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THE MAZINAW LAKE METAVOLCANIC
COMPLEX, GRENVILLE PROVINCE
SOUTHEASTERN ONTARIO

by

John Albert Ayer, B.Sc.

A thesis submitted to the Faculty of
Graduate Studies in partial fulfilment
of the requirements for the degree of
Master of Science

Department of Geology
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Ottawa, Ontario
May, 1979

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The undersigned hereby recommend to the Faculty of Graduate
Studies acceptance of this thesis, submitted by John Albert Ayer,
B.Sc., in partial fulfilment of the requirements for the degree of
Master of Science.

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ABSTRACT

The map-area lies 125 km southwest of Ottawa on the eastern margin of the Hastings Lowlands, an area which contains the only rocks of undisputed volcanic origin in the Grenville Province. Mapping was augmented by petrography and chemical analysis in order to interpret the stratigraphy, lithology and compositional variation of the metavolcanic complex.

The oldest unit consists of submarine basalt flows correlated with the Tudor formation. These flows are overlain by a succession of basalt, basaltic-andesite, andesite and rhyolite flows and pyroclastic deposits defined as the Mazinaw Lake formation. Associated synvolcanic intrusions range in composition from ultrabasic to granitic and they are concentrated, along with coarse pyroclastics, in the eastern Pringle Lake area, an area interpreted to be the centre of volcanic activity. Volcanic rocks in the eastern part of the map-area are overlain by thick carbonate units. Small copper occurrences are related to the volcanic rocks and shallow intrusions. Lead-zinc-gold occurrences are found in the marbles directly overlying the volcanics.

Volcanics and sediments were intruded by granite plutons. The Mazinaw Lake Granite underlies a large proportion of the central and northern portion of the study area. Two major phases of deformation followed and concurrent regional metamorphism reached middle amphibolite facies.

Chemical analyses of representative specimens have confirmed the tholeiitic nature of Tudor formation basalt. The Mazinaw Lake succession is also shown to be tholeiitic and displays an iron-enrichment trend in mafic and intermediate members of the series. A distinct compositional gap is present between andesite and rhyolite members of the Mazinaw Lake formation.

Rhyolite is thickest around the southern portion of Mazinaw Lake and locally exhibits relict eutaxitic structures indicative of deposition as ash flow units, perhaps in a subaerial environment. Systematic sampling across rhyolite horizons has revealed chemical zonation and progressive increase in phenocryst content with stratigraphic height. Based on variations of molecular ratios of major oxides, the zonation can best be explained by eruption from a zoned magma chamber, with the zonation produced by crystal-settling of phenocrysts of plagioclase, alkali feldspar and an iron-rich silicate.

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I: INTRODUCTION

I.1 Purpose of Study

Field work by the Ontario Geological Survey in the Grenville Province in southeastern Ontario (Moore and Morton, m.s.), revealed portions of a previously unrecognized mafic to felsic metavolcanic complex, centred around the southern end of Mazinaw Lake. Through the extension of geological mapping, the purpose of the present investigation is:

- 1) to outline the boundaries of the complex and define its lithology and stratigraphy;
- 2) to interpret the structure and metamorphism;
- 3) to determine the petrochemical characteristics of the meta-igneous rocks and chemical trends in the metavolcanic rocks;
- 4) to propose a model for the geological evolution of the area.

I.2 Location, Access and Physiography

The Mazinaw Lake area is located 125 km southwest of Ottawa, Ontario near the southeastern border of the Grenville Province (Fig. 1). The area includes parts of Barrie, Anglesea and Effingham Townships. Much of the northwestern portion of the map-area lies within the boundaries of Bon Echo Provincial Park. Highway 41 passes through the area. From this highway several gravel-surfaced secondary roads provide adequate access for foot or canoe traverses.

The average elevation is 350 m above sea level. Lowest elevations

occur in the east, around Shawenegog Lake (300 m); the highest are found on the east shore of Mazinaw Lake (400 m). Generally relief is low, with hummocky topography containing numerous bogs, swamps and a number of lakes. Locally relief is spectacular: sheer rock cliffs rise 100 m above the water on the eastern side of Mazinaw Lake (Plate 6b). These cliffs are the most dramatic physical feature of the area and are additionally interesting as their lower portions were used as the 'canvas' for ancient Indian paintings, many of which are still well preserved.

Drainage of the western part of the map-area is southerly into Skootamatta Lake. The central and eastern portions are part of the Mississippi River drainage system which flows through Mazinaw Lake.

Bedrock exposure is good on the major pluton bodies, good to poor on the metavolcanic rocks and sparse in the areas underlain by meta-sedimentary rocks. Surficial deposits of unconsolidated glacial till cover much of the low-lying regions. The area is covered with a mixed forest vegetation including red and white pine, spruce, tamarack, poplar, birch, aspen, beech and maple.

1.3 Methods of Study

Geological mapping was conducted during portions of the summers of 1976 and 1977. Geology of the southern portion of the map-area is compiled from an Ontario Geological Survey map (Moore and Morton, m.s., Fig. 3). The author assisted or independently mapped on most of the traverses over this area. The remainder of the map-area (north of an east-west line approximately coinciding with the south shoreline of Little Shabomeka Lake, Fig. 3 - in pocket) was mapped by the author. Mapping was at a reconnaissance scale towards the eastern, western and

northern margins and over the large plutonic bodies. Traverses were more closely spaced (typically $\frac{1}{2}$ mile) in the central portion of the metavolcanic complex.

Outcrop distribution and rock-unit contacts were recorded in the field on air photographs (scale: 1 in. = $\frac{1}{2}$ mi.) and the data were transferred to a base map of the same scale (Fig. 3). Petrographic study was concentrated on rocks of meta-igneous origin, but thin-sections of rocks representative of all map-units were examined. Modes and textures of representative specimens of the meta-igneous rock-units have been tabulated (Appendix I).

Fifty-eight specimens were analysed by X-ray fluorescence and chemical techniques for major oxides and selected traces by three separate analytical laboratories. The results of the analyses, laboratories responsible and techniques used are included in Appendix II.

I.4 Previous Work

The earliest work in the region was performed in the Hastings Lowlands (Bancroft-Madoc area) west of the study area by Logan (1863). He recognized the metavolcanic rocks and included them in the "Grenville Series". Vennor (1869) produced the first published geological map of the eastern portion of the region, including Grimsthorpe, Elzevir and Anglesea Townships, at a scale of four miles to the inch.

Miller and Knight (1914) mapped several separate areas in the region. They were the first to suggest that the mafic metavolcanics represent the oldest rocks of the Hastings Lowlands and were first to propose a major unconformity separating older volcanics and sediments from a younger sedimentary group, the "Hastings Series".

Systematic geological mapping of Anglesea and Barrie Townships was first carried out by Meen (1944) at a scale of one inch to the mile. For a portion of the study area, this work represents the most recent report. Smith (1956) mapped just east of the study area (Clarendon and Palmerston Townships) at the same scale.

Hewitt (1964) considered the metasedimentary rocks, not the meta-volcanics, to be the oldest rocks in the Bancroft-Madoc area. The low-grade metavolcanic rocks were thought to form the upper part of the stratigraphic column.

Lumbers (1967a) compiled stratigraphic, plutonic and metamorphic data for the region. He suggested a regional stratigraphic succession consisting of an older, predominately metavolcanic group (Hermon group) and a younger, marble-rich metasedimentary group (Mayo group). The metavolcanic rocks in the map-area are correlated with the Hermon group and these are overlain by predominantly calcareous metasediments which correlate with the Mayo group.

Spence (1968) described metavolcanic and metasedimentary rocks east of the study area, near Plevna, and studied relict plagioclase phenocrysts in the metavolcanic rocks.

Moore (1967) and Sethuraman (1970) mapped an angular unconformity between metavolcanic rocks with associated marble, and the pelitic schist and conglomerates of a younger group of rocks. The name Flinton group (Thompson, 1972; Moore and Thompson, 1972) was applied to this younger group. The Flinton Group was shown to post-date all major igneous activity in the low to medium grade areas of eastern Hastings region (Fig. 1).

Sethuraman (1970) and Sethuraman and Moore (1973) divided the meta-volcanic rocks in the Bishop Corners-Ompah area (Fig. 1) into five

petrographic units based on colour index and the presence or absence of fragments. They also established metamorphic zones based on the distribution of mineral assemblages in the mafic metavolcanic rocks.

