of the rocks and thence eastward across the sand plain to its junction with the Gatineau river. As indicated by its meandering path on the sand plain, the Kazabuzua river probably flows at about grade.

Stag Creek, which flows eastward from Cawood in the southern part of the area has a course which passes directly across the structural trends of the underlying rocks. As its path parallels, and in part is superimposed, on the trend of a fault which has displaced the bedrock, it is proposed that the course of the creek may be controlled by a zone of weakness along the fault plane.

There are numerous small lakes in the region. Many of the lakes in the highland area have rock basins, but most of the lakes are in areas covered by Pleistocene sand and hence probably have sand bottoms. Danford and Sinclair lakes, which are the two largest lakes in the area, are mostly fed by the seepage of ground water through the very porous and permeable Pleistocene sand. It is suggested that the origin of the larger lake basins is due to a combination of effects of bedrock topography and Pleistocene sand deposition. Thus, in most cases, the present large lakes reflect the bedrock topography and probably occupy positions of former rock-basin lakes which were present prior to Pleistocene sand deposition.

Most of the area is heavily wooded; however, outcrop coverage is adequate for the map scale used.

GENERAL GEOLOGY

Introduction

Most of the area is underlain by crystalline rocks of pre-Cambrian age. Paleozoic rocks are absent. Unconsolidated sedimentary deposits of Pleistocene and Recent age cover much of the area.

The oldest rocks in the area are highly metamorphosed and metasomatized sedimentary rocks including crystalline limestone, various gneisses, some quartzites and, in addition, complex rocks such as skarns, metamorphic pyroxenite and some garnet gneisses which have originated from the interaction between metasediments and the younger igneous rocks. These rocks are Grenville-like (Dresser and Denis, 1944, p. 50) and are hence referred to as members of the Grenville series. Pink granite or granite gneiss and greenish quartz diorite are rocks which occur in large volumes and appear to be of intrusive igneous origin and are younger than the Grenville series. A subordinate amount

TABLE OF FORMATIONS

CENOZOIC	Recent and Pleistocene	Gravel, sand, clay and glacial drift
LATE PRECAMBRIAN		Diabase
EARLY PRECAMBRIAN	Post-Grenville Rocks	<p>Early dikes: Meta-lamprophyre and meta-syenite.</p> <p>Granitic injection complex: largely pink granite, granite gneiss and pegmatite with Grenville series.</p> <p>Pink granite, granite gneiss and pegmatite.</p> <p>Dioritic injection complex: largely green quartz diorite and related facies with Grenville series.</p> <p>Greenish quartz diorite and related facies.</p> <p>Anorthosite.</p>
	Grenville Series	<p>Crystalline limestone, Graphitic and biotitic gneiss, Quartzite, Hornblende gneisses and biotitic hornblende gneiss, Sillimanite-garnet-biotite gneiss, Garnet-hornblende gneiss, Pyroxene and hornblende skarns, Metamorphic pyroxenite.</p>

of anorthosite is present. Early dikes (meta-lamprophyre and meta-syenite) cross-cut the Grenville series and some of the other intrusive rocks. Diabase dikes cross cut all the other pre-Cambrian rocks in the area. The rocks and their probable age relationships are summarized in the Table of Formations.

In mapping the rocks of the Grenville series it was possible to separate several lithologically distinct formations. In general, however, it proved impossible to determine the relative ages of these formations. Therefore, in the accompanying table of formations the Grenville-like rocks (Dresser and Denis, 1944, p. 50) are all grouped together under the conventional category of the Grenville series as though they were all of the same age. However, as discussed in the section on structural geology, there is some evidence which indicates that the Grenville series in this area may be composed of Grenville-like rocks of two distinct ages.

Grenville Series

Introduction

The Grenville formations as shown on the geologic map of the Aylwin-Cawood area are highly generalized. In most cases each formation is composed of an interlayered mixture of the various lithologic types characteristic of the Grenville series as well as layers of the younger igneous rocks. In the appendix the overall nature of each of the mappable formations is briefly described. In the following section a detailed description of the chief lithologic types of which the Grenville formations are composed is given.

Crystalline limestone

Crystalline limestone is the principal rock type within the Grenville series. A more or less north-south belt of crystalline limestone, which

is continuous with a similar belt in the Wakefield area (Beland, 1954) to the southeast and forms the western margin of the broad belt of crystalline limestone present in the eastern half of the Denholm-Hincks area (Mauffette, 1949), underlies most of the sand and clay plain in the eastern (lowland) part of the Aylwin-Cawood area. In addition crystalline limestone occurs in large mappable bodies in the highland region of the area as well as distributed in smaller quantities within other Grenville formations.

There appear to be no major differences between crystalline limestones throughout the area. A relatively low topographic expression is characteristic of all the limestone formations. The typical limestone is a gray to white color (rarely pinkish) on fresh fracture and weathers to a dull gray color.

Generally the crystalline limestones are composed of over 90 percent calcite; however, in places 10 to 20 percent of dolomite is present, and some few layers contain sufficient quartz to be called quartzitic limestone. Graphite and phlogopite are ubiquitous minor minerals of the crystalline limestones. In addition, sulphides, quartz, apatite, muscovite, tremolite, diopside, and olivine, which is always partly to completely altered to a mixture of antigorite and chrysotile, i.e. serpentine, are frequent minor constituents. Some limestones such as those immediately south of the village of Cawood give off a fetid hydrogen sulphide odor when struck with a hammer.

In general the crystalline limestone is medium grained and even grained. In some cases, however, the rock is very coarse grain with calcite crystals up to 1 to 2 inches in diameter. Calcite grains as well as most of the other minerals show no crystal form and are hence xenomorphic. However, olivine frequently has good crystal outlines, indeed, when it is completely altered to serpentine, its idiomorphic outlines remain and provide a means for identifying the parent mineral.

The crystalline limestone generally possesses a foliation which is manifest by the preferred orientation of minerals, by slight textural differences between layers, by compositional layering and by faint color banding. Generally, the calcite grains are lenticular shaped and have a preferred planar orientation such that a true gneissic structure is imparted to the rock. Compositional layering is due to the concentration of the minor minerals along certain planes which are always parallel to the gneissic structure. Flowage structures are particularly evident in bodies of crystalline limestone. Masses of metamorphic pyroxenite and other gneisses are in many places distended and drawn out in boudinage fashion as though they were broken apart as a result of limestone flowage. In addition, in some places there is clear evidence that the limestone has actually flowed around more competent layers of gneiss, pegmatite, etc.

Crystalline limestone is generally associated with metamorphic pyroxenite, quartzites, and graphitic-biotitic gneisses. The latter frequently have a characteristic rusty-weathering color due to the presences of sulphide minerals and have come to be called rusty-weathering gneisses. The occurrence of these rocks with crystalline limestone is so characteristic that their complete absence in the vicinity of limestone outcrops would be surprising. Rare special rocks such as pyroxene-scapolite rocks are also associated with the crystalline limestone. In addition alaskite and pegmatite layers which are probably related to the younger intrusions are also closely associated with the crystalline limestones. In the crystalline limestone formation underlying the area between Sinclair and Isabel lakes, such alaskites and pegmatites which have a characteristic white to buff color are especially abundant.

Graphitic and biotitic gneisses

Closely associated with the crystalline limestone are gneisses which characteristically carry small amounts of graphite and biotite. Many of these weather to a rusty color and are hence called rusty-weathering gneisses. However, this descriptive term is quite general in that it is applied to any gneiss which shows such weathering. The rusty-weathering is caused by small amounts of iron sulphide mineral.

Graphitic and biotitic gneisses are usually a gray to grayish white color on fresh surface. The major minerals are always quartz, microcline and microperthite, and plagioclase (oligoclase). Quartz varies from about 10 up to 60 percent in different samples of this rock type. The proportion of microcline and plagioclase feldspar are generally complementary. Graphite and biotite rarely form more than 5 to 10 percent of the rock. Minor minerals include sulphides, sphene and epidote. The latter is probably a secondary mineral after plagioclase.

In general the graphitic and biotitic gneisses are fine or medium grained and even grained. The bulk of the minerals are xenoblastic. Generally the rock has a well developed gneissic structure due to the preferred orientation of biotite and graphite plates and lenticular shaped quartz grains. However, some samples appear quite massive. It is believed that these may have been spared from deformation as a result of their positions in easily deformed crystalline limestone.

It is believed that the graphitic and biotitic gneisses which have a very high quartz content are probably metamorphosed clastic sedimentary rocks which were interlayered with the original limestone of the Grenville series. On the other hand highly feldspatic graphitic and biotitic gneisses may be of more complex origin and be closely related to the younger granitic intrusive rocks.

Quartzite

Quartzite occurs as small unmappable bodies closely associated with other members of the Grenville series. When associated with crystalline limestones quartzites weather out in sharp topographic relief.

Quartz generally forms over 90 percent of this rock type, while minor minerals include microcline, phlogopite, pyroxene (diopsidic), hornblende, sphene, apatite and occasionally calcite. In general the quartzites are medium and even-grained with the quartz in lense-shaped, xenoblastic grains. Compositional layering is usually absent, however, gneissic structure due to the preferred orientation of the lenticular quartz grains is generally present.

Undoubtedly the quartzites represent highly metamorphosed sandstone layers which were interbedded with the limestones of the Grenville series.

Biotite-quartz-feldspar gneiss

A very characteristic type of rock which generally occurs as layers within the granitic injection complex is biotite-quartz-feldspar gneiss. Typically this gneiss contains various proportions of sillimanite and garnet. It is believed that biotite-quartz-feldspar gneiss is a paragneiss which has been modified in various degrees, both by metasomatism (chiefly potash) and injection by granitic solutions to yield a series of rocks which vary in character from almost unaltered paragneiss to migmatite (see section on granitic injection complex).

Biotite-quartz-feldspar gneiss is usually a light gray color, medium grained and fairly even grained. Because of the preferred orientation of biotite plates it has a nearly schistose structure. Typically all the minerals are more or less xenoblastic. As described in the section on the granitic injection complex, the gneiss may contain microcline porphyroblasts in areas where it has been thoroughly mixed with granite and pegmatite; otherwise the texture is uniform.

The principal minerals in the gneiss are always quartz, microcline, plagioclase (oligoclase) and biotite. The proportion of quartz varies from 10 to 50 percent. Plagioclase is always more abundant than microcline in samples of the gneiss which are not much mixed with granite and pegmatite. On the other hand microcline (sometimes perthitic) may be present almost to the exclusion of plagioclase in thoroughly injected samples of the gneiss. The total feldspar content of the gneiss varies from 40-60 percent while biotite varies from 10-20 percent. Sillimanite and garnet are present in quantities of less than 5 percent in many samples of the gneiss. They appear to be most abundant in gneiss which has been injected and permeated by the associated granites and pegmatites. Minor minerals include magnetite, apatite, zircon and rarely muscovite.

The biotite-quartz-feldspar gneiss corresponds closely to the paragneiss described by (Engel and Engel, 1953) from the northwest Adirondacks. The variety in the Aylwin-Cawood area which contains plagioclase (oligoclase) to the exclusion of microcline is mineralogically very similar to the "least altered gneiss" which Engel and Engel (1953) believe is a paragneiss probably resulting from the extreme metamorphism of a clastic sediment of graywacke composition. The varieties in this area which are richer in microcline are similar to the partially granitized paragneisses described by Engel. Therefore, it is proposed that the biotite-quartz-feldspar gneiss in this area is a similar paragneiss which has been modified to various degrees by granitic material.

Hornblende gneiss

Several varieties of hornblende gneiss occur as layers of variable size throughout the entire area. One variety of hornblende gneiss is especially abundant in the southwest corner of the area where it has been mapped as a

separate formation. In addition, a rather large body of hornblende gneiss which is closely associated with the granitic injection complex has been mapped in the central part of the area. Other bodies of hornblende gneiss are present in small quantities throughout the entire area, but appear to be most common within the granitic injection complex and mixed with the Grenville formations and younger igneous rocks in the southwest part of the area, eg. mixed hornblende gneiss formation.

The typical rock in the hornblende gneiss formation in the southwest part of the area is a biotite-hornblende-plagioclase gneiss. It is a light to dark gray color, and is generally medium to coarse grained and somewhat uneven grained. Such gneisses always have a well developed foliation or lineation which result from the preferred mineral orientation and the concentration of dark and light minerals into separate layers and streaks. Generally plagioclase (An_{20-30} , calcic oligoclase) forms 50 to 60 percent of the rock whereas dark green hornblende forms from 20 to 40 percent and red-brown biotite forms up to 15 percent. Quartz is generally present in quantities up to 5 percent, and pyroxene (augite) is present in some samples in a similar proportion. Minor minerals include opaque oxides, apatite and sphene. The biotite-hornblende-plagioclase gneiss is closely associated with crystalline limestone and white pegmatite, and with subordinate amounts of other Grenville-type gneisses and younger granites. It is proposed that this characteristic gneiss may have originated as a result of extensive and complex metasomatism of the crystalline limestones. Although the possibility that it is a meta-igneous rock is not excluded.

The body of hornblende gneiss in the central part of the area is composed of a rather uniform rock which is dark gray to black on weathered surface and a dark gray color on fresh fracture. This gneiss is usually medium and

even grained and most of the mineral grains are xenoblastic. Except for some granite and pegmatite veining, the minerals of this rock are not much separated into layers. Instead, the rock is quite uniform and the gneissic structure results from the strong preferred orientation of the elongate hornblende crystals. Dark green hornblende forms 50 to 60 percent of this variety of hornblende gneiss and plagioclase (sodic andesine) forms the remaining bulk of the rock. Minor minerals include quartz, ore and apatite.

A typical variety of gneiss which is commonly mixed on a rather small scale with other Grenville-type gneisses and younger igneous rocks in the southwest corner of the area is biotite-hornblende-feldspar gneiss. This rock has been mapped as a member of the mixed hornblende gneiss formation. The rock is typically less mafic than the other varieties of hornblende gneiss. Ordinarily it contains only up to 30 percent of biotite and dark green hornblende combined. Plagioclase (calcic oligoclase) and microcline make up 50 to 60 percent of the rock and quartz is always present (sometimes in amounts up to 20 percent). Sphene is a ubiquitous minor mineral in this gneiss and may be present in amounts up to 5 percent. Other minor minerals include opaque oxides, apatite and zircon (sometimes rounded). In general the gneiss is fine to medium grained, even grained and composed mostly of xenoblastic grains. It has a well developed gneissic structure manifest by the preferred orientation of hornblende and biotite grains, and by a certain amount of mineral layering. This rock is quite distinct from the other varieties of hornblende gneiss in its smaller proportion of ferromagnesian minerals, the presence of a significant proportion of microcline and quartz, and the presence of sphene as a characteristic minor mineral. In general, this hornblende gneiss is closely associated with granite and pegmatite and in many places has been intimately injected by them. It is therefore proposed that this

variety of hornblende gneiss owes its less mafic character and its significant proportion of microcline and quartz to modification by granitic and pegmatitic solutions.

Within the granitic injection complex hornblende gneiss layers stand out in sharp color contrast to the less mafic rocks which make up the bulk of this formation. In many places hornblende gneiss layers are injected and intimately mixed with the granitic and pegmatitic material of this complex. Where layers are apparently unmodified by younger intrusive rocks they are generally fairly uniform, medium and even grained and possess a well developed gneissic structure due to the preferred orientation of hornblende. One such sample of hornblende gneiss from the granitic injection complex consisted of about 50 percent dark green hornblende, 40 percent plagioclase, which was a sodic labradorite, and 10 percent pyroxene (augite).

As indicated by the discussion above, there are several distinct varieties of hornblende gneiss in the area which differ from one another not only in terms of texture, structure and mineralogy, but also somewhat in terms of areal position and extent. It seems evident that these varieties may be of several different origins. The close association of the hornblende gneiss with crystalline limestone in the southwest corner of the area indicates that the former may have originated by the modification of the latter. On the other hand, the relative uniform texture and structure and the bulk mineral composition of the hornblende gneiss mass in the center of the area and the similar layers within the granitic injection complex indicated that they may have originated from the regional metamorphism of igneous rocks of basaltic composition (such as andesite or basalt lava flows). In other cases such as the sphene bearing biotite-hornblende-feldspar gneiss in the southwest part of the area, the influence of younger intrusive granite and pegmatite

appears to have been responsible for much of the present character of the gneiss. Clearly all the hornblende gneisses have originated as a result of regional metamorphism and to various extents the regional metasomatism of rocks of the Grenville series.

Metamorphic pyroxenite

Metamorphic pyroxenite is found as small bodies usually within the crystalline limestone formations, although in some places enclosed in granitic rocks. The size of the bodies varies from small nodules up to layers or lenses several tens of feet long. However, none of the bodies are of a large enough size to show on the geologic map.

Metamorphic pyroxenite appears to be most abundant in the discontinuous crystalline limestone belt which extends from north of Danford's Lake southwest along the Kazabazua river to the vicinity of Cawood. This belt is closely associated with the younger intrusive quartz diorite. Further, the overall abundance of the metamorphic pyroxenite is greater in limestones of the highland area where the proportion of igneous rocks is also greater than in limestone underlying the lowland area. Clearly there appears to be a cause and effect relation between the metamorphic pyroxenite, crystalline limestone and intrusive rocks.

Metamorphic pyroxenite is pale green to white and weathers to a dull gray color. It is usually medium and even grained and is distinctly massive. The grains are usually xenoblastic although occasional outlines of crystal faces are present.

Metamorphic pyroxenite is essentially monomineralic with a colorless diopsidic pyroxene as the chief mineral. Minor minerals include muscovite, biotite, phlogopite, actinolitic amphibole and occasionally an iron sulphide. In some places, such as in the vicinity of Cawood, the metamorphic pyroxenite

is closely associated with quartzite and is cross-cut by small quartz veins. In such places a small amount of quartz is generally present in the pyroxenite. In a number of other places massive white and pink pegmatite are intruded into metamorphic pyroxenite (Plates 3 and 4).

The term metamorphic pyroxenite was introduced by Wilson (1924) in order to distinguish the rock type described here from igneous pyroxenites. The general opinion of modern observers is that the metamorphic pyroxenite originated as a result of the complex interaction of crystalline limestone (perhaps fairly rich in magnesium) and younger acidic intrusive rocks. The close association of metamorphic pyroxenite with granitic intrusive rocks on both a regional and detailed scale as indicated previously provides considerable support for this opinion. Hence, the writer also believes in a metamorphic (or better a metasomatic) origin for the metamorphic pyroxenite.

In this region the metamorphic pyroxenites are of considerable economic significance, because in some places they are the host rock for phlogopite and apatite deposits. Further, geiger counter observations indicate that some of the pyroxenites have a radioactivity slightly higher than the normal background count for the region.

Skarns

Rare, small layers and very small masses of rocks which are best classified as skarns are present in the area. In general, these rocks are found within the granitic injection complex and are hence closely associated with granite and pegmatite. There appears to be no obvious association with other characteristic rock types such as crystalline limestones.

The skarns are black on weathered surface and have a dark green color on fresh fracture. Mineralogically they are extremely mafic rocks and consist chiefly of dark green hornblende and pale green pyroxene (diopside). Hence,

they are properly called hornblende-pyroxene skarns. Minor minerals include garnet, plagioclase, magnetite, rutile and biotite. In general the skarns are fine to medium grained slightly uneven grained (sometimes porphyroblastic) and xenoblastic. Generally they are massive, but locally are slightly gneissic.

Mineralogically the skarns appear closely related to metamorphic pyroxenite. The diopsidic pyroxenes in each type appear very similar. However, dark green hornblende is not present in the pyroxenites. In some of the skarns hornblende replaces the pyroxene. This suggests that the skarns are simply a hornblende rich variant of the pyroxenites. However, the presence of magnetite, garnet and some plagioclase in the skarns is quite distinct from the pyroxenites. Clearly, the skarns are considerably more iron rich than the pyroxenites. Therefore, it seems possible that they are iron rich equivalents to the magnesian rich pyroxenites, and hence may have originated by a metamorphism or metasomatism of limestone layers similar to that postulated for the origin of the metamorphic pyroxenites only involving the introduction of considerable iron instead of magnesium. This proposal is partly supported by the fact that the two rock types are never closely associated in the field. The iron rich skarns appear most frequently in the granitic injection complex while the magnesian rich pyroxenites are characteristic of crystalline limestone formation. Therefore, perhaps it is feasible to postulate that iron metasomatism was characteristic of the former formation whereas magnesian metasomatism was typical of the latter.

Post-Grenville Rocks

Anorthosite

Several small bodies of anorthosite which are located within the granitic injection complex were mapped. These masses have been shown on the geologic map by exaggeration of their outcrop width. It is interesting to note that

the isolated bodies occur in roughly the same structural position within the injection complex as though they formed a single discontinuous layer.

On weathered surface the anorthosite is a dull gray color, but the fresh rock is a greenish white. The rock is medium grained with the average grain diameter being 1 to 2 mm. The texture is even grained and only occasional grains of feldspar show crystal outlines. In general, the anorthosite is rather uniform and massive. However, in some places it is definitely deformed and possesses a gneissic structure. In addition, in some places distinct layering is present as a result of the concentration of the subordinate amount of dark minerals into separate layers.

Plagioclase (sodic labradorite, An_{55}) forms essentially one hundred percent of the anorthosite. Medium green hornblende and pale green pyroxene (augite), which may be intergrown with one another, are the principal primary minor minerals. A small proportion of scapolite occurs as interstitial irregular shaped grains. Pale brown biotite and sphene are present in some samples of the anorthosite. Zoned allanite and isotropic grains which are surrounded by an irregular rim of partly metamictized epidote are common in highly altered samples of the anorthosite. Typically the epidote rim has a low and anomalous birefringence. Radial fractures usually extend outward from the allanite or isotropic core.

Generally the plagioclase is partially to nearly completely altered to sericite and subordinate amounts of calcite and epidote. Chlorite is a common mineral in the anorthosite and occurs both as an alteration product of pyroxene and biotite and as independent grains. Clearly the anorthosite has been subjected to considerable alteration characterized by the development of greenschist facies minerals, such as sericite, chlorite and epidote at the expense of primary hornblende, pyroxene and labradorite. In general this

alteration has been very incomplete, but occasional samples are nearly completely modified.

In some places the anorthosite is cut by small quartz veins and lodes, and in several places pink granite and pegmatite clearly cross-cut it. These relationships are best seen at the exposures of anorthosite in the north half of range A, Low township. In that locality nearly massive pink granite and pegmatite engulf and cross-cut the structure of large blocks of the anorthosite. In addition, such blocks are injected by granite and pegmatite in the form of cross-cutting dikes and thin layers parallel to the structure in the anorthosite. These smaller intrusive masses frequently can be traced directly into the body of the granite which surrounds the anorthosite block. Clearly the pink granite and pegmatite are younger than the anorthosite, and inasmuch as the gneissic and layered structure of the latter are cross-cut by nearly massive granite, it is suggested the anorthosite was somewhat deformed prior to the intrusion of the granite.

A considerably larger proportion of anorthosite is present in the Onslow-Masham area (Sabourin, 1954) to the south than in the Aylwin-Cawood area. In addition no gabbros or gabbroic facies of anorthosite were found in this area. It is possible that the anorthosites (and related gabbros) in the region are of igneous origin. In this case, they could be closely related to the anorthosites of the Morin, or Buckingham, series which are present in large proportion to the east (Osborne, 1936). However, it seems unwise to correlate the anorthosites in this area over such a large distance of essentially unmapped terrain with the similar rocks in the east. Furthermore, it is conceivable that the anorthositic rocks in this general region may not be of igneous origin but may have originated from some complex set of processes such as the metasomatism of crystalline limestone or some other

Grenville-type rock. More regional and detailed studies are necessary to answer these problems.

Quartz diorite and related facies

In the western half of the Aylwin-Cawood area the principal intrusive rock is quartz diorite with related facies. The intrusive mass underlying O'Brien Mountain and the adjacent area is typical. In the southeast corner of the area quartz diorite, etc. is interlayered with a large proportion of Grenville-like rocks, and in most cases has been mapped with them. However, about one mile north of Sinclair lake a small phacolithic body of a granitic facies of the quartz diorite has been mapped and immediately southwest of Cawood a fairly sizeable layer or sheet of quartz diorite has been separated from the surrounding Grenville series. The principal body of quartz diorite is the elongate mass which extends from southwest of O'Brien Mountain northeast to the region just north of Danfords Lake. The path of the Kazabazua river just about parallels the central part of this mass. West of the river the quartz diorite is not much mixed with Grenville rocks and outcrops on hills of prominent relief; on the other hand, the quartz diorite underlying the area east of the Kazabazua river is well mixed with Grenville rocks (especially crystalline limestone) and is in general an area of low relief. On the southeast the elongate mass of quartz diorite passes into a sheet shaped body which extends to the east for a distance of about three miles before it pinches out in favor of the Grenville series. As may be seen from the map this sheet is at least in part a phacolithic mass. Quartz diorite and related facies are present throughout the dioritic injection complex and especially in the southeastern margin of the complex. The western margin of the granitic injection complex definitely seems to mark the eastern limit of quartz diorite. Only in the extreme north central part of the area in

the outcrops mapped as dioritic injection complex in range XI, Aylwin township have quartz diorite and pink biotitic granites been found interlayered with one another. Otherwise, the western part of the area is strictly the domain of the quartz diorite.