Hutcheon (1972) mapped and sampled several areas in southern Barrie Township, underlain primarily by marbles and determined a tremolite isograd based on the appearance of tremolite with calcite. He also (Hutcheon and Moore, 1973) estimated metamorphic temperatures from the magnesium content of calcite associated with dolomite.

Rivers (1976) remapped an area east of the study area, around Ompah (Fig. 1), to determine the structural history and textural variations with progressive metamorphism.

Geological mapping of the Clarendon Lake map sheet (Moore and Morton, m.s.), at a scale of one inch to one quarter mile, includes the southern portions of Anglesea and Barrie, the western extremity of Clarendon, and the extreme northern parts of Kaladar and Kennebec Townships. This work is the most recent geological report and includes the southern portion of the map-area.

The Mazinaw Lake aeromagnetic sheet (1949) includes the present map-area.

I.5 General Geology

Figure 2 is a generalized geological map of the study-area and surrounding region. The oldest rocks are metabasaltic flows which can be traced westwards into the Tudor formation of Lumbers' (1967a) Hermon group. In the map-area these rocks are overlain by a complex succession of metamorphosed mafic to felsic flows and pyroclastic deposits and their associated synvolcanic intrusions and volcanoclastic sediments

Figure 2

LEGEND

FLINTON GROUP

GRANITOID PLUTONS

MARBLE

CALC-ALKALIC METAVOLCANIC ROCKS

DACITE & ANDESITE

BASALT

MARBLE

MAZINAW LAKE FORMATION

RHYOLITE & ANDESITE

BASALT & BASALTIC ANDESITE

TUDOR FORMATION

BASALT

SYMBOLS

GEOLOGICAL CONTACT

FOLD AXIAL TRACE (defined)

FOLD AXIAL TRACE (assumed)

Figure 2: General geology map, study area outlined by thin line

called the Mazinaw Lake Metavolcanic Complex. Numerous dykes, small intrusions and abundant coarse pyroclastic deposits suggest that the Pringle Lake area was a centre of volcanic activity. The northern margin of the complex is an intrusive contact with a large granite pluton which has displaced an unknown amount of the complex. Carbonate metasedimentary rocks overlie the metavolcanic succession in the eastern part of the map-area.

South of the map-area (Fig. 2), both the Tudor and Mazinaw Lake metavolcanic rocks are overlain by carbonate rocks. These marbles are in turn overlain by a younger succession of metavolcanic rocks (calc-alkaline basalts to dacites). These younger metavolcanics terminate in marble just south of the study area, and are also overlain by carbonate rocks.

In the northern, western and southern parts of the region (Fig. 2) metavolcanics and metasediments are intruded by large granitoid plutons. Within the map-area, they are predominantly granite, but outside the study area the plutons are predominantly granodiorite to trondhjemite.

The Flinton Group metasediments lie unconformably not only on the older Hermon and Mayo group rocks but also on granodiorite and trondhjemite that intrude these groups.

The structure is complex and appears to be dominated by the presence of large plutonic bodies. Rocks of the map-area have undergone at least two phases of deformation, and regional metamorphism to the middle amphibolite facies. Metamorphism accompanied and outlasted most of the penetrative deformation.

In the region, two periods of magmatism are recognized: an earlier biotite diorite series; and a granitic series (Lumbers, 1967a). The

results of lead isotopic ages on rocks of the region (Silver and Lumbers, 1966) have been recalculated according to more recent data on uranium decay constants (Bell and Blenkinsop, 1979). The modified results are: an age of 1286 ± 15 Ma for Tudor formation metavolcanics; 1226 ± 25 Ma for the Elzevir pluton (Biotite diorite series); and 1104 ± 25 Ma for the Addington pluton (granitic series). Bell and Blenkinsop (1979) are at present involved in a rubidium-strontium isotope study of the plutonic bodies of the region. Preliminary results of this study revealed the following ages: Northbrook-Mellon Lake plutons (biotite-diorite series) 1180 ± 90 Ma; Addington pluton 1072 ± 22 Ma. As yet unpublished data on samples from the Mazinaw Lake pluton yielded a Rb-Sr age of 1170 ± 40 Ma (Blenkinsop, personal communication, March 1979). Regional metamorphism and intrusive activity continued until approximately 1050 Ma (Krogh and Hurley, 1968).

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II: LITHOLOGY AND STRATIGRAPHY

II.1 Introduction

The distribution of lithological map-units in the Mazinaw Lake area is shown on Figure 3 (in pocket). The map-area is underlain by a succession of complexly folded and metamorphosed volcanic and sedimentary rocks intruded by large granite plutons. Although metamorphic grade throughout the area is in the amphibolite facies, there is sufficient preservation of primary features to permit inference of the original character of much of the rock. The composition of representative specimens of the meta-igneous rock units has been determined through chemical analysis (Chapter IV.3 & 4). This data in conjunction with relict textures is used in the classification of the meta-igneous rock units, thus for the sake of brevity, in many places in the text, the prefix 'meta' has been omitted.

The lithology section below includes descriptions of each map-unit, including typical textures and mineralogy. Modes and textures of individual specimens representative of the meta-igneous map-units are given in Appendix I (Tables 10 and 11). Descriptions of the map-units are followed by a speculative interpretation of the original premetamorphic nature and environment of deposition.

II.2 Metamorphosed Volcanic Rocks

II.2.1 Unit 1a Rocks of this map-unit (Fig. 3) constitute the upper portion of a thick succession of basaltic flows which can be directly traced into metavolcanic rocks of the Tudor formation (Lumbers, 1967a). Tudor formation basalts are more extensive south and west of the map-

area. West of Highway 41 (Fig. 2) the basalt succession is at least 4 km thick (Sethuraman and Moore, 1973) and the base is not exposed, because the lower boundary is an intrusive contact with the Elzevir Batholith. However, within the map-area, unit 1a rocks are restricted to the extreme southwest and northwest sections and comprise a relatively small proportion of the total amount of metavolcanic rock present.

The rock of this unit is typically a fine-grained, dark green amphibolite of basaltic composition (Chapter IV.3). Primary volcanic textures are variably preserved depending on the amount of deformation the rock has experienced. Horizons of deformed pillow lavas are recognizable in rocks just south of the map-area, along strike with unit 1a. Within the map-area relict volcanic textures include: autoclastic breccias consisting of amphibolitic fragments in a similar but slightly more schistose matrix; quartz and/or carbonate filled amygdules; and small relict plagioclase phenocrysts. However, the majority of unit 1a rocks are uniform, aphyric and non-amygdaloidal. A tectonically derived schistosity is ubiquitous and is defined by planar alignment of hornblende crystals.

Published geological compilation maps which include the map-area (e.g. Ont. Dept. Min., Map No. 2053; Lumbers, 1964, Fig. 7; MacDonald, 1968) indicate the area directly north of Joeperry Lake to be underlain by granitic rocks. This information is contradicted by the present mapping which shows this area is underlain by fine-grained amphibolite similar to that of unit 1a in the southwestern part of the map area. Typically this metabasalt is uniform, locally with horizons up to several meters thick containing small relict plagioclase phenocrysts. In one outcrop (1.5 km north of the small peninsula on the northeast shoreline

of Joeperry Lake) the metabasalt is unusually amygdaloidal (Plate 1a), for rock of this unit, and also contains numerous epidotized amygdaloidal fragments (Plate 1b).

The colour index of these amphibolites ranges from 45 to 55. They are composed of plagioclase and hornblende. Accessories include biotite, epidote, sphene, opaques (predominantly pyrite with subordinate pyrrhotite, chalcopryite and magnetite), quartz, carbonate and garnet. Grain size is typically very fine (averaging 0.1 mm) and a fabric is defined by alignment of idiomorphic hornblende crystals into a foliation plane and/or a lineation direction. Typical modes and textures of specimens from this unit are tabulated in Appendix 1 (Table 10).

Pillowed horizons south of the map-area on the northeastern shore of Skootamatta Lake indicate the succession is slightly overturned and facing northeasterly. Facing criteria were not found in the metabasalt north of Joeperry Lake. However, it is suspected that the succession here faces the south, and that Tudor formation metabasalts were folded into this area by an east-west trending synclinal fold (Fig. 2). This relationship is suggested by the physical and chemical (Chapter IV.3) similarity of these rocks, and by the fact that intervening metavolcanic rocks (Unit 2) can be shown to overlie Unit 1a rocks in the Pringle Lake area (see below).