The most abundant rock type within this formation is quartz diorite. In most places the quartz diorite possesses a dark and light "ghost-like" layering which is caused by variations in mineral proportions. The dark layers in many cases are diorite facies related to the quartz diorite, whereas in other cases the dark layers are merely more mafic facies of quartz diorite. These overall mineral variations impart a characteristic but quite subtle streaky character to most outcrops of the quartz diorite. On weathered surface the quartz diorite and associated diorite have a very characteristic olive drab or olive buff color while fresh surfaces are an olive to a greenish gray color. This greenish hue which is due to a mixture of green plagioclase with dark mafic minerals is typical of almost all the facies related to the quartz diorite and is in marked contrast to the pink granites. Typically the quartz diorite and related facies are medium (average grain diameter generally 2 - 3 mm) and even grained, generally xenomorphic-granular and rarely hypidiomorphic-granular. However, coarse grained layers and seams of pegmatitic character are a frequent textural variation related to the quartz diorite. A distinct gneissic structure is usually apparent although some massive facies are present. Gneissic structure is due both to small scale compositional layering and to the preferred orientation of such minerals as hornblende, lenticular quartz and feldspar grains and aggregates of dark or light minerals. In most cases the gneissic structure is a planar feature; however, in some places it is a linear structure.

The principal mineral in the quartz diorite and diorite is plagioclase feldspar frequently in antiperthitic intergrowths. The plagioclase is as basic as calcic-andesine (An_{40-45}) in some samples of diorite, but is generally sodic andesine (about $An_{35 \pm 5}$) in the quartz diorite and dioritic facies. A few grains of antiperthite are present in most samples of the quartz diorite and related rocks. Generally the K-feldspar is intergrown as irregular shaped bodies and some thin plates and never forms more than 20 percent of antiperthite grains. Plagioclase generally forms from 55 - 65 percent of the quartz diorite and diorite. Quartz varies from zero percent in many of the diorites up to 20 - 25 percent in the quartz diorite. It appears as if there is a complete series of rocks between diorite and quartz diorite in which an increase in quartz is accompanied by a decrease in dark mineral content.

The quartz diorite and diorite carry a very characteristic suite of dark minerals. Dark green hornblende is present in all samples of these rocks and is hence a major varietal mineral. Pyroxene, either augite or hypersthene, or sometimes both, is also present as a characteristic constituent of these rocks. The augite is pale green with:

$$\begin{array}{l} Ny \quad 1.692 \pm .001 \\ 2V \quad 55^\circ \pm 3^\circ \end{array}$$

which corresponds to an augite of composition of about $Ca_{42}Mg_{40}Fe_{18}$ (Hess, 1949). Hypersthene has a very characteristic flesh pink color parallel to X and a pale green color parallel to Z. In one sample the hypersthene had

$$\begin{array}{l} Nx \quad 1.690 \pm .001 \\ 2V \quad 60^\circ \pm 3^\circ \end{array}$$

which corresponds to a composition of En_{70} (Hess, 1952). A deep red variety of garnet (pyrope-almandite) is a characteristic accessory mineral of much of the diorite and quartz diorite and seems to occur most frequently in facies of these rocks which carry hypersthene. This would suggest that the hypersthene

and garnet mineral assemblage was equivalent to augite and/or hornblende. In some diorites hypersthene forms as much as 20 percent of the rock, in others augite is present in similar amounts to the exclusion of hypersthene. Hornblende varies from 2 - 3 percent in the quartz diorite and forms up to 30 percent of mafic diorite layers. Clearly there is a complementary relationship between the various ferromagnesian minerals. Garnet when present never forms more than 3 percent of the rock. Magnetite is a ubiquitous accessory mineral and in some samples of the quartz diorite and diorite occurs in amounts up to 5 percent. Minor accessory minerals include apatite and sometimes zircon and sphene. Biotite is present in more acid facies of the quartz diorite.

Mixed with the quartz diorite are many layers and masses of rock which texturally and structurally are very similar to the quartz diorite but which differ somewhat in bulk mineral composition. These form acid facies of the quartz diorite and are characterized by the presence of microcline or orthoclase feldspar (sometimes perthitic and rarely microperthite) as a major constituent, plagioclase (calcic oligoclase, An_{30}), and a larger proportion of quartz and a smaller proportion of dark minerals than the quartz diorite. The typical acid facies are mostly quartz monzonite and granites. Typically, these acid facies have the same greenish color and are always characterized by dark green hornblende and in most cases by pyroxene of the augite type, and in rare cases by hypersthene of the identical type found in the quartz diorite. Biotite and garnet are frequently present in these acid facies and magnetite, apatite and zircon are minor constituents. Clearly the quartz monzonites and granites differ from the quartz diorite chiefly in their greater proportion of quartz and potash feldspar and more sodic composition of their plagioclase. Although these acid rocks carry a smaller proportion

of dark mineral than the quartz diorite, the dark mineral species in the two types appear identical. Clearly the acid facies are not only closely related to the quartz diorite in areal extent but also in terms of texture, structure and mineral composition.

It is interesting that garnet and hypersthene which are characteristic minerals developed in the dioritic injection complex as a result of reaction between hornblende gneiss and quartz diorites, etc. are also characteristic minerals in the intrusive quartz diorites. The presence of hypersthene in the quartz diorites and related rocks definitely allies them to the charnokites of igneous rock series and to the granulite mineral facies of metamorphic rocks. Hence, the question arises as to whether the garnet and hypersthene are of metamorphic origin or whether they are primary minerals having formed at the time of intrusion. The fact that the quartz diorites, etc. are not intensely deformed and in some cases nearly massive suggests that these rocks have not been intensely metamorphosed. In addition the textural relations and mineral distribution do not suggest that garnet and hypersthene are metamorphic reaction products from other minerals within the quartz diorites. On the other hand, the fact that garnet and hypersthene are formed as reaction products adjacent to hornblende gneisses (see description of dioritic injection complex) suggests that these minerals may well be present in the quartz diorite and related rocks as a result of contamination and mixing of them with other Grenville-types such as hornblende gneiss. This concept would help explain the greater frequency of garnet and hypersthene in the more mafic or dioritic members of the series. In view of the above discussion it seems likely that the quartz diorites and related rocks have not necessarily been subjected to metamorphism of the granulite facies, but instead owe their charnockitic or granulitic mineral assemblage to peculiar chemical conditions

caused by their contamination by hornblende gneiss and perhaps other Grenville-type rocks.

In general the quartz diorite and related rocks are completely conformable on both a regional and detailed scale with the older Grenville-type gneisses. However, in some places, such as within the dioritic injection complex, the quartz diorite or some of its facies clearly cross-cut the structures in the older rocks, and therefore, are clearly of intrusive origin. The quartz diorite, etc. is older than the meta-syenite dikes and obviously older than the pink pegmatites which cross-cut these dikes (see section on early dikes). In a few places massive (undeformed) pink pegmatite was found closely associated with and in rare cases actually cross-cutting the quartz diorite or related rocks. Therefore, if these pegmatites are co-magmatic with those found in the granitic injection complex and with the pink granite, granite gneiss, etc, it seems evident that the quartz diorite and related rocks are older than the pink granites, etc., and finally, inasmuch as the quartz diorite and related rocks are somewhat deformed and on the whole conformable to the adjacent country rock it seems likely that they were intruded into the Grenville series during the period of regional metamorphism and are hence para-tectonic.

The quartz diorites and related rocks as found in this area appear to correspond very closely to intrusive rocks of the Morin, or Buckingham, series of the areas to the east (Dresser and Denis, p. 173, p. 188, 1944; Osborne, 1936). As in the quartz diorite and related rocks of this area, hypersthene is a characteristic mineral of most rocks of the Buckingham and Morin series including the quartz monzonites and other acid facies. On the other hand, the more basic facies such as peridotite, pyroxenite, anorthosite and gabbro typically found along with the acid facies of these series to the east are not present in the Aylwin-Cawood area. (It is believed that the small bodies

of anorthosite described previously are unrelated to the quartz diorites, etc.) Again it requires more detailed regional mapping before these possible correlations can be substantiated.

Dioritic injection complex

In the extreme northwest corner of the Aylwin-Cawood area, mostly in the township of Alleyn, a body of rock which is called the dioritic injection complex has been mapped. This formation has the general form of a layer which trends more or less northeast parallel to the local structure. In its southwestern part the dioritic injection complex has an outcrop width of about one mile; however, to the northeast the outcrop width decreases to about one half to three-quarters of a mile. On the northwest the dioritic injection complex is bordered by the granitic injection complex. On the southeast the quartz diorite and related rocks make contact with the complex.

The dioritic injection complex, as its name implies, is a complex body of rock which consists mostly of Grenville gneisses which have been intruded and somewhat modified by quartz diorite and diorite. Of the apparently unmodified Grenville rocks in the complex, crystalline limestone, graphitic gneiss and especially hornblende gneiss appear to be the most abundant. The complex is especially characterized by a rock called garnet-hornblende gneiss (Plate 5), which is considered to have originated through the modification of normal Grenville hornblende gneiss by reaction with quartz diorite and diorite intrusive rocks. In addition, pink granite gneiss and pegmatite are interlayered within the dioritic injection complex. Such interlayering is especially evident in the northeast extension of the complex where the layering may be on a scale of tens of feet and the proportion of pink granitic types may be nearly as great as dioritic types.

In general, the southeastern margin of the dioritic injection complex, adjacent to the large mass of quartz diorite, contains a larger proportion of quartz diorite and diorite, relative to Grenville-type rocks, than the northwestern parts of the complex. In other words, the geologic boundary between the quartz diorite, etc. and the injection complex appears to be gradational through a distance of 1/4 to 1/2 mile. Clearly the dioritic injection complex is closely related to the large mass of intrusive quartz diorite, etc. in the west-central part of the area. The close spatial and structural relationships between the two, plus the fact that layers of quartz diorite and diorite identical to those in the intrusive mass form a major component in the dioritic injection complex precludes a close genetic association between the two rock formations. In brief, the dioritic injection complex is believed to have originated as the result of injection and modification of Grenville-type rocks by the typical greenish quartz diorite and diorite.

Excellent accessible exposures which clearly show the relationships between the garnet-hornblende gneiss and the younger intrusive dioritic rocks are present in the north half of lot 10, range 5, Alleyn township. At such ideal exposures it may be seen that the garnet-hornblende gneiss varies from mafic gneiss, containing as much as 50-60 percent dark mineral, to dioritic gneiss, containing 20-30 percent of dark mineral (compare Plates 5 and 6). Such variations on the whole are imperceptible, but nevertheless impart a marked heterogeneity to the complex. Thus there appears to be a complete gradation from garnet-hornblende gneiss (Plate 5) into more or less ordinary Grenville hornblende gneiss on the one hand (Plate 7) and into typical diorite on the other hand (Plate 6). Further, contaminated facies of quartz diorite and pegmatite characterized by garnet clearly cross-cut

the various facies of the garnet-hornblende gneiss and do not appear to be gradational in composition with them (Plates 8 and 9).

The typical facies of garnet-hornblende gneiss is a medium gray color on weathered surface and a greenish buff color on fresh fracture. The rock is medium to coarse grained and slightly uneven grained. The mineral grains are intergrown in a sutured fashion and are markedly xenoblastic. Due to some preferred mineral orientation and small scale layering, the rock has a definite but not intense gneissic structure. Plagioclase (calcic andesine, An_{40-45}), generally forms about 60 percent of the rock, and is the only feldspar present. Dark green hornblende and deep red garnet (pyrope-almandite) are the chief mafic minerals in the gneiss and together form about 30 percent of the rock. Hypersthene, which is pale green parallel to Z and pale flesh-pink parallel to X and Y is a very characteristic mineral and occurs in amounts up to 10 percent. Magnetite is present in amounts as large as 5 percent of the rock. Minor minerals include quartz, red-brown biotite and apatite.

Lithologic variations of the typical garnet-hornblende gneiss involve mostly differences in bulk mineral composition and some differences in texture. The actual mineral species present in these variations are identical to those in the typical gneiss. More mafic rich facies are simply richer in garnet, hornblende, hypersthene and magnetite; whereas, more dioritic facies are richer in plagioclase (again calcic andesine). The actual proportions of the various dark minerals varies between samples as well. For example, garnet may be nearly absent in some places and in some mafic layers hypersthene may form up to 25 percent of the rock. In general, the more mafic layers appear to be slightly finer grained than the typical garnet-hornblende gneiss.

Garnet bearing pegmatite and quartz diorite and quartz monzonite definitely cross-cut the garnet-hornblende gneiss (Plates 8 and 9). The pegmatites are generally very thin discontinuous layers or seams. They are composed of quartz and andesine plagioclase (An_{40-45}) identical to that in the garnet-hornblende gneiss. Typically, garnet is enriched along the borders of the pegmatite seams within the gneiss as though it were formed as a reaction product between the pegmatite and the gneiss. The cross-cutting layers of quartz diorite and quartz monzonite are aplitic in nature. Garnet makes up about 3 percent of the rock and is the only dark mineral present. Their texture is fine and even grained and the grains are intergrown in a xenomorphic fashion. Layers of this type are extremely uniform and hence are in marked contrast to the garnet-hornblende gneiss which they intrude. Quartz, plagioclase (calcic oligoclase, An_{30}), some antiperthite and orthoclase feldspar make up the bulk of the rock. The rock is quite undeformed.

The relationships described above seem to warrant the following general conclusions concerning the development of the dioritic injection complex. The original rocks were various Grenville-types of which hornblende gneiss was the most abundant. Rather thorough injection by the quartz diorite and diorite from the adjacent body on the southeast led to considerable modification of the Grenville rocks. Specifically, the hornblende gneisses underwent a sort of dioritization which led to the development of a considerable amount of garnet and hypersthene at the expense of hornblende and completely modified the original structure and texture of the hornblende gneiss. The resulting product from this modification process was the typical garnet-hornblende gneiss described above. Clearly, even after this extreme modification of the original Grenville rocks, further intrusion of rocks

related to the quartz diorite mass took place and is manifest by the andesine pegmatites and garnet bearing quartz diorites which actually cross cut the garnet-hornblende gneiss.

Granite, granite gneiss and pegmatite

Granite and several closely related rocks of which granite gneiss and pegmatite are the most important are present throughout the entire area. These rocks occur as small seams, layers, and sheets and as large masses which have been intruded into rocks of the Grenville series. At the south-central border of the area a fairly large body of granite and granite gneiss has been mapped. The body is apparently continuous with a similar mass of rock in the Onslow-Masham area (Sabourin, 1954) to the south. Other small masses of granite and related rocks have been mapped in the southeastern third of the area where they are mostly intruded into crystalline limestone. Despite the paucity of large mappable bodies of granite and granite gneiss these rocks are some of the most abundant in the area, but because they occur so intimately mixed with Grenville gneisses, it is impossible to map them separately. For example the granitic injection complex consists of a very large proportion of granite and related rocks and in fact in many places could probably be mapped as granite or granite gneiss as well as injection complex. In addition granite, etc. are mixed intimately with Grenville crystalline limestones and other paragneisses in the area east of the granitic injection complex and as indicated in the discussion of the quartz diorite and related rocks, to a lesser extent with Grenville rocks west of the granitic injection complex. On an areal scale the granite and granite gneiss bodies are conformable to the structure in the Grenville rocks; however, on a detailed scale these rocks clearly cross-cut the older Grenville series.

Massive pink granite on the whole is considerably less abundant than pink granite gneiss. The massive granite is generally medium or coarse grained, fairly even grained and xenomorphic-granular. The very characteristic pink color is due to pink microcline feldspar which is the principal mineral in the rock and occurs in amounts up to 50 percent. Sometimes the microcline is slightly perthitic. Plagioclase (sodic oligoclase) is always present in subordinate proportions to the microcline. Quartz generally makes up 20-30 percent of the rock. Biotite is the only major dark mineral and forms rarely more than 5-10 percent of the rock. Accessory minerals include magnetite, apatite, zircon and rarely sphene and allanite. Massive pink pegmatites which have the same mineral composition as these granites are always associated with them and on the whole are probably more abundant than the granites. It seems likely that they are simply coarse grained variants of the normal massive granite. Frequently fine grained pink aplites are closely associated and in places irregularly mixed with the pink pegmatite. These aplites are undoubtedly co-magmatic with the pegmatites.

Granite gneiss is a very pink to pinkish gray color on fresh surface and weathers to light gray color. In contrast to varieties of granite gneiss of complex origin found within the granitic injection complex, the granite gneiss described here is ordinarily very uniform. It is usually medium grained but fined grained facies are present. In general the rock is even grained; however, in some places microcline porphyroblasts (or perhaps metacrysts) are well developed and give the rock an uneven grained texture. All the principal minerals are highly xenomorphic and are usually intergrown along very irregular sutured boundaries. Gneissic structure is due to the preferred orientation of biotite plates and lenticular shaped grains of quartz and feldspar, as well as to the parallelism of thin layers

and seams of light and dark mineral aggregates. The degree of gneissic structure varies considerably. On the one hand granite gneiss appears so slightly deformed that its gneissic structure may be due to primary magmatic flowage. On the other hand much of the granite gneiss has a very strong gneissic structure and has definitely been subjected to considerable deformation. Microcline (sometimes perthitic) is the principal mineral in the granite gneiss and plagioclase (sodic oligoclase) and quartz are the other main constituents. Biotite is the only mafic mineral present and occurs in mere traces up to 10-15 percent. Actually, alaskitic facies of granite gneiss are fairly common. Accessory minerals are the same as those in the massive pink granite.

Granite gneiss is generally very closely associated with massive pink granite and pegmatite and is probably somewhat more abundant than these rock types. As is apparent from the above descriptions, granite and granite gneiss have very similar mineral compositions and textures. It seems evident that these rock types are closely related. Specifically, the granite gneiss is considered to be an orthogneiss which is probably the deformed and recrystallized equivalent of the massive pink granite. It seems likely that the gneissic granitic rocks were emplaced prior to or during regional metamorphism whereas the massive granites and pegmatites were intruded subsequent to the major period of metamorphism. Furthermore, as there is some evidence which indicates that the pink granites, etc. are younger than the quartz diorites, etc. which are probable equivalents to the Buckingham series, it is quite possible that the pink granite, granite gneiss and pegmatite are equivalent to the Pine Hill granites of the Morin series as mapped by Osborne (1938) and others to the east.

On the other hand it is possible that the granite gneiss described here is the same age as the Trembling Mountain granite gneiss which is one of the oldest intrusives to cut the Grenville series and has been mapped by Osborne (1938) in the Lachute area. In this case it is conceivable that only the massive granites and pegmatites in this area may be equivalent to facies of the Pine Hill granites.

Granitic injection complex

The granitic injection complex is composed of rocks of the Grenville series which have been permeated, injected and intruded by younger pink granite, granite gneiss, pegmatite, and some quartz veins. Hornblende gneiss, sillimanite-garnet-biotite gneiss and biotite-quartz-feldspar paragneiss are the chief Grenville type rocks present in the complex. However, crystalline limestone, quartzite and skarns are also present. The granite, granite gneiss and pegmatite which have intruded these Grenville rocks are identical to and believed to be co-magmatic with the granites, etc. described previously.

The granitic injection complex has the form of a sheet or layer which forms a central belt in extending from the southern to the northern margin of the area. At its southern end the complex is about 2 miles in outcrop width and passes into granite and granite gneiss just north of the southern edge of the area. Similar injection complex has been mapped by Sabourin (1954) in the north part of the Onslow-Masham area. The granitic injection complex appears to thin northward such that at its northern limit near Danford Lake it has an outcrop width of only one-half mile. Throughout its extent the complex is conformable with the structure of the adjacent rocks of the Grenville series.

Besides being composed of varieties of Grenville-type rocks and granite,

granite gneiss and pegmatite as indicated above, the complex contains several distinctive rocks which are believed to have originated as a result of mixing and interaction of some of the Grenville series with the intrusive granites. Ordinary injection gneiss or migmatite composed of layers and seams of pink granite and pegmatite which alternate with layers and seams of Grenville-type gneiss are extremely common. Migmatitic mixtures of granite and hornblende gneiss are typical, but the most common is injected sillimanite-garnet-biotite gneiss and biotite-quartz-feldspar gneiss. Migmatites composed of the latter have a characteristic banded appearance due to the alternating layers of coarser grained pink granite or pegmatite with the fine grained gray biotite-quartz-feldspar gneiss. The presence of pink microcline (sometimes as porphyroblasts) indicates that the gneiss has been permeated (metasomatized) as well as injected by the granites.

The most distinctive type of complex rock within the granitic injection complex is a very heterogeneous augen granite gneiss. This rock is closely associated with the migmatites described above and in many cases is gradational with them. The augen granite gneiss is a mixture of two components: (1) pink granitic and pegmatitic material which is medium to coarse grained, uneven grained and is composed mostly of quartz and microcline with some sodic plagioclase (oligoclase), and (2) a gray, fine and even grained component composed of biotite, quartz, microcline and sodic plagioclase (oligoclase), which is essentially a matrix for the granitic and pegmatitic component. Typically the microcline occurs as augen or less regular shaped porphyroblasts enclosed by the gray matrix material. Often the microcline porphyroblasts are quite perthitic. The granitic material occurs as isolated patches and masses as well as in seams and layers within the gray matrix material. The augen granite gneiss is believed to be a migmatite

and to have originated from the injection and permeation of Grenville biotite-quartz-feldspar paragneiss by granitic and pegmatitic material. The gray matrix material in the augen granite gneiss is identical in texture and mineral composition to such paragneiss. By a decrease in the proportion of microcline porphyroblasts the augen granite gneiss passes into typical injection gneiss. On the other hand by an increase in the proportion of microcline porphyroblasts and granitic material the augen granite gneiss approaches a fairly massive heterogeneous granite in appearance. Clearly all gradations from unmodified paragneiss through injection gneiss to heterogeneous augen granite gneiss are present and grade into one another. Apparently the augen granite gneiss is a sort of end product resulting from the most thorough injection and permeation of the paragneiss by granite and pegmatite.

In conclusion it might be pointed out that the dioritic injection complex appears to be a basic counterpart to the granitic injection complex. Specifically, whereas the latter formed as a result of the injection and modification of Grenville-type rocks by pink granite and pegmatite, the former originated as the result of injection and modification of Grenville-type rocks by the typical greenish quartz diorite and diorite. Analogous to the biotitic augen granite gneiss which is the characteristic reaction product between pink granite and Grenville biotite-quartz-feldspar paragneiss within the granitic injection complex, garnet-hornblende gneiss and related facies are the typical reaction product between dioritic rocks and Grenville hornblende gneiss within the dioritic injection complex.

Early dikes

Meta-lamprophyre dikes. In an outcrop, which is located about 3/8 mile south of the junction of the Cawood-Low road with the Sinclair lake road on the boundary between range A and B (lot 31) of Low township, a

meta-lamprophyre dike is well exposed. The dike cross-cuts typical Grenville-type garnet-biotite-quartz-feldspar paragneiss which has been injected and modified by pink pegmatite. The body of the dike truncates the compositional layers and gneissic structure of the paragneisses; however, the dike itself has been metamorphosed and possesses a plane of schistosity which is exactly parallel to that in the adjacent gneisses (Plates 11, 12 and 13). Furthermore, the dike has been injected by pink pegmatite veins which are identical to those in the adjacent gneisses (Plate 11). The dike has been drawn or sheared-out along the schistosity plane and appears to have been deformed into a shear-fold. The limbs of the fold are about 1 foot thick, but the body of the dike at the crest of the fold is about 3-4 feet thick (Plates 11 and 12). It seems evident that the lamprophyre dike was intruded into the Grenville rocks before or during regional metamorphism, and that subsequent to intrusion, as indicated by the common schistosity plane, the dike was subjected to the same forces which deformed the gneiss. In addition, injection of some of the pegmatite layers appears to have taken place after or during the late stages of the regional metamorphism.