These mafic metavolcanics were probably derived predominantly from basalt flows. The presence of preserved pillow lavas in the sequence is evidence of subaqueous deposition. The lower portion of the Tudor formation lacks amygdules (i.e. the lavas were not vesicular), whereas the upper portion is locally amygdaloidal. An explanation of this feature may be that the lower Tudor formation was extruded into a deep

Plate 1a - Amygdaloidal metabasalt 1.5 km north of Joeperry Lake. Note the bimodal size distribution of amygdules (magnet holder is 10 cm long).

Plate 1b - Epidotized amygdaloidal metabasalt fragment in a matrix of unepidotized metabasalt. Photograph is from the same outcrop as Plate 1a.

submarine environment (i.e. greater than 800 m) with the resultant absence of a gas phase (Moore, 1965) and the upper portion was extruded into shallower water.

II.2.2 Unit lb Map-unit lb metabasalt is found in the southwestern part of the map-area (Fig. 3), stratigraphically overlying Unit la metabasalt. These two basaltic units are both texturally and compositionally distinctive. Another horizon of Unit lb basalt is found east of McCausland Lake, stratigraphically underlying marble. South of the map-area, a horizon of basalts similar to those of Unit lb can be traced for 3 km south of Mazinaw Lake, along Highway 41 (Fig. 2). Here, the unit is underlain by Tudor formation metabasalt and overlain by carbonate meta-sediments.

The amphibolite of this map-unit is fine-grained, dark grey to green; has a well developed schistosity and is of basaltic composition (Chapter IV.3). Relict volcanic textures include; large and numerous relict plagioclase phenocrysts (Plate 2a and b), quartz or carbonate-filled amygdules, flow laminations and volcanic breccias. Amygdaloidal and uniform flows predominate over breccias. No pillow lavas were observed in the flow units. Autoclastic flow breccias consist of fine-grained amphibolite fragments in a matrix of similar composition and are commonly restricted to the top and/or bottom of flow units. Other breccias consist of lapilli to block-sized fragments of diverse origin and composition in a fine-grained amphibolite matrix. These fragments include metamorphosed equivalents of basalt, gabbro, diorite, andesite and minor rhyolite.

Map-unit lb amphibolite has a colour index which ranges from 35 to 40 and consists of plagioclase (oligoclase), hornblende, biotite and

quartz. Accessories include opaques (predominant magnetite with subordinate pyrite, pyrrhotite, chalcopyrite and hematite), epidote, sphene, carbonate and apatite (Appendix 1, Table 10). Grain size is fine (averaging 0.2 mm) and a well developed metamorphic foliation is defined by parallel alignment of idioblastic hornblende and biotite crystals.

Numerous large relict lath-shaped plagioclase phenocrysts are characteristic of the basalt of this unit; locally they constitute up to 25% of the rock by volume. In thin section, they commonly appear as rectangularly-shaped monomineralic aggregates of anhedral plagioclase with an average grain size slightly coarser than that of the groundmass. Rarely, partially unrecrystallized plagioclase phenocrysts (typically oligoclase) are preserved (Plate 2a and 2b) with minor recrystallization at their margins or wherever tectonic strain was greatest (Plate 2b).

Numerous amygdules are also typical in the basalt of this unit. The amygdules are variably-sized up to a maximum of about 5 cm in diameter and consist of carbonate or quartz, with or without minor epidote, hornblende and sulfide.

The abundance and size of amygdules suggests these basalts were extruded in a shallow subaqueous or subaerial environment (Moore, 1965). Their limited lateral (and volumetric) extent relative to that of the Tudor formation basalts is evidence of a local source related to a volcanic centre within the map-area.

II.2.3 Unit 1c Rocks of this map-unit are restricted to the north-eastern portion of the map-area (Fig. 3). The unit consists predominantly of metabasalt which is texturally different but compositionally identical to the basalt of Unit 1b (see Chapter IV.3). Intercalated with Unit 1c

Plate 2

Plate 2

(Photomicrographs with crossed polars)

- a) Mazinaw Lake formation metabasalt with abundant relict plagioclase phenocrysts, partially recrystallized at their margins.
- b) Relict plagioclase phenocryst, extensively recrystallized in the central portion as the result of extensional strain.
- c) Relict microcline phenocryst in metarhyolite.
- d) Recrystallized alkali feldspar phenocryst in metarhyolite. A small relict core of unrecrystallized microcline is preserved.
- e) Partially recrystallized plagioclase phenocryst in metarhyolite.
- f) Relict granophyric texture in synvolcanic granite.

metabasalt are numerous horizons of felsic to intermediate metatuff and metasediment.

Meen (1944) interpreted the rock of this area as metamorphosed sediments (greywackes and quartzites). However, evidence for a volcanic origin is present in the local preservation of relict volcanic textures (such as phenocrysts and amygdules) and the volcanic signature of chemical analyses of representative specimens (Chapter IV.3). Reinterpretation of rocks of this unit as metavolcanic correlates well with the interpretation of similar rocks along strike east of the map-area. Smith (1956), Spence (1969) and Rivers (1976) all cite evidence of relict volcanic textures in amphibolites around the nose of the Shawanegog Antiform (Fig. 2).

The amphibolites of Unit 1c are typically fine-grained, dark grey, biotite-rich and contain numerous randomly oriented hornblende porphyroblasts. Intercalated with these metabasalt layers are thinner horizons of: fine-grained, light pinkish-grey metarhyolite with relict alkali feldspar phenocrysts; fine-to medium-grained, grey meta-andesite with relict plagioclase phenocrysts; and fine-grained schistose metasediments with thin, regular compositional layering which contain abundant biotite and muscovite, and accessory garnet. Some of these horizons of metasediment are sufficiently thick to be represented on the geology map (Fig. 3 - Unit 5).

Colour index of the metabasalt ranges from 30 to 40. These amphibolites are composed of plagioclase (oligoclase to andesine), hornblende, biotite and quartz. Accessories include opaques (predominantly magnetite with subordinate pyrite and hematite), sphene, epidote, microcline, garnet, carbonate and apatite (Appendix 1, Table 10). Groundmass

grain size is fine (averaging 0.3 mm) and a foliation is defined by aligned biotite and hornblende crystals. Hornblende also occurs as fine-to coarse-grained poikiloblasts randomly oriented across the fabric.

The hornblende of Unit 1c metabasalt is variable in appearance. In the western part of the map-unit, hornblende has a blue-green pleochroic colour, whereas in the east, it tends to have a darker green pleochroism and occurs as coarser poikiloblasts. Sporadic occurrences of microcline poikiloblasts are only present in amphibolite in the northeastern part of the map-unit. These crystals are clearly post tectonic as they include matrix material which has a similar attitude to the fabric in the groundmass. The above features indicate a higher metamorphic grade in the northeastern part of the map-area (Chapter III.4).

Rocks of Unit 1c occur predominantly on the north and south limbs of a northeasterly trending synform (Fig. 3). Based on regional stratigraphic correlation, this structure most probably is a syncline with the marble in the core stratigraphically overlying the metavolcanic rocks. The base of the metavolcanic succession is not exposed, as the lower boundary is in intrusive contact with granitic plutons.

Metabasalts of Unit 1c and Unit 1b are chemically identical (Chapter IV.3) but have significant textural differences. The cause of this diversity may be twofold; a contrasting mode of deposition, and the result of a higher grade of metamorphism experienced by rocks in the eastern part of the study area. The tabular nature of Unit 1c metabasalt and the abrupt intercalation of horizons of more felsic metavolcanic and metasediments suggests that much of this unit was deposited as fine-grained ash tuffs in a subaqueous environment.

II.2.4 Unit 2 The amphibolite of this map-unit is distinguished from basaltic amphibolite (Unit 1) primarily on the basis of its lower colour index. Chemical analyses of representative specimens reveal a basaltic-andesite composition (Chapter IV.3). In the Pringle Lake area (Fig. 3), deposits of this rock type consist predominantly of lapilli tuffs and tuff breccias. These fragmentals are composed of up to 60% angular to subrounded fragments which appear to be predominantly accessory or accidental (MacDonald, 1972, p. 123-4) in origin. Fragments are composed of basalt, andesite, gabbro, diorite and minor rhyolite in a matrix of fine-grained, greenish-grey, schistose, biotite-rich basaltic-andesite. Locally the fragments and/or matrix are highly epidotized. The fragments are variably deformed and range in size up to two meters across. Flow rocks are subordinate to the polymodal breccias and consist of uniform amygdaloidal amphibolite. In places, large relict plagioclase phenocrysts are abundant.

In the western part of the map-area, rock of this map-unit is typically more uniform, locally with thin horizons (up to 2 m thick) containing a small percentage of epidotized, lapilli-sized fragments.