The meta-lamprophyre is dark greenish gray, very fine grained and quite even grained except for the development of small prophyroblastic aggregates of hornblende and biotite along the pronounced plane of schistosity. Because of the pronounced xenoblastic character of the mineral grains, the texture appears almost hornfelsic in thin section. Medium green hornblende which has a weak bluish tinge parallel to Z forms from 50 to 60 percent of the rock, while pale yellowish-brown biotite makes up 10 percent. Granular aggregates of muscovite which appear to be the alteration product of potash feldspar form 20-30 percent of the rock. Very clear, unaltered and untwinned albite occurs in amounts up to 10 percent, and magnetite and pale green

epidote are minor minerals. It is proposed that none of these minerals is primary, but that they all have resulted from the metamorphism of the original minerals.

The bulk mineral composition of the meta-lamprophyre suggests that the original dike rock was a syenitic lamprophyre such as a minette or vogesite.

Meta-syenite dikes. Metamorphosed syenite dikes were found in two localities in the Aylwin-Cawood area. In the extreme south part of the area several outcrops of this rock type are exposed on the northwest slope of the hill which is located in the south half of lot 14, range VI east, Aldfield township or about a mile northwest of the village of East Aldfield. The other meta-syenite dike exposure is in the extreme northwest corner of the area in the north half of lot 16, range IV of Alleyn township. In the south the meta-syenite is intruded into a complex of Grenville gneisses and granite, whereas the dike in the north is intruded into the dioritic injection complex.

The meta-syenite in the south has a characteristic pinkish buff color and is fine grained with the xenoblastic grains averaging 0.5 mm in diameter. Except for the development of porphyroblastic aggregates of hornblende which average about 2-3 mm across, the rock is very even grained and uniform. It seems likely that these porphyroblastic aggregates may be deformed and completely recrystallized primary phenocrysts of such a mineral as pyroxene. Finally, the rock possesses a very well developed plane of schistosity which is due mostly to the preferred orientation of hornblende and biotite grains. On the other hand, the meta-syenite dike found in the north part of the area is a gray color, very fine grained, even grained, xenoblastic and possesses a poorly developed schistosity plane.

Although there are small textural differences as outlined above, mineralogically the meta-syenite dikes from the two localities are identical. Microcline and a subordinate amount of albite make up about 60 percent of the rock. Dark green hornblende forms 25 percent of the rock and greenish-brown biotite about 15 percent. Sphene is a characteristic minor mineral, and forms up to 5-10 percent of the rock. Apatite and magnetite are the other minor constituents. Typical of a metamorphic texture, the feldspar contains a large proportion of many minute inclusions of apatite and sphene.

The meta-syenite in the south part of the area intrudes and cross-cuts a complex of Grenville gneisses and granites. In one place a small dike, about 1 foot thick, of meta-syenite cross-cuts the surrounding gneisses and granite along a plane essentially perpendicular to their foliation plane. In this case the schistosity plane in the meta-syenite dike can be clearly identified and is exactly parallel to the foliation plane of the intruded gneisses and granite. However, the body of the dike has not been sheared-out along its schistosity plane, so that it still retains its original form. Clearly the dike was intruded after the Grenville rocks were injected and modified by the granite, and after the major period of metamorphism. However, as the dike itself has been deformed along the same deformation plane as the surrounding gneisses and granites, clearly the meta-syenite was intruded before the complete cessation of the regional metamorphism. In the same locality, completely undeformed, very massive, pink pegmatite intrudes, engulfs and cross-cuts the meta-syenite. Therefore, the conclusion that some pegmatites in the area are post-regional metamorphism in age and younger than the meta-syenite is completely valid.

The meta-syenite dike in the northwest corner of the area intrudes and cross-cuts the gneissic structure of uniform greenish hornblende quartz

monzonite gneiss which is undoubtedly a facies of the quartz diorites to the south (Plate 14). Only a border facies of the dike is exposed. Most probably the very fine grained character of the meta-syenite here represents a relict primary chill facies at the border of the dike. Within the dike several small inclusions of the quartz monzonite gneiss, which have dislodged and reoriented so that their gneissic structure is not parallel to that in the adjacent wall rock, can be identified (Plate 14). Clearly the meta-syenite dikes are younger than the quartz diorite and related intrusive rocks.

Regional significance. Judging entirely by their more deformed character, the meta-lamprophyre dikes are older than the meta-syenite dikes. Furthermore, the quartz diorite and related rocks were intruded and deformed prior to the intrusion of the meta-syenite dikes; and, inasmuch as massive undeformed pink permatite intrudes the meta-syenite, clearly the quartz diorite, etc. is older than at least some pink granite and pegmatite. This conclusion agrees well with the concept that the quartz diorites were intruded before the cessation of regional metamorphism, whereas the massive pink granites and pegmatites are essentially post metamorphism in age.

Dresser and Denis (p. 180, 1944) point out that in both the Maniwaki and Buckingham districts lamprophyre dikes which intrude the Grenville series are present. According to them, there are dikes both older and younger than regional metamorphism and in addition some of them are cut by massive pegmatite. Osborne (1944) reports lamprophyre dikes from Calumet Island which he believes are older than the undeformed diabase dikes. In addition highly deformed "basic dikes" are present in the Kensington area to the north (de la Rue, 1953). Clearly the meta-lamprophyre present in this area probably corresponds in age and type to some of these others, but at this time it is impossible to make an absolute correlation.

It is interesting to note that Beland (1954) reports that the syenite in the Wakefield area truncates the layering of the Grenville paragneisses and sends off dikes and sills across their foliation. Furthermore, he reports that the syenite itself is sometimes deformed. In addition, the mineralogical composition of the syenites he describes is very similar to the meta-syenite described here. Therefore, it seems very likely that the meta-syenite dikes in the Aylwin-Cawood area are simply minor intrusive bodies directly related to the larger masses of syenite to the south.

Diabase

Diabase dikes which generally trend about east-west to west-northwest and dip steeply cross-cut all the pre-Cambrian rocks in the area. These dikes vary from very small bodies less than one foot thick up to masses as thick as 300 feet. The largest dike is located in the southeast corner of the area in lot 34, range V of Low township. This dike cross-cuts crystalline limestone and has been traced for 3000 feet along its strike and in places is over 300 feet thick. A second prominent dike which is about 300 feet thick and was traced about 1000 feet along strike is located just east of Sinclair lake in lot 46, range B, Low township. In general the dikes do not appear to be concentrated in any particular part of the area. It is interesting that the dikes in this area parallel the prominent system of diabase dikes mapped in the Buckingham area to the southeast (Dresser and Denis, p. 181, 1944). Inasmuch as these dikes are completely unmetamorphosed and cross-cut all the rocks of the basement complex, the dikes are considered as Late-Precambrian age.

The typical diabase is a dark gray to nearly black color on fresh surface and weathers to a very characteristic rusty buff color. It is either fine or medium grained and generally quite even grained. Plagioclase

(labradorite) laths make up about 50 percent of the rock and subhedral to anhedral pyroxene (augite) makes up most of the remainder. The pyroxene occupies the space between the subhedral plagioclase laths and in some places surrounds them. Therefore, the texture is largely intergranular grading into subophitic and even ophitic in places. This typical diabasic texture is particularly evident on the weathered surface. Opaque oxides are present as an accessory constituent.

Although the dikes probably were intruded into a system of east-west tension joints, their actual boundaries with the country rock is not always along a smooth fracture plane as might be expected. In some places the boundaries are quite irregular and there may even be small dikelets extending outward from the parent dike intruding, cross-cutting and engulfing small masses of the wall rock. Although the dike itself frequently shows an aphanitic chill facies at its margins, the country rock never appears to be modified in any way by the dike. In the outcrops in the north half of lot 7, range V of Cawood township several diabase dikes which cross-cut the granitic injection complex are well exposed. In some places as shown in Plate 15 the boundaries of these dikes are not smooth flat planes but instead are slightly irregular sinuous surfaces. It seems that such irregular fracture surfaces would most likely result from pure tension, whereas plane fracture surface would result when some shear forces were involved. That the walls of the dike were "pulled apart" under tension is clearly indicated by the way in which crests and troughs in the sinuous wall-rock surface so perfectly match-up (Plate 15). It seems clear that the region was subjected to north-south tensional forces during the Late-Precambrian time.

Pleistocene and Recent

Pleistocene and Recent sedimentary deposits cover much of the bedrock of the area. All of these deposits are related in one way or another to the extensive Pleistocene glaciation which affected the region. Recent unconsolidated sand, gravel and boulder material, most of which has been derived from Pleistocene sediments is present along all of the main drainage ways. These Recent materials have not been separated on the geologic map from the older unconsolidated sediments. The most important and extensive unconsolidated deposits include glacial drift and stratified gravel, sand, silt and clay which are all of Pleistocene age.

Glacial drift does not form extensive deposits within the area. The only sizeable areas covered by such drift occur on the slopes of some of the hills in the highland part of the region. Apparently, glacial drift which may have been deposited in the eastern lowland part of the region has been covered by the younger sand and clay deposits. The largest body of glacial drift has been mapped in the extreme northwest corner of the area in Alleyn township. There the drift forms a thin veneer which is plastered on to the northwest slope of a fairly prominent group of hills. The drift is composed of much boulder material which imparts a characteristic rough aspect to the hillslope. The drift attains a maximum elevation of about 1050 feet in this locality and extends down to an elevation of a little over 700 feet where it is covered by Pleistocene sand. The only other extensive bodies of glacial drift occur on the hillslopes surrounding the village of Cawood and in the central part of the area. As with the deposits in the northwest, these appear to be only thin veneers composed of boulders and finer materials which are more or less plastered onto the sloping surfaces. All of this

material is believed to be simply ground moraine which was dropped by the retreating glaciers.

The northeastern corner of the area north of Venosta is mostly covered by stratified gravel, sand and some silt. In addition, much of the low-lying areas within the highland part of the region is covered by similar materials. Such deposits are especially evident in the areas adjacent to the courses of the Picanoc and Kazabazua rivers. Nearly all of this stratified material is of Pleistocene age; however, no attempt was made to separate it from Recent sands, etc. which occur mostly along the main drainage-ways. Nevertheless, of the material mapped as undifferentiated till, gravel, sand, etc., by far the largest proportion is made up of Pleistocene stratified gravel and sand. It is this material which underlies the lowland sand plain which forms the characteristic physiographic unit in the eastern half of the area. These stratified deposits are present from elevations of about 550 feet up to nearly 800 feet. Generally the sands are well stratified and fairly well sorted and of a yellowish brown color. The gravels are always poorly sorted and consist of material from sand or silt size up to boulder size. Stratification varies from 1 to 2 inches thick up to 1 to 2 feet thick in the coarser materials (Plate 16). In some places (Plates 17 and 18) excellent cross-bedding was observed. In the gravel quarry about one-half mile east of Danford Lake on the Kazabazua road the cross-bedding had a strike of northwest and dipped 20-25 degrees southwest.

The southeastern corner of the area south of Venosta and below an elevation of about 550 feet is covered by heavy dark gray to black well stratified clay. Similar clay has been mapped by Beland (1954) in the Wakefield area and by Muffette (1949) in the Denholm-Hincks area to the east. The clay deposits in all these areas are undoubtedly continuous and belong to the

same formation. Although no fossils were found in any of the stratified deposits during the writer's investigation, Antevs (1939) has found marine shells at Venosta and at Brennan (Hill in the Denholm-Hincks area). In addition, Beland (1954) has found marine fossils in clays in the northern part of the Wakefield area. Clearly the fossil evidence indicates that the clays are of marine origin and not lake deposits as has sometimes been supposed.

The Pleistocene marine clays are believed to have formed during a post-glacial marine submergence when the area was flooded by the Champlain sea. Marine deposits are very extensive in the lower Ottawa and St. Lawrence valleys where the so called Champlain sands overlie the Champlain clays (Dresser and Denis, p. 523, 1944). It is interesting that the same stratigraphic relationship between sand and clay was observed in the Aylwin-Cawood and adjacent areas. It seems likely that part if not all of the Pleistocene gravel and sand deposits in this area are also of marine origin and were deposited in the Champlain sea. However, it is quite possible that some of these deposits, especially the coarser ones, are of glacial-fluviatile origin. However, it seems more likely that the Champlain sea had a great northern arm or estuary which extended up the present Gatineau river valley (Keele, 1916 and Wilson, 1924) and that in this body of water the marine clays and later the gravels and sands were deposited. With such an interpretation the fine grained clays probably represent deep water deposits formed during the maximum advance of the Champlain sea, whereas the gravel and sand deposits are near shore deposits which were formed at a late stage after the major advance of the sea. The uniform level of the sand plain in the eastern lowland part of the area is simply a reflection of the controlling level of the Champlain sea during sedimentation. Obviously the glacial drift dropped by the retreating glaciers provided the major source of these clastic deposits.

STRUCTURAL GEOLOGY

Introduction

The structural pattern of the Alywin-Cawood area is extremely complex on both a detailed and regional scale. The rocks of the Grenville series seem to dominate the general structural pattern; however, the post-Grenville intrusive rocks have modified the structure considerably. Structurally the area appears to be divided into two parts. The highlands region in the western two-thirds of the area appears to be structurally distinct from the lowlands region on the east. After more detailed discussion below, it is proposed that the contact between the highland and the lowland regions, i.e. the contact between the granitic injection complex and the crystalline limestones, etc. in the eastern part of the area, may be a major structural break such as an unconformity or fault. In such a case the structural histories of the highlands and lowlands parts of the area would at least in part be quite distinct. The principal structural features throughout the area are foliation (and lineation) and folds; faults and joints are of subordinate importance.

Foliation

Foliation is the most prevalent and obvious structure within the various lithologic formations. The term foliation is applied to any planar structure within the rock. Foliation is manifest either by the preferred orientation of inequidimensional minerals or mineral aggregates such as mica, amphibole, sillimanite, lenseoid shaped quartz, feldspar or calcite grains, etc., or by distinct rock layers with compositions different from adjacent layers. The former kind of foliation might be called rock cleavage and the latter compositional layering.

The various rock formations themselves represent the largest scale case of compositional layering. The best examples of compositional layering are hornblende gneiss layers interlayered with less mafic gneisses or granite; or granite and pegmatite interlayered with biotite-quartz-feldspar paragneiss in the granitic injection complex. Such layering is on a scale of fractions of an inch to tens of feet. Compositional layering in rocks of the Grenville series is probably parallel to the stratification planes of the original Grenville sediments. On the other hand much of the compositional layering is related to the intrusion of post-Grenville rocks as layers and sheets more or less parallel to the pre-existing layering in the Grenville series. This is certainly the case in the dioritic and granitic injection complexes.

Rock cleavage, which is due to the preferred orientation of minerals and mineral aggregates, is present in nearly all of the rocks. It is particularly well developed in mica or hornblende rich rocks of the Grenville series and is usually clearly apparent in Grenville crystalline limestones. Such cleavage is generally less well developed in the post-Grenville intrusive rocks. Rock cleavage is a secondary structure and is undoubtedly the result of deformation during the metamorphism of the rocks. Gneissic structure in some of the intrusive rocks may in part be primary and due to the flowage of partly-crystalline magma.

Lineation, which is the term applied to any linear structure within a body of rock, is much less prevalent than foliation. Lineation is caused by either the preferred orientation of elongated minerals or mineral aggregates or by the directional alignment of elongated rock masses. The former is analogous to rock cleavage and the latter to compositional layering. Lineation is believed to have developed directly as a consequence of the

deformation of the rocks during metamorphism. No consistent pattern of lineation was established in the area. This may in part be caused by the fact that few linear observations were available to be made.

Throughout the region compositional layering and rock cleavage are parallel. In addition this foliation is parallel to the geologic boundaries of the formations. Thus in the southwestern corner of the area the foliation trends about northeast and dips steeply. This trend changes gradually to a northerly direction in the north-central part of the area. In addition, still paralleling the general geologic boundaries of the formations, the foliation in the northwestern part of the area trends in general northeast and even east-west in the extreme northwest corner. It is believed that these trends are directly related to the trends of several fold axes which are present within the highland core of the area.

Folds

The lithologic formations in the area broadly define several structures in the highland region which are best interpreted as folds. The axial trace of the most prominent fold passes directly through the southwest corner of the area and extends about 6 miles to the northeast and then swings to the north and extends about 7 miles in that direction to where it is covered by Pleistocene sand deposits.

This fold which forms a sort of structural core to the area is best defined by the granitic injection complex as well as some Grenville formations including hornblende gneiss and crystalline limestone. The fold appears to be an anticline which plunges to the northeast. However, as no stratigraphic data to tell the relative ages of members of the Grenville series are available, it is not absolutely certain that this fold is an anticline. However,

as it is of anticlinal form, in the subsequent discussion it shall be referred to as an anticline. The anticline appears to be continuous to the west with a very poorly developed syncline. The axial trace of the syncline appears to pass about 1-1/2 miles southeast of the village of Cawood and extend to the northeast essentially parallel to the axial trace of the anticline. The syncline is best defined by the granitic injection complex and crystalline limestone formations.

The structural relationships in the extreme west and northwest part of the area are very complex. It is believed that a major fold of anticlinal form which plunges to the northeast dominates the structure there. Further, it seems as if the quartz diorite and related rocks in the vicinity of O'Brien Mountain occupy the core of the fold in this area. Thus the north-northeast trend of the Kazabazua river in this vicinity is about parallel to and probably a little east of the axial trace of the proposed fold. It is believed that this fold is continuous with the syncline to the southeast, only is a much more open structure than the latter. Aside from the quartz diorite core, the fold is best defined by the granitic injection complex. It appears as if the latter in the extreme north part of the area just west of Danford Lake swings to the northwest and is continuous with the granitic rocks northwest of the dioritic injection complex on both sides of the Picanoc river. In fact much of the Grenville type rock within the dioritic injection complex may be equivalent to those in the granitic injection complex to the east (on the opposite limb of the fold) but differ only in their modifications due to the influence of dioritic intrusive rocks instead of granitic. Clearly then, the granitic rocks in the extreme northwest corner would be on the northwest limb of the proposed fold and the granitic injection complex near Danford Lake would be on the southeast limb of the fold. The axial

trace of the proposed fold would then extend north-northeastward generally through O'Brien Mountain and pass immediately west of the string of lakes which lie directly north of the village of Danford Lake.

A complete understanding of the nature of the folding in this region necessitates a knowledge of the geology of adjacent areas particularly those to the immediate west and southwest. It is expected that these folds will extend into the adjacent regions. Furthermore, judging from the structural observations in the Aylwin-Cawood area it seems most likely that the anticlinal fold in the northwest part of the area will prove to be the major structure in this region and that the syncline and anticline to the southeast may be essentially minor folds along the southeast limb of the major fold. It is proposed that the folding took place during the major period of regional metamorphism of the pre-Cambrian rocks.

Faults and Joints

A transverse east-west fault with a 1-1/4 to 1-1/2 mile horizontal offset was mapped in the central part of the area in the western part of Low township. The fault offsets the granitic injection complex and Grenville crystalline limestones. In the granitic complex immediately south of the fault a considerable amount of epidote veining is present. The eastward extension of the fault is indeterminate as it is covered by a Pleistocene sand plain. The fault can only be traced about a mile west from the point where it is covered by the sand plain. However, it seems likely that the fault or a zone of fracture related to it extends for a mile or two farther west, and that the east-west course of Stag creek is developed on the less resistant fractured rock and indeed along the fault plane itself to the east.

Jointing is not a conspicuous structure in the area. The most prominent

system of joints appear to be transverse to the foliation and hence strikes about east-west and dips steeply. Very likely the fault described above and this joint system are closely related. Furthermore, the east-west diabase dike system is probably related to this joint system.

Special Structural Considerations

Intrusive masses

On a regional scale the intrusive masses of dioritic and granitic aspect are conformable to the intruded Grenville series. In general it is only on a small local scale that these intrusive rocks clearly cross-cut the gneisses, etc., of the Grenville series. As is apparent from the geologic map the granite and granite gneiss body in the south-central part of the area is simply a large layer continuous with similar rocks in the granitic injection complex immediately to the north. In fact it is evident in the field that these two bodies lense into one another. Other smaller bodies of pink granite, granite gneiss and pegmatite which are generally too small to show on the geologic map are layers and sheets conformably interlayered with the Grenville series.

The large mass of quartz diorite and related rocks centered around O'Brien Mountain occupies the core of what is probably a major anticline. In this sense the body is of phacolithic nature. In addition the body of quartz diorite in the central part of the area which stems from the major intrusive mass is a sheet shaped body which is intruded conformable to the adjacent Grenville rocks and follows the pattern of folding in detail. Furthermore, to the south a small mass of an acid facies of the quartz diorite is intruded along the axis of the southeastern anticline and is hence a phacolithic body. Clearly the morphology of all the intrusive bodies in

this area was controlled to a large extent by the nature of the folding in the Grenville series. It is further evident that the dioritic and granitic rocks were probably intruded during the period of major folding of the Grenville series.

Stratigraphic considerations

As mentioned previously there is some evidence which indicates that the geologic boundary between the highlands and lowlands parts of the area (the boundary between the granitic injection complex and the crystalline limestone belt in the east) is of considerable structural significance. As is apparent on the geologic map the north-south belt of crystalline limestone on the east side of the area is at least to some extent folded with the rocks of the highland region. If this broad belt of limestone is in stratigraphic sequence with the Grenville series of the highlands, it is to be expected that the formation would swing to the southwest in the south part of the area and to the northwest in the north part of the area following the major folds as described above. However, judging from the geologic map of the Onslow-Masham area on the south (Sabourin, 1954) the crystalline limestone belt does not change its general trend and swing to the southwest, but instead continues on its trend south into the Wakefield area (Beland, 1954) perhaps as far as Hull. In addition it seems very likely that this limestone belt is continuous with the similar mass of rock mapped by de la Rue (1953) in the Kensington area about 20 miles north of the Alywin-Cawood area. Therefore, it seems that the north-south crystalline limestone belt continues north and does not swing northwest parallel to the other folded rocks of the highlands region in the northwest corner of the area. In summary with the limited geologic data on hand it appears as if the crystalline limestone formation in the eastern part of the area is part of a great limestone belt which extends from near Hull north to at least the Kensington area. That

this belt is structurally distinct from the rocks of the adjacent highlands in the Aylwin-Cawood area is proved by the fact that the belt does not apparently follow the folds to the southwest and northwest, and in addition the general structural trend in the highlands area is northeast which is at an angle to the north-south trending belt of crystalline limestone. Therefore, it is believed that the contact of this limestone belt with the granitic injection complex in the Aylwin-Cawood area and with other rocks typical of the highlands area to the north and south represents a definite structural break.

This structural break might be either purely stratigraphic, i.e. an unconformity, or could be a fault, i.e. low angle thrust fault, or could be a combination of the two. The fact that Grenville limestone is much less abundant in the rocks of the highland region than in the lowlands to the east suggests that the structural break may be of stratigraphic nature with the areas east and west of the break representing different original sedimentary facies. This conclusion would fit with the general regional observation (Osborne, personal communication) that the Grenville series east of the Aylwin-Cawood area is considerably richer in limestone; whereas, the Grenville series to the west is much richer in rocks of clastic origin. Furthermore, it is suggested that if the structural break is of stratigraphic nature, then the large belt of crystalline limestone on the east is younger than the Grenville series in the highlands part of the area. This is in keeping with the regional angular discordance between the highlands and the lowlands rocks as described above which suggests that the clastic rich "older" Grenville rocks were deposited first and probably somewhat folded and then the "younger" Grenville rock of dominantly limestones were deposited above them in mild angular discordance. It is interesting to note

that Osborne (1944) suggested that, "the section at Calumet may be visualized, therefore, as originally a series of muds and more or less calcareous shales passing by intercalation and gradation into a relatively pure limestone." Perhaps this apparently younger limestone in the Calumet area is of the same age as the crystalline limestones in question here. At any rate it seems very instructive to keep in mind the possibility that the structural break under discussion here is a major unconformity within the Grenville series separating a dominantly clastic section below from a dominantly limestone section above.

As indicated above the structural break could be a fault. It is difficult to evaluate the relative merits of this hypothesis against that of a stratigraphic break. In either case it appears as if the rocks on both sides of the structural break have to some extent been folded together. Even if the structural break is a fault, it seems likely that there might be considerable difference in age between the Grenville rocks on either side of the break.

GEOLOGIC HISTORY

The geologic history of the Aylwin-Cawood area is highly complex and only incompletely known. The principal parts of the history which emerge from this study are summarized below:

- (1) Deposition of "older" Grenville series consisting of mostly clastic and lime sediments.
- (2) Mild folding of the "older" Grenville series.
- (3) Deposition of "younger" Grenville series consisting dominantly of lime sediments.
- (4) Strong folding and regional metamorphism of the Grenville series with development of various gneisses, crystalline limestones, etc.

(5) Intrusion of anorthosite into the Grenville series.