An unusual breccia horizon was found in the eastern part of the map-area, southwest of Quebec Lake (Fig. 3). Here the fragments are numerous, highly angular, very poorly sorted with respect to size and compositionally diverse. They are composed of basalt, rhyolite tuff and a minor amount of more rounded "granitic-looking" cobbles in a matrix of basaltic-andesite (Plate 3a and b). Epidotization appears to be restricted to the cobbles. Both basalt fragments and basaltic-andesite matrix are hornblende porphyroblastic. One fragment was observed with a well developed reaction rim defined by a concentration of fine-grained mafic material around its outer rim (Plate 3b).

Plate 3a - Polymodal breccia with fragments of diverse composition in a matrix of basaltic-andesite, 1.5 km southwest of Quebec Lake.

Plate 3b - Close-up of Plate 3a, basaltic fragment with coarse, randomly oriented hornblende porphyroblasts and a well developed reaction rim.

Basaltic-andesite ranges in colour index from 25 to 35 and is typically composed of oligoclase, hornblende, biotite and quartz. Accessories include opaques (predominantly magnetite), epidote, sphene, microcline, carbonate, apatite and garnet (Appendix 1, Table 10). Fine- to medium-grained hornblende porphyroblasts and lath-shaped monomineralic aggregates of anhedral plagioclase pseudomorphing plagioclase phenocrysts are locally abundant. Matrix grain size is fine (averaging 0.3 mm) and a metamorphic fabric is defined by alignment of matrix hornblende and biotite crystals.

Several top determinations, based on grading of fragment sizes in polymictic breccias south of Pringle Lake (Fig. 3), indicate a northeasterly facing direction. This top direction is consistent with that determined from Unit 1a pillow lavas on the northeastern shore of Skootamatta Lake. This evidence supports the contention that the volcanic succession in the Pringle Lake area stratigraphically overlies Unit 1a.

II.2.5 Unit 3 Rocks of andesitic composition (Chapter IV.3) are exposed in the south central portion of the study area (Fig. 3). One thick northeasterly trending zone extends from Pringle Lake to Shabomeka Lake. Several thinner horizons with a similar trend are exposed to the south of the main horizon.

Meta-andesites are fine-to medium-grained, schistose, light grey on fresh surface and weather a light pinkish-grey. Fine-to medium-grained magnetite porphyroblasts are ubiquitous. Rarely, relict feldspar phenocrysts can be observed in hand-specimen (they are more obvious in thin section). The andesite south and west of Semicircle Lake (Fig. 3)

is typically uniform in texture and composition, however, tabular horizons 5 to 30 meters thick can be separated on the basis of slight variations in colour index.

In the Pringle Lake area, the andesite contains a relatively high proportion of coarse breccia. The breccias contain predominantly angular to subrounded andesitic fragments but subordinate basalt, gabbro, diorite and rhyolite are also present. Some of these breccias resemble agglomerates, with numerous rounded fragments of light-grey rhyolite in a matrix of fine-grained, dark-grey, schistose andesite.

Meta-andesite colour index ranges from 15 to 20 ; it is typically composed of albite, quartz, microcline, biotite and hornblende. Accessories include opaques (predominantly magnetite), sphene, carbonate, apatite and rarely garnet and fluorite. Rock of this unit is typically coarser-grained than that of the other metavolcanic units as a result of more extensive metamorphic recrystallization. The average matrix grain size is 0.4 mm. The recrystallization has proceeded to such an extent as to make identification of relict feldspar phenocrysts difficult in hand specimen. However they are recognizable in thin section as fine to medium-grained monomineralic aggregates of anhedral albite crystals slightly coarser than the matrix grains. These aggregates are free of mafic minerals other than very fine mica flakes which are the result of feldspar alteration. Metamorphic fabric in the matrix is deflected around these relict crystals and rarely a core of unrecrystallized albite is preserved. Hornblende typically occurs as fine-grained subhedral poikiloblasts which are commonly aligned parallel to lepidoblastic biotite flakes which define the metamorphic fabric. Fine to coarse euhedral magnetite porphyroblasts are very common.

II.2.6 Unit 4 Thick horizons of metarhyolite occur interlayered with meta-andesite (Unit 3) in the south central portion of the map-area (Fig. 3). Much of the rock interpreted as rhyolite (and the intercalated andesite) was originally mapped as granitoid (Meen, 1944).

Metarhyolite is very fine-grained, pink on fresh and weathered surfaces, massive to schistose and commonly has relict phenocrysts. Superficially the rock of this map-unit appears similar to the fine-to medium-grained pink homogeneous gneissic granite around the northern part of Mazinaw Lake (Unit 10). However, on close inspection, many significant differences are apparent: the granite is very rarely porphyritic; the rhyolite unit contains numerous horizons of lapilli tuff; and there are distinct compositional differences (Chapter IV.3, 4 and 6).

The thick rhyolite horizons between Mazinaw Lake and Shabomeka Lake contain numerous laterally continuous layers (up to 20 m thick) of lapilli tuff with features interpreted as relict eutaxitic structure. These zones consist of numerous moderately to very highly flattened fragments in a rhyolitic groundmass (Plate 4a and b). The degree of flattening is consistent along strike but commonly varies across strike and within different horizons. Locally length to thickness ratios exceed 50:1 and individual fragments have been observed up to 1 m long with a thickness of only 3 to 4 cm. In three dimensions, the fragments are "pancake"-shaped and the large ones display delicate flame-like interdigitated terminations with the groundmass. The fragments commonly contain relict phenocrysts and are deformed (welded?) around phenocrysts in the groundmass (Plate 4b). Their colour index is typically two to three times greater than that of the matrix, by virtue of an increased content of very fine-grained magnetite.

Plate 4a - Relict fiamme in blastoporphyrritic metarhyolite, 0.3 km north of Semicircle Lake.

Plate 4b - Close-up of relict fiamme including, and deformed around, relict alkali feldspar phenocrysts. Photograph is from the same outcrop as Plate 4a.

The extreme and variable flattening ratios of fragments in close association with relatively undeformed phenocrysts (which have a grossly similar composition to the rock in general) precludes a solely tectonic origin for this feature. The most reasonable explanation is that part of the rock (the phenocrysts) was rigid while the remainder acted in a ductile manner (the original groundmass ash and pumice fragments). Later tectonism has resulted in transposition of the eutaxitic foliation into parallelism with the metamorphic fabric and probably enhanced the flattening ratios. However, locally the relict eutaxitic foliation is cut by the fabric, which is interpreted as S_1 foliation (Chapter III.2), and thus suggests a primary origin for much of the flattening.

Metarhyolite south of Semicircle Lake, assumed to be higher in the stratigraphic succession (see below), was found to contain similar fragments, but here they are only slightly flattened and perhaps represent tuffs with only incipient welding.

In a few places, rhyolite flows are distinguishable on the basis of a relict flow lamination structure defined by thin, weak, but very persistent compositional lamination (1 to 5 mm thick), outlined by slight variations in the content of very fine-grained magnetite crystals. Most commonly this layering is transposed into parallelism with the foliation, but rarely it is cut at a high angle by the S_1 metamorphic fabric (Plate 5a), indicating its primary origin.

In the eastern part of the map-area, south of Shabomeka Lake, thin horizons of metarhyolite are intercalated with mafic metavolcanic rocks in map-unit 1c. Here the rhyolite appears similar to the rhyolite elsewhere (Unit 4), but no coarse fragmentals were detected and along with the relict alkali feldspar phenocrysts are fine-to medium-grained, light pinkish garnet poikiloblasts.

2 cm

Plate 5a - Metarhyolite with relict flow laminations cut by S_1 fabric, 0.8 km north of Semicircle Lake.

2 cm

Plate 5b - Metarhyolite lapilli tuff with deformed lithic fragments (light grey) and alkali feldspar phenocrysts (pink), 0.3 km south of Semicircle Lake.

A well exposed contact between rhyolite and andesite crops out south of Semicircle Lake (Fig. 3 - sample locality 25). The relationship between the metarhyolite, meta-andesite and an intervening horizon of metasedimentary rocks indicates a southeasterly facing direction. Several horizons (1 to 2 m thick) of rhyolite lapilli tuff strike northeasterly across the northwestern half of the outcrop. The tuffs contain abundant silicic lithic fragments and relict alkali feldspar phenocrysts (Plate 5b). The contacts are sharp and separate horizons are distinguishable by variations in colour index, and the proportion of fragments and relict phenocrysts. Near the centre of the outcrop, rhyolite lapilli tuff grades into a layer of very fine-grained and thinly laminated ash tuff about 0.5 m thick. This rock is abruptly overlain to the southeast by a thin layer (30 cm thick) of calcareous amphibolite totally unlike any of the metavolcanic amphibolites of the map-area. The amphibolite is dark green, thinly laminated and consists of varying proportions of fine-grained, hornblende, calcite, quartz, magnetite and biotite in decreasing order of abundance. Adjacent to the rhyolitic ash tuff the proportion of hornblende is greatest (>80%), towards the southeast contact laminations are progressively richer in calcite, quartz and biotite with a few layers (2 to 5 mm thick) enriched in magnetite (up to 15%). The southeast contact is gradational over a few cm into a medium-grained calcareous biotite-quartz schist with up to 10% coarse pyrite euhedra. The schist unit is 2 m thick and is abruptly overlain to the southeast by massive, fine-grained, dark grey meta-andesite with relict plagioclase phenocrysts, which underlies the remaining southeastern third of the outcrop.

The succession from lapilli tuffs grading into ash tuffs to chemical

sediments which are abruptly overlain by massive andesites; strongly suggests tops are southeasterly. This conclusion is also supported by the direction of compositional grading of calcareous amphibolite into calcareous biotite schist. The amphibolite is interpreted as a metamorphosed volcanogenic banded iron formation and the calcareous schist is also believed to be chemical sediment of volcanogenic origin.

In two traverses across the thick succession of rhyolites north of Semicircle Lake, it was observed that the rhyolites in the northern half are essentially aphyric, whereas those towards the south are progressively richer in relict alkali feldspar phenocrysts (up to 15% of the rock by volume). The rhyolites in the horizon south of Semicircle Lake are also rich in alkali feldspar phenocrysts. This feature probably denotes an original compositional variation across the rhyolite succession (Chapter IV.8).

Metarhyolite colour index ranges from 5 to 10. It is typically composed of albite, quartz and microcline. Accessories include magnetite, biotite, muscovite, sphene, apatite, zircon and hematite; rarely pyrite, garnet and fluorite may be present (Appendix 1, Table 10). The groundmass grain size is very fine (averaging 0.05 mm) and a metamorphic fabric is defined by parallel alignment of micas. Fine-to medium-grained magnetite and muscovite porphyroblasts are common.

In many places the metarhyolites contain abundant relict phenocrysts. The most abundant are medium to coarse-grained (up to 7 mm) alkali feldspar crystals. In thin section, they are locally observed as 'unrecrystallized' microcline crystals (Plate 2c), but mostly they occur as medium-grained, angular to subrounded, monomineralic aggregates of anhedral microcline slightly coarser than the average groundmass grain

size. Locally the aggregates have preserved cores with recrystallization around their margins (Plate 2d). It is unlikely that the original phenocrysts were microcline, most probably they were sanidine or orthoclase which have since inverted in the solid state to the more ordered microcline structure. Minor fine-to medium-grained plagioclase crystals are also present as partially to totally recrystallized aggregates of albite (Plate 2e). Quartz phenocrysts have the poorest state of preservation, and generally occur as lens-shaped aggregates of anhedral quartz slightly coarser than the average groundmass grain size.

Most of the metarhyolite unit is interpreted as deposits of pyroclastic origin. The thickness of these ash flow tuffs and the presence of textures interpreted as relict eutaxitic structure implies that they were deposited as ~~ignimbrites~~, and suggests a subaerial environment (however, recent work by Sparks and Carey (1970) has shown that pyroclastic flows entering the sea can deposit densely welded tuffs). Volcanogenic sediments, including iron formation, imply volcanic exhalative activity in a subaqueous environment. It is not known if these sediments were precipitated in a localized subaqueous environment (e.g. crater lake sediments) or through subsidence of a previously subaerial volcanic edifice into the sea.

II.2.7 Volcanic Centre The area around the east end of Pringle Lake (Fig. 3) was first suggested as an area close to an original volcanic centre by Moore and Morton (m.s.). The following criteria support this interpretation:

- 1) The abundance of coarse pyroclastic deposits that range from lapilli tuffs to tuff breccias and possible agglomerates which typically flank

volcanic centres;

2) Swarms of mafic to felsic dykes thought to be

feeders to the extrusions;

3) The presence of numerous and compositionally varied intrusive bodies, which are mineralogically similar to the extrusive rocks in the vicinity;

4) Decrease in fragment size and proportion in volcanic rocks away from the area;

5) Evidence of hydrothermal activity (epidotization) in and adjacent to the centre.

II.3 Metamorphosed Sedimentary Rocks

II.3.1 Unit 5 Thin horizons of metasedimentary rock occur intercalated with metavolcanic rock throughout the map-area (Fig. 3). These sediments are interpreted to be of epiclastic (volcaniclastic) origin. Confusion as to the primary origin (i.e. sedimentary or volcanic) of this type of material can arise even in fresh rocks. This problem is compounded in the study area by regional metamorphism and deformation. Criteria for recognition of volcaniclastic sediments include:

1) a regular persistent compositional layering;

2) semipelitic composition, exemplified by the presence of abundant micas (particularly muscovite), garnet and in one locality (south end of Mazinaw Lake) staurolite;

3) rounded clasts of volcanic material in a mica-rich, schistose matrix;

4) abundant carbonate.

Abundant intercalated layers of volcanoclastic metasediments occur within the metavolcanic units near the contact with overlying marble. In Unit 1c, numerous thin horizons of epiclastic rocks were observed, but they were generally not sufficiently extensive to be represented on Figure 3.

The rocks of this map-unit are compositionally diverse as a result of the varied mineralogy of the source volcanic rocks. Typically the colour index ranges from 10 to 25. Common essential minerals include quartz, plagioclase, biotite, muscovite, hornblende, carbonate and epidote; accessories include garnet, microcline, tourmaline, zircon, pyrite, magnetite and staurolite. Typically a well developed schistosity is defined by parallel alignment of micas and hornblende.

II.3.2 Unit 6 A thick succession of marbles stratigraphically overlies the metavolcanic rocks in the northeastern and southeastern sections of the map-area (Fig. 3). These rocks consist of massive to layered white, grey, bluish-grey and buff, fine-to coarse-grained varieties of calcitic (Unit 6a) or dolomitic (Unit 6b) composition.

Commonly a relict bedding structure is defined by thin to thick colour laminations resulting from variations in quartz, mica and graphite content (Plate 6a), and by thin schistose laminations between beds. Locally, thin concordant amphibolite layers are present, up to several meters thick. Some of the thicker more massive amphibolite layers are metamorphosed gabbroic sills which belong to a swarm of late stage mafic dykes (Unit 11). Others are of thin (up to 20 cm) calcareous amphibolite and these may represent metamorphosed mixed carbonate-silicate sediments (i.e. para-amphibolite). The large competency difference between amphibolite and marble has commonly resulted in boudinage of the amphibolite

Plate 6a - Calcitic marble on the north shoreline of Shawenegog Lake. Relict bedding is outlined by colour banding. Note the boudinaged amphibolite layers.

Plate 6b - Cliffs of Mazinaw Lake granite on the east side of Mazinaw Lake. Note the decrease in the dip of foliations towards the north (left-hand side of the photo).

during deformation (Plate 6a).

In the northeast (Fig. 3), the marble is uniformly calcareous (Unit 6a), also containing minor amounts of quartz, phlogopite, graphite and pyrite. Dolomitic marble (6b) is present with calcite marble in the southeastern part of the map-area. Here, in addition to carbonate, they contain minor amounts of quartz, phlogopite and graphite, and locally tremolite and actinolite are abundant in the dolomitic marble.

Carbonate rocks south of the map-area, along the east side of Highway 41 (Fig. 2), are texturally different from the carbonate in the study area. These carbonate metasediments to the south have primary structures which demonstrate the carbonates stratigraphically overlie the metavolcanic rocks (Moore and Morton, m.s., Fig. 3). These marbles appear to be on the same stratigraphic horizon as the marble in the southeastern portion of the map-area and this implies that the marble in the study area also stratigraphically overlies metavolcanic rocks. The carbonate rock south of the map-area consists of sandy dolomite, calcareous siltstone and wacke which constitute a marker horizon traceable for a distance of 7 km south of Mazinaw Lake (Moore and Morton, m.s.). Primary sedimentary structures in these rocks include grain size and colour gradations, rip-ups and flame structures.

The marble in the northeast (Fig. 3) occupies the core of a northeasterly-trending synform. The marble in the southeast part of the map-area occurs on the north limb of a broad northeasterly-trending synclinalorium closing to the south of the study area (Fig. 2 and Moore and Morton, m.s.).