(6) Further intense folding and regional metamorphism of the Grenville series and intrusion of the quartz diorite and related rocks (Buckingham series?) with the consequent development of mixed and modified rocks as characteristic of the dioritic injection complex.

(7) Intrusion of pink granite and pegmatite (Pine Hill?) and continued regional metamorphism with consequent development of mixed and modified rocks as characteristic of the granitic injection complex.

(8) Intrusion of lamprophyre dikes continued regional metamorphism.

(9) Intrusion of meta-syenite dikes near the cessation of regional metamorphism.

(10) Intrusion of late massive pegmatites and probably some pink granites.

(11) Intrusion of diabase dikes.

(12) Faulting.

(13) Erosion to Laurentian peneplain.

(14) Pleistocene glaciation with resulting drift deposits.

(15) Insurgence of Champlain sea and deposition of Pleistocene marine clays and sands.

Although the pre-Cambrian geologic history as outlined above is probably oversimplified and incomplete, clearly the bulk history of the area is concerned with the sedimentation of the Grenville series and its subsequent regional metamorphism and metasomatism. It seems most likely that the regional metamorphism was a continuous process, but that it was characterized by periods of maximum intensity corresponding to the intrusion of the large amounts of igneous material.

ECONOMIC GEOLOGY

Introduction

Surrounding the Aylwin-Cawood area active prospecting and considerable small and some large scale mining has taken place. The principal kinds of mineral deposits present in the surrounding region include brucite as in the Wakefield area (Beland, 1954), mica and apatite (Osann, 1902), lead and zinc sulphides as in the Calumet area (Osborne, 1944), and molybdenite as in the Onslow-Masham area (Sabourin, 1954). Mineral deposits of subordinate importance in the surrounding region include barite, feldspar, graphite, marble and magnetite. Within the Aylwin-Cawood area proper several mica prospects are present and recently there has been considerable prospecting for uranium. Otherwise only small occurrences of asbestos, sulphides, magnetite and garnet are worthy of mention.

Mica

Several mica prospects and old workings are located in the area. The old working in the west half of lot 30, range A, Low township was examined in detail. There small books (up to 3 inches across by 6 inches high) of inferior dark phlogopitic mica occur in pale green phlogopitic metamorphic pyroxenite which is intruded and cross-cut by pink granite. Star shaped clusters of amphibole (tremolite), pink calcite, apatite and pale green feldspar are closely associated with the phlogopite. The general relationships indicate that the phlogopite formed as a result of the interaction of the pink granite and the metamorphic pyroxenite. Additional mica prospects are reported in lot 36, range XIII, Low township; lot 22, range II and lots 23-24, range III, Cawood township; and lot 12, range I, lot 4 and 10, range II, Alleyn township.

Uranium

At the present the area is of considerable interest to the uranium prospector. Pegmatites appear to have normal activity; however, much of the metamorphic pyroxenite which is generally found as small bodies within the crystalline limestone formations, appears to have an abnormal activity. Several such outcrops of metamorphic pyroxenite which are intruded and cross-cut by pink granite are located in lots 5 and 6, range II, Alleyn township. The pyroxenite here contains traces of sphene and much of the diopside is altered to clinocllore. In addition the granite carries a minor amount of thorite (?) which probably accounts for the abnormal radio-activity of the rocks. It is recommended that further uranium prospecting be concentrated in limestone areas where metamorphic pyroxenite is most abundant. It is especially recommended that the outcrops of crystalline limestone in the vicinity of Cawood be thoroughly prospected. In addition, inasmuch as the mica deposits of the region are generally found in metamorphic pyroxenite, it is suggested that old mica prospects might be re-prospected with activity counters.

Sulphides

Iron sulphides are disseminated in many of the Grenville gneisses and in crystalline limestone. Rarely pyrrhotite is found in small cross cutting veinlets in the rusty gneisses, e.g., locality northeast of Doyley Lake, range B, Low township and lot 16, range III, Cawood township. Rarely minor amounts of copper sulphide are found such as in the gneiss at lot 37, range VI, Alywin township.

Molybdenite occurs in various quantities in adjacent regions. It has been reported from lot 1, range II, Alleyn township; otherwise no significant

quantities have been indicated.

Magnetite

In the extreme southeastern corner of range V, Cawood township a small mineral occurrence of magnetite is present. The mineral occurs in amounts up to 10-15 percent in a hornblende-pyroxene skarn which is closely associated with hornblende gneiss. Similar deposits have not been found elsewhere in the Aylwin-Cawood area; however, at the Bristol Mine, in Bristol township, Pontiac county magnetite is associated with mafic gneisses and limestones of the Grenville series (Dresser and Denis, 1949, p. 399). Obviously this deposit is quite similar to the occurrence in this area.

Asbestos

A small outcrop of rather harsh, short fiber, tremolite asbestos is located in lot 21, range I, Cawood township. The asbestos mass occurs in a formation of crystalline limestone and is considerably mixed with quartz and calcite. Asbestos has also been reported from lot 4, range II, Alleyn township, and lot 27, range II, Cawood township.

Garnet

In some of the rocks of the dioritic injection complex garnet may locally occur in amounts up to 10 percent. In the north half of lot 10, range 5, Alleyn township in the northwest corner of the area garnet is particularly abundant in some of the hybrid rocks of the dioritic injection complex. The garnet which is probably a pyrope-almandite is believed to have formed from hornblende gneisses as a result of intrusion and modification by quartz diorite. It is possible that more detailed prospecting

within the dioritic injection complex for garnet deposits could be worthwhile.

Gravel and Sand

Pleistocene deposits of gravel and sand are present throughout the northeast corner of the area and provide ample material for construction purposes within the area. A recently opened quarry for sand and gravel for road maintenance purposes is located about one-half mile east of the village of Danford Lake in Aylwin township.

APPENDIXDescription of Formations on Geologic Map of the
Aylwin-Cawood Area, Pontiac and Gattineau Counties.CENOZOICPleistocene and RecentUndifferentiated till, gravel and sand

Largely Pleistocene (Champlain) sand with some gravel; subordinate glacial drift mostly on hillslopes; recent gravel and sand mostly along main drainage ways.

PleistoceneChamplain clayGlacial driftPRECAMBRIANPost-Grenville RocksDiabase dykesEarly dykes

Meta-lamprophyre and meta-syenite

Granitic injection complex

Hornblende gneiss, sillimanite-garnet-biotite gneiss and much biotite-quartz-feldspar paragneiss of the Grenville series which have been intruded and modified by pink granite and pegmatite; augen granite gneiss and injection gneiss are characteristic modification products of the biotite-quartz-feldspar paragneiss.

Granite, granite gneiss and pegmatite

Predominantly pink, massive granite and pegmatite and pink granite orthogneiss.

Dioritic injection complex

Crystalline limestone, graphitic gneiss and much hornblende gneiss of

the Grenville series which have been intruded and modified by quartz diorite and related facies; garnet-hornblende gneiss is the characteristic modification product of hornblende gneiss.

Quartz diorite and related facies

Predominantly greenish quartz diorite and diorite and subordinate quartz monzonite and granite.

Anorthosite

Very small bodies of greenish white, medium grained, massive to gneissic anorthosite.

Grenville Series

Mainly crystalline limestone

Chiefly crystalline limestone with subordinate amounts of other Grenville gneisses and some pink granite and pegmatite.

Crystalline limestone and mixed gneisses

Roughly equivalent amounts of crystalline limestone and Grenville gneisses of which quartzite, graphitic and biotitic gneisses (often rusty-weathering) and metamorphic pyroxenite are the most important; some pink granite and pegmatite.

Mixed gneisses

Grenville gneisses of which quartzite, graphitic and biotitic gneisses (often rusty-weathering) metamorphic pyroxenite and sillimanite-garnet-biotite gneiss are most important with subordinate crystalline limestone; some pink granite and pegmatite.

Hornblende gneiss

Chiefly a uniform, dark gray, medium grained hornblende-plagioclase gneiss; some granitic and pegmatite veining.

Biotitic-hornblende-plagioclase gneiss

Chiefly gray, medium to coarse grained non-uniform biotitic-hornblende-plagioclase gneiss interlayered with crystalline limestone and white pegmatite and subordinate amounts of other Grenville gneisses and granite.

Mixed hornblende gneisses

Chiefly gray, fine to medium grained biotite-hornblende-feldspar gneiss interlayered with other Grenville gneisses and crystalline limestone and generally injected intimately with granite and pegmatite.

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Plate 1. The boundary between the highland and lowland parts of the area. In background are hills underlain by granitic injection complex in the highlands; foreground is the lowland Pleistocene sand plain which is underlain by crystalline limestone. View looking south from a point on the Kazabazua road about one mile east of Danfords Lake, in Aylwin township.



Plate 2. Picanoc river valley. View of the northwest corner of the Aylwin-Cawood area showing the Picanoc river valley and the pre-Cambrian highlands on its northwest side. View from a point in north half of lot 10, Range 5, Alleyn township.

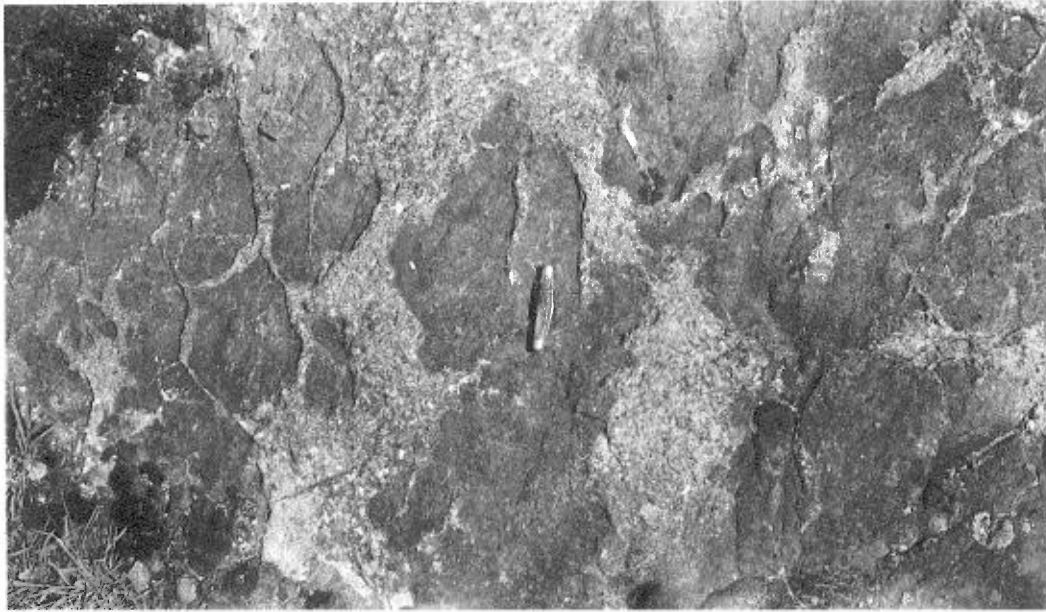


Plate 3. Metamorphic pyroxenite and pegmatite. Dark gray metamorphic pyroxenite intruded and cross-cut by white pegmatite. Lot 7, Range VI east, Aldfield township.



Plate 4. Metamorphic pyroxenite and pegmatite. Same as plate 3.

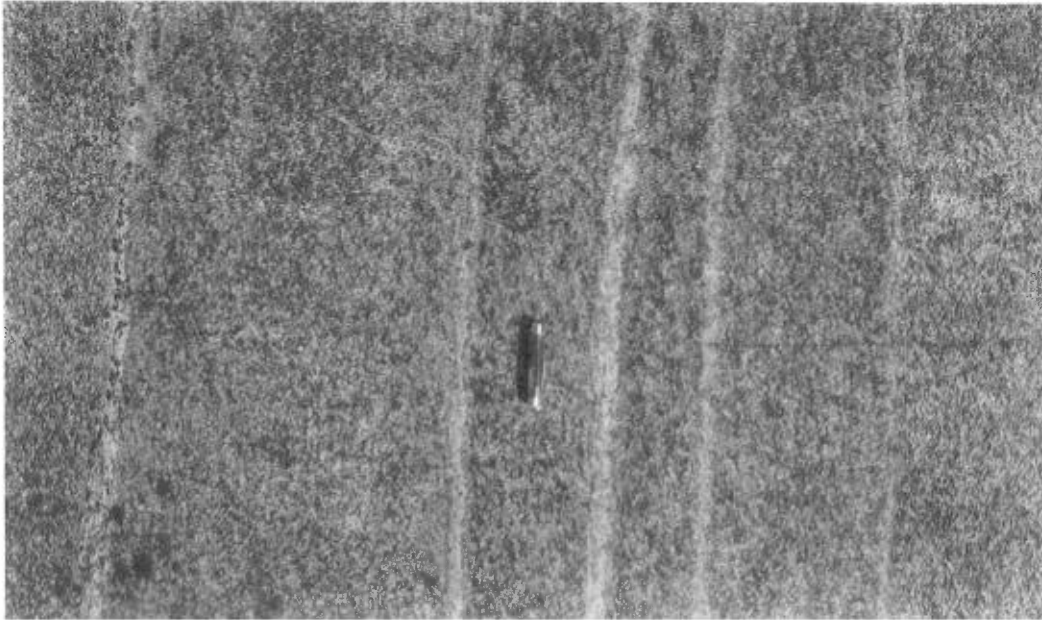


Plate 5. Garnet-hornblende gneiss. Flat smooth exposure of very typical garnet-hornblende gneiss with thin layers or seams of quartz dioritic pegmatite parallel to the foliation in the gneiss. Note development of garnet along borders and within pegmatites. Lot 10, Range V, Alleyn township.