In most places the contact between marbles and underlying metavolcanic rocks appears to be abrupt. However, locally the contact is not well defined. For example, south of the east end of Shabomeka Lake,

a few thin marble layers (up to 0.5 m thick) occur interlayered with biotite schist just north of the contact between Unit 5 and Unit 6a (Fig. 3), also southeast of McCausland Lake thin pyroclastic horizons (up to 2 m thick) were found intercalated with marble 50 m south of the metavolcanic-marble contact.

The uniform, massive to thinly bedded marble in the map-area was probably precipitated in situ, in a relatively shallow marine environment on the flanks of a paleo topographic high, centred in the southern Mazinaw Lake area. The carbonate south of the map-area along Highway 41 has sedimentary structures indicative of transported sediment. Thus these carbonates were probably deposited in deeper water from turbidity currents derived by collapse of the unstable 'reefs' of precipitated carbonate around the flanks of the volcanic centre to the north.

II.3.3 Unit 7 Mappable units of clastic metasedimentary rock occur within the marble. Typically they are fine-grained, thin to thickly bedded (up to 50 cm thick), light-grey mica schist. Relict beds are defined by slight compositional variations and thin schistose bedding laminae which separate individual beds. Locally thin layers (up to 20 cm thick) of fine-grained, dark grey, garnet-rich schist occur interlayered with the light grey garnet-free schist.

The light grey rock is composed of quartz, plagioclase, biotite and muscovite and the darker grey schist is composed of differing proportions of the above minerals (i.e. proportionately more biotite and muscovite), as well as garnet porphyroblasts. Accessories in both rocks include carbonate, opaques, sphene, zircon and tourmaline. In thin section, a subtle thin internal lamination (up to 2 mm thick) is

defined by tourmaline-rich bands. A schistosity is defined by parallel alignment of micas subparallel to the compositional layering.

II.4 Metamorphosed Intrusive Rocks

II.4.1 Unit 8 Rock of this unit is classified ultramafic on the basis of a colour index greater than 90. This assumption is not strictly correct for metamorphic rocks because the ferromagnesium minerals (principally amphibole and chlorite) are hydrous, may contain alkalis and have a higher proportion of silicon and aluminum in their structure than do the mafic minerals in unmetamorphosed ultramafic rocks. However, chemical analyses of several specimens classified as ultramafic exhibit similar values to the fresh ultramafic rocks (Chapter IV.4).

The ultramafic and associated rocks (Unit 8) are restricted to variably sized inclusions within gabbroic stocks and to a small layered stock in the metavolcanic rocks north of Pringle Lake (Fig. 3). The inclusions occur in two intrusions; one exposed on the northeast shore of Joeperry Lake and the other southeast of Pearson Lake. The inclusions occur as blocks of ultramafic rock up to tens of meters across and locally are cut by thin gabbroic dykes.

The small stock north of Pringle Lake occurs in a succession of rhyolite and andesite. The body has certain aspects of a layered intrusion. Numerous small outcrops are present; some consist of ultramafic rock, others consist of plagioclase-rich gabbro with anorthositic affinities (Chapter IV.4). Within some of these outcrops thin layers of magnetite-rich rock (1 to 5 cm thick) are locally abundant.

Typically the ultramafic rocks are uniform, weakly foliated, fine to coarse-grained and are light to dark green on fresh surfaces. They

are composed primarily of amphibole and chlorite (Appendix 1, Table 11). Accessories include magnetite, epidote, sulfides and rarely garnet. Several varieties of clinoamphibole can be seen in thin section. Most common are intergrowths of two amphiboles; one variety with a light green pleochroic colour (actinolite?), the other is colourless (tremolite?). In some thin sections coarse relict crystals appear to be outlined by a 'swiss cheese'-like intergrowth pattern of light green to colourless amphibole, and dark green pleochroic amphibole (hornblende?) with numerous very fine-grained opaque inclusions.

The anorthositic gabbro is composed of calcic plagioclase, amphibole and chlorite with accessory opaque, epidote and sericite. The plagioclase occurs as lath-shaped crystals of bytownite (up to 5 mm long) and are locally altered to sericite and epidote. The anorthite content of this plagioclase is much higher than that observed in any other thin section from the map-area (Appendix 1).

II.4.2 Unit 9 Stock-sized bodies of gabbroic to dioritic composition (Chapter IV.4) occur in several geological settings in the study area.

Small intrusions in the metavolcanic succession contain abundant xenoliths of metavolcanic rock and are themselves cut by basaltic to rhyolitic dykes. These features suggest a synvolcanic origin for the intrusions.

In the north, mafic bodies occur as large inclusions within the granite pluton (Fig. 3). They are commonly bounded by zones of intrusive breccia with gabbroic fragments in a granitic matrix and are cut through-out by numerous granite dykes. These features indicate the gabbro was emplaced before the granite pluton and probably are roof pendants or

undisplaced inclusions intruded by the granite. A relatively large body of this type occurs northeast of Joeperry Lake. It is variable in composition (predominantly diorite) and contains numerous variably-sized inclusions (mostly too small to be represented on Fig. 3) of ultramafic rock (Unit 8). This body is the centre of a strong positive aeromagnetic anomaly which was probably the basis for Lumbers' interpretation of a syenite intrusion underlying the area east of Joeperry Lake (Lumbers, 1964, Fig. 7).

The eastern margin of a large gabbroic intrusion occupying the northern border of the Elzevir Batholith occurs in the southwest corner of the map-area.

Map-unit 9 rocks are fine-to medium-grained, mottled black and grey on fresh surface and weather a medium brownish-grey. A pinkish cast can be observed on fresh and weathered surfaces of many specimens. Colour index ranges from 20 to 45 and the typical mineralogy consists of plagioclase (oligoclase to andesine), hornblende, biotite and quartz. Accessories include epidote, scapolite, magnetite, pyrite and muscovite (Appendix 1, Table 11). The central portions of the larger stocks are medium-grained and have preserved igneous textures, whereas the margins and smaller bodies are fine-grained and moderately to strongly foliated.

II.4.3 Unit 10 Uniform pink gneissic granite underlies much of the northern portion of the map-area (Fig. 3). This pluton is henceforth referred to as the Mazinaw Lake Granite. Along the southern border with the supracrustal rocks, the contact is a complex zone of intrusive breccia with a matrix of late phase, distinctly sodic granitoids (Unit 10a).

Other granitic intrusions occur within the metavolcanic-metasedimentary belt. The largest of these is a granite pluton which extends

from Little Shaboneka Lake to Shawenegog Lake. Smaller stocks of granite (Unit 10) and granodiorite to trondhjemite (Unit 10a) occur within the metavolcanic succession. Some of these stocks may be synvolcanic in origin as they are intimately associated with subvolcanic mafic intrusions (Unit 9) and locally are cut by basaltic to rhyolitic dykes. This suggestion is supported by the local preservation of granophyric texture (Plate 2f) in the central portions of some of the stocks.

North of the map-area, the Mazinaw Lake Granite is in contact with a large trondhjemitic pluton (650 km^2), the Weslemkoon Batholith. Lumbers (1967a) interpreted the Weslemkoon as an older intrusion related to the biotite diorite series and the Mazinaw Lake Granite he related to a younger granitic series of intrusions. A study of the Weslemkoon Batholith (Hodgson, 1965) has revealed a number of igneous phases, consisting mainly of trondhjemite, granodiorite and tonalite, and with local concentrations of late phase sodic granite. Age dating by Silver and Lumbers (1966), and Bell and Blenkinsop (1979) confirm the bimodal age grouping of the major intrusions of the region (i.e. biotite-diorite series, approximately 1200 Ma; granitic series, approximately 1100 Ma). A recently determined Rb-Sr isochron on samples of Mazinaw Lake granite yielded an age of $1170 \pm 40 \text{ Ma}$ (Blenkinsop, personal communication, March 1979). This age is closer to that of the biotite diorite series than that of the granitic series. As well, the close physical and structural relationship (Chapter III.1) of the two intrusions suggests a possible genetic relationship. Perhaps the Mazinaw Lake Granite was coeval with the late phase Weslemkoon sodic granite, although the former appears to be more extensive and has a more potassic composition (Chapter 4, Table 9).

A hybrid zone of variable thickness occurs along the contact between the Mazinaw Lake Granite and the metavolcanic belt (Fig. 3). It consists of abundant xenoliths in a matrix of variable composition from granite to trondhjemite. The fragments are angular and range in size up to tens of meters across. Intrusion appears to have been by a process of magmatic stoping (Plate 7a) and locally granitic material was injected into brecciated fractures (Plate 7b). Amphibolite xenoliths are most abundant. They consist of two varieties: uniform, medium-grained, diorite to gabbro (Unit 9) and finer-grained metavolcanic amphibolite with local preservation of volcanic textures. A thick zone of mafic metavolcanic xenoliths in intrusive breccia is exposed in the cliffs north of Snyder Bay on the east side of Mazinaw Lake (Fig. 3). This feature indicates that the thick pile of southerly facing felsic and intermediate metavolcanic rocks between Mazinaw Lake and Shabomeka Lake was originally underlain by mafic metavolcanic rocks.

Late phases of igneous activity related to intrusion of the Mazinaw Granite are of trondhjemitic composition (Chapter IV.4) in the hybrid marginal zone. Trondhjemite dykes cut granite-hosted intrusive breccia and locally intrusive breccia occurs in a trondhjemite matrix. Thin dykes of albite trondhjemite are the last observed phase; they cut granite, trondhjemite and extend into the metavolcanic belt south of the hybrid zone. Trondhjemite is fine-to medium-grained, light-grey, moderately foliated and it is composed of oligoclase, quartz and biotite. Albite trondhjemite is very fine-grained, light pinkish grey and is composed of albite, quartz and biotite. Accessories in both rock types include magnetite, muscovite, sphene, microcline, epidote, apatite, carbonate, zircon, pyrite and hematite (Appendix 1, Table 11).

Plate 7a - Intrusive breccia; stoped blocks of amphibolite in a granite matrix. East shoreline of Kishebus Lake.

Plate 7b - Intrusive breccia dyke; meta-diorite cut by trondhjemite dyke. Outcrop on Highway 41.

Granite has a colour index of less than 5 and is composed of plagioclase (albite or oligoclase), quartz and microcline. Accessories include biotite, muscovite, magnetite, sphene, epidote, zircon, apatite and hematite (Appendix 1, Table 11). Grain size is fine to medium and locally a relict hypidomorphic-granular texture is preserved. Commonly a weak fabric is present defined by alignment of fine-grained micas.

II.4.4 Unit 11 An easterly-trending swarm of thin gabbroic dykes were the last phase of intrusive activity in the map-area. Commonly these tabular bodies are too thin to be represented on Figure 3. However, where they are sufficiently thick or numerous they were schematically depicted (Unit 11). They are most numerous in the Mazinaw Lake Granite as 'sills' concordant with the foliation. In the metavolcanic succession they are difficult to distinguish from mafic synvolcanic dykes, and in the marble they can be confused with para-amphibolite layers.

These metadiabase dykes are fine-to medium-grained, dark-grey to green amphibolites. The thicker bodies have preserved igneous textures in the central portions but are strongly foliated towards their margins. Thin bodies (less than 1 m) are strongly foliated throughout. Locally, relict plagioclase phenocrysts are visible in hand specimen and in one locality these phenocrysts were observed concentrated in the central portion of the dyke as a result of flow differentiation during emplacement of the magma.

The colour index ranges from 30 to 40 and they are composed of plagioclase (andesine), hornblende, quartz and biotite. Accessories include pyrite, sphene, epidote, apatite, carbonate and hematite (Appendix 1, Table 11). The foliation is defined by alignment of fine-grained hornblende and biotite crystals.

II.5 Mineral Occurrences

Metallic mineral occurrences in the area fall into two main associations:

- 1) Copper and iron sulfide minerals in volcanic and associated shallow intrusive rocks;
- 2) Lead-zinc-gold mineralization in carbonate sedimentary units overlying the volcanic rocks.

Disseminated chalcopyrite, pyrite and pyrrhotite occur in minor amounts in mafic and intermediate composition volcanic rocks with localized concentration in narrow stringers and as amygdale fillings. Sulfide-rich zones range from a single vein to areas 15 m wide and 10 to 30 m in length. This type of mineralization occurs in metavolcanic rocks throughout the map-area but is common in the area south of Pringle Lake (Fig. 3).

Copper mineralization is associated with two sill-like diorite intrusions; one south of Pringle Lake, the other west of Little Shabomeka Lake (Buffadison Option-Moore and Morton, m.s.). In the latter, the elongate diorite stock is composed of plagioclase, hornblende, biotite and quartz with accessory apatite, zircon, sphene and magnetite. Chalcopyrite, bornite, chalcocite and pyrite are sparsely disseminated, and may represent original accessory minerals. Both the stock and the adjacent country rock are moderately to intensely fractured, schistose and altered. Shear zones are filled with chalcopyrite, pyrite, bornite, chalcocite and covellite accompanied by magnetite, hematite, epidote, microcline, carbonate, quartz and biotite. The mineralized fractures vary from 0.1 to 5 mm in width. The nature and distribution of the sulfides and associated alteration minerals are suggestive of the "porphyry copper" type of deposit.

Minor quantities of gold, lead, zinc, copper, tungsten and bismuth are associated with marble in the southeastern part of the map-area. The mineralization varies from disseminations to cross-cutting veins and stringers, and is situated within a few tens of meters of the marble-metavolcanic contact. Detailed descriptions of two of these deposits (the Star of the East Mine and Big Dipper Mine) can be found in reports by Meen (1944) and Moore and Morton (m.s.). A minor amount of disseminated sphalerite and pyrite was found in a few thin (5 to 10 cm thick) siliceous layers interbedded with calcitic marble on the north shore of Shawanegog Lake (Fig. 3).

II.6 Stratigraphy

Lumbers (1967a) has subdivided the regional stratigraphy of the Grenville Supergroup in the Hastings Lowlands into two major groups. The lower group (Hermon) is predominantly volcanic rock whereas the upper group (Mayo) consists predominantly of sedimentary rock. These groups were subdivided into a number of formations as presented in Table 1 and Figure 4. A possible correlation to this stratigraphy is presented in Table 2.

Within the map-area, the oldest rocks are metabasalts (Unit 1a) which can be traced directly into Lumbers' Tudor formation. Limited top criteria indicate that these rocks are directly overlain by a texturally and compositionally distinct succession of mafic metavolcanic rocks (Unit 1b and Unit 2). These units are in turn succeeded by a thick but laterally restricted accumulation of intermediate (Unit 3) and felsic (Unit 4) metavolcanic rocks. This localized deposit of mafic to felsic volcanic rocks and associated subvolcanic intrusions and epiclastic

Table 1: General lithology of formations of the Hermon and Mayo Groups. (after Lumbers, 1967b).

Group	Formation	Lithology
Mayo	Lasswade	marble, minor calcareous metasandstone and metasiltstone, rare recrystallized chert
	Apsley	poorly sorted feldspathic metasandstone with upper and lower members of calcareous metasandstone and metasiltstone
	Dungannon	80% marble; remainder mainly calcareous metasandstone and metasiltstone, poorly sorted feldspathic metasandstone, well sorted quartz-rich metasandstone, and rare recrystallized chert; mafic metavolcanic flows and iron-formation rare near base of formation overlying Tudor metavolcanics
Hermon	Burnt Lake	mainly rhyolite, trachytic, dacitic, and andesitic metavolcanics with minor metabasaltic flows; lensoid marble units and sandy siliceous metasediments found locally
	Turriff	75% pillowed basaltic and andesitic metavolcanic flows; remainder dacitic and felsic flows and pyroclastic rocks, and minor iron formation
	Vansickle	mainly poorly sorted feldspathic metasandstone locally with abundant marble, felsic and mafic metavolcanics, metaconglomerate, and well sorted quartz-rich metasandstone; arkosic metasediments commonly associated with felsic metavolcanics
	Oak Lake	mainly metamorphosed felsic pyroclastic rocks and arkose with some mafic and felsic metavolcanic flows; rare marble and metaconglomerate in upper part of formation
	Tudor	mainly metamorphosed, pillowed, basaltic and andesitic flows; minor dacitic and felsic metavolcanics and rare iron formation

Figure 4. Section showing the hypothetical relationship of the Mayo and Hermon Groups (after Lumbers, 1967b).

Table 2: Stratigraphy of the Mazinaw Lake Area

Group	Formation	Lithology and Description	Map Unit	Correlation with Table 1 Formation	Group
		metadiabase dykes	11		
		granite plutons	10		
		intrusive contact			
		minor metagreywacke	7	Dungannon	Mayo
		calcareous and dolomite marble	6		
		possible local unconformity			
	Mazinaw Lake	minor epiclastic metasediments	5	Oak Lake	
		minor subvolcanic intrusions	8 & 9		
		Metarhyolite ignimbrites & minor flows	4		
		meta-andesite flows and pyroclastic rocks	3		
		metabasaltic andesite flows and pyroclastic rocks	2		Hermon
		metabasalt flows and pyroclastic rocks	1b & c		
	Tudor	metabasalt submarine flows	1a	Tudor	

sediments (the Mazinaw Lake Metavolcanic formation) may correlate with the Oak Lake formation (Table 1).