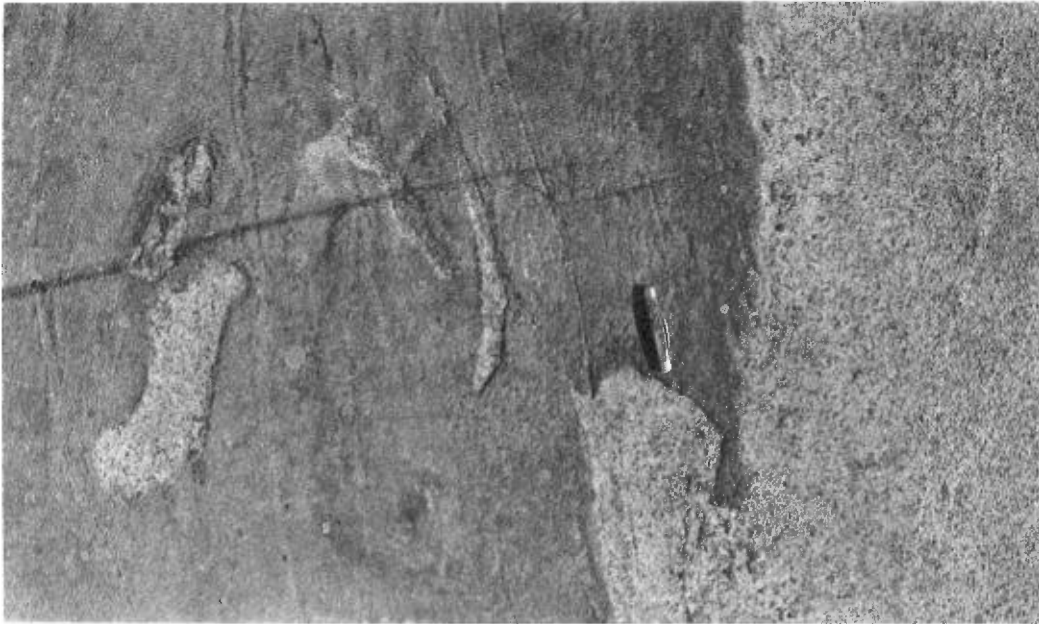


Plate 6. Hornblende gneiss and garnet rich diorite. Hornblende gneiss (dark gray) intruded and cross-cut along an irregular contact by a garnet rich facies of diorite (light gray). Note the isolated bodies of diorite surrounded by hornblende gneiss. Lot 10, Range V, Alleyn township.



Plate 7. Hornblende gneiss and garnet-hornblende gneiss. Hornblende gneiss (dark gray) modified to garnet-hornblende gneiss along the foliation plane. Note the relict patches of hornblende gneiss and the large round aggregates of garnet. Lot 10, Range V, Alleyn township.



Plate 8. Garnet-hornblende gneiss cross-cut by quartz diorite pegmatite vein. Note the dark aggregates of garnet near the borders of the pegmatite. Lot 10, Range V, Alleyn township.

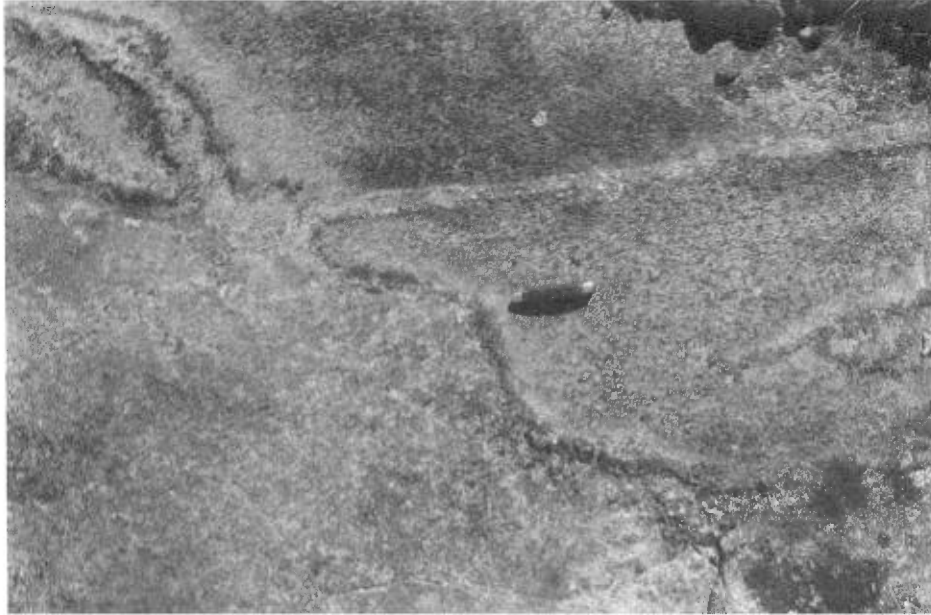


Plate 9. Garnet-hornblende gneiss and garnet quartz monzonite. Garnet-hornblende gneiss with foliation parallel to the knife intruded and cross-cut by garnet quartz monzonite (on left). Note marked (dark colored) garnet reaction zone between the two rocks. Lot 10, Range V, Alleyn township.

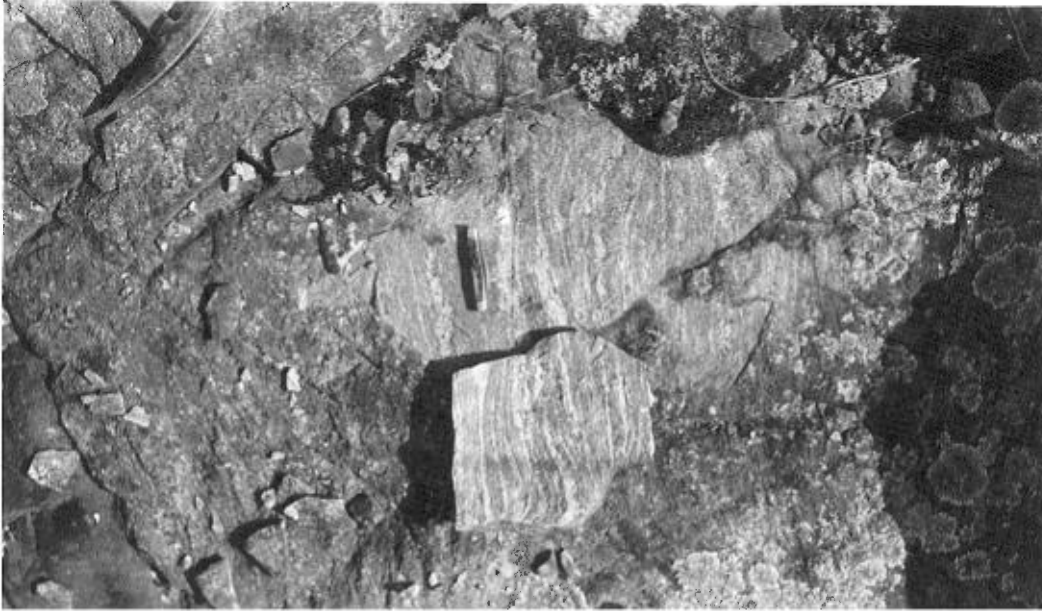


Plate 10. Injection gneiss. Biotite-quartz-feldspar paragneiss (gray) injected by thin layers and seams of pink granite and pegmatite. Lot 28, Range XI, Aylwin township.



Plate 11. Meta-lamprophyre dike. Dark gray meta-lamprophyre intruded into Grenville garnet-biotite-quartz-feldspar paragneiss which has been injected and modified by pink pegmatite. Note that the body of the dike cross-cuts the foliation in the gneiss and that the dike itself possesses a plane of schistosity which is exactly parallel to that in the adjacent gneisses. The scale is placed parallel to this schistosity plane. Note that in the lower right hand corner the dike thickens, this probably corresponds to the crest of a shear fold (see text). Note that pegmatite veins extend from the paragneiss into the meta-lamprophyre along the schistosity plane. Lot 31, Range A, Low township.



Plate 12. Meta-lamprophyre dike. Same as Plate 11. Note thickening of dike toward crest of shear fold (on the right) and thinning toward limb of shear fold (on the left).



Plate 13. Meta-lamprophyre dike. Same as Plates 11 and 12. On limb of shear fold.



Plate 14. Meta-syenite (dark gray) dike intruded into greenish quartz monzonite (light gray). Gneissic structure in quartz monzonite parallel to knife and obviously cross-cut by dike. Note inclusions of quartz monzonite in dike. Gneissic structure in inclusion not parallel to that in adjacent wall rock. Lot 16, Range IV, Alleyn township.



Plate 15. Diabase dike. Diabase dike (beneath knife) intruded into granitic injection complex. Foliation in complex is parallel to knife. Note very irregular sinuous boundary of the dike and that "crests and troughs" in opposite sides of the wall "fit" together. Lot 7, Range V, Cawood township.



Plate 16. Pleistocene gravel and sand. Stratified poorly sorted gravel and sand. Quarry one-half mile east of village of Danfords Lake. Aylwin township.



Plate 17. Pleistocene gravel and sand. Upper layers are nearly horizontal; lower layers show cross-bedding which dips 20-25° southwest. Locality same as Plate 16.

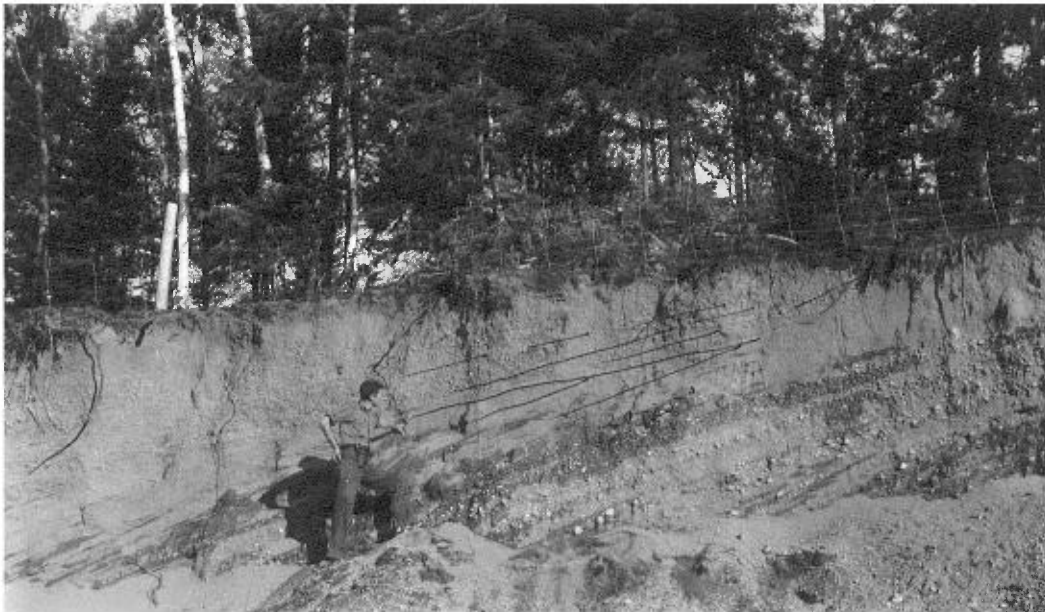


Plate 18. Pleistocene gravel and sand. Close-up of exposure in Plate 17.
Note upper layers truncate cross-bedding at small angle.