A thick marble unit (Unit 6) and intercalated greywacke (Unit 7) overlies the metavolcanic units in northeastern and southeastern portions of the map-area. These metasediments are probably equivalent to the Dungannon formation, a member of the predominantly sedimentary Mayo group (Table 1).

In the map-area, the above supracrustal rocks were then intruded by large granite plutons. The last intrusive event was emplacement of a swarm of diabase dykes.

III: STRUCTURE AND METAMORPHISM

III.1 Folding

Structures in the region (Fig. 2) are dominated by large granitic plutons. In the east the supracrustal rocks lie in a broad, northeast-trending synclinorium, closing westward and ringed on three sides by plutons: the Mazinaw Lake and Weslemkoon plutons in the north; the Elzevir Batholith in the west and the Cross Lake and Northbrook plutons in the south. The supracrustal rocks (predominantly metavolcanic) in the western part of the area are split into two belts: one trending northwesterly around the north end of the Elzevir Batholith; the other trending southerly along the east margin of the batholith. Thus a 'Y' shaped pattern is outlined in the attitude of the supracrustal rocks, with the northeasterly trend in the east deflected in two different directions around the batholith in the west. Foliations in the metavolcanic rocks close to the Elzevir batholith dip steeply towards its border. Further from the margin, the supracrustal rocks are deformed into tight peripheral synclines.

In the map-area, major folds are difficult to define on the basis of reversals in the attitude of foliations. However, some major folds have been inferred where their presence is required based on the interpretation of stratigraphy and a few reliable top determinations. The approximate locus of their axial surface traces has been shown on Figure 2.

One well defined major fold occurs in the marble in the northeastern part of the map-area (Fig. 3). In the Shāwenegog Lake area, this structure is outlined by a reversal in the attitude of primary layering. The

attitude of the layering and the approximate parallelism of the limbs indicates a close to tight, northeast-trending synform, slightly overturned to the south, with an approximately horizontal hinge line.

Based on stratigraphic interpretation (i.e. marble overlying meta-volcanic) this structure is a syncline. Southwest of Shawenegog Lake, this fold is more complex: it is tighter (probably isoclinal); there are infolds of metavolcanic rock; part of the southern limb has been sheared away (Chapter III.3); and the nose is truncated by granite.

The syncline can also be traced eastward, outside the study area, where it appears to join the 'Plevna Synform' as defined by Rivers (1976). Rivers also outlined a parallel-trending antiform, the 'Shawenegog Antiform' which has its axial surface trace in the granite pluton south of the above syncline (Fig. 2). It is not known how far this antiform (anticline?) extends into the map-area. It may continue through the southeastern corner of the map-area to join an inferred anticlinal structure outlined in the southern Mazinaw Lake area (see below). Rivers concluded that both of these folds are second phase structures (F_2) and in the area just east of the map-area, both have a gentle northeasterly plunge (10 to 20°).

In the central and western portions of the map-area major folds are difficult to precisely define for the following reasons: the rocks generally lack primary layering, facies changes are numerous and abrupt in the metavolcanic succession, and structures have been complicated by plutonic bodies.

The metavolcanic succession south of Pringle Lake is overturned to the northeast (Fig. 3). South of Mazinaw Lake (Fig. 2) metasediments overlying the metavolcanic rocks are overturned to the east (Moore and

Morton, m.s., Fig. 3). These features imply an open overturned anticline (synformal anticline) plunging steeply to the southeast between Skootamatta Lake and Mazinaw Lake (axial trace shown on Fig. 2).

The felsic and intermediate metavolcanic rocks face the south between Mazinaw Lake and Shabomeka Lake (Chapter II.2.6). This succession is continuous along strike to the west, across Mazinaw Lake. Thus the rocks northeast of Pringle Lake are southerly facing whereas those south of Pringle Lake are northerly facing. This reversal outlines an east-west trending syncline east of Pringle Lake (axial trace shown on Fig. 2). This syncline is probably the western extension of the fold defined in the Shawenegog Lake area. The distribution of metavolcanic units along the east side of Mazinaw Lake can be best explained by the presence of the above syncline, as well as a parallel anticline to the south. This inferred anticline (axial trace shown on Fig. 2) is an easterly extension of the overturned anticline occurring on the west side of Mazinaw Lake. Figure 5 is an idealized north-south cross-section showing the interpreted disposition of rocks on the east side of Mazinaw Lake (Fig. 3). From this section it is apparent that there are two major horizons of meta-rhyolite and two of intermediate to mafic metavolcanic rock (andesite and basaltic-andesite), underlain by metabasalt and overlain by marble. It also indicates that the volcanic succession is progressively thinner towards the south.

A southeast-trending syncline is inferred in the area south of Joeperry Lake (axial trace shown on Fig. 2). This fold explains the repetition of Tudor formation basalt in the area north of Joeperry Lake with an intervening horizon of younger Mazinaw Lake formation rock.

In the northeastern part of the map-area, structures plunge gently

LEGEND

- GRANITE
- MARBLE
- INTERMEDIATE METAVOLCANIC
- FELSIC METAVOLCANIC
- MAFIC METAVOLCANIC
- — — — GEOLOGICAL CONTACT
- — — — ANTICLINE, SYNCLINE
- — — —

Figure 5: A simplified north-south section along the east side of Mazinaw Lake (see Fig. 3 for precise location).

towards the northeast. However, in the south-central and western part of the area plunges become westerly-tending and steeper. This change in attitude reflects the disruption caused by the presence of the large intrusive bodies during the deformation. Steepening plunges and tighter folds in proximity to plutons have been described from other areas in the Hastings Lowlands. Divi and Fyson (1973) demonstrated that second phase structures between Bancroft and the western margin of the Weslemkoon Batholith show progressive increase in plunge and degree of flattening towards the border of the pluton. They have suggested that the presence or emplacement of the pluton during D_2 imposed an element of constrictional strain on the adjacent rocks which caused L_2 to be rotated towards the down dip direction of maximum extension.

Foliations within the plutons are generally concordant with those within the surrounding country rock and the overall regional trend. Within the Mazinaw Lake Granite, the southerly dipping foliation is progressively shallower toward the northern part of the map-area (Plate 6b), and becomes essentially horizontal at the north end of Mazinaw Lake. Hodgson (1965) described a similar feature in the Weslemkoon Batholith. The following account is derived from his report. The northern part of the pluton consists of a roughly circular dome of about 500 km^2 emplaced concordantly into schist of the Tudor formation on the west and their stratigraphic equivalents on the east. In section this domal body is asymmetrical with a vertically dipping western margin and an easterly dipping eastern margin. The granitoid rocks within the dome display a well developed foliation which is also concordant with the batholith margins and centred on a point in central Ashby Township.

Steeply dipping around the margins, the foliation becomes essentially horizontal towards the centre of the intrusion.

III.2 Mesoscopic Folds and Fabric Development

III.2.1 First Phase In general it appears that the development of a penetrative metamorphic fabric was strongest during the first recognizable deformation event (D_1). A regional schistosity (S_1) is defined by planar alignment of platy minerals. Locally a lineation (L_1) is defined by linear alignment of elongate minerals or mineral aggregates and/or the axis of minor folds in primary layering surfaces (S_0). Small scale F_1 folds are tight to isoclinal and commonly have a well developed axial plane cleavage. Where visible, S_0 has typically been transposed into parallelism with S_1 . In a structural study just east of the map-area, Rivers (1976) found that F_1 folds were gently inclined to recumbent before D_2 deformation.

III.2.2 Second Phase The second deformational event (D_2) resulted in steeply dipping to vertical axial surfaces with northeasterly trends. The major folds of the map-area are all thought to be the result of folding during this phase of deformation. In the northeast the F_2 folds are more open and plunge gently towards the northeast. Towards the south-central and western portion of the study area (Fig. 3) F_2 folds are much tighter and are steeply plunging towards the west. In general F_2 folds are more open than those of F_1 , and can be distinguished by the presence of folded S_1 surfaces. Rarely a weak S_2 schistosity is detectable in the axial surface of F_2 folds and the only F_2 lineation observed was that defined by the hinge lines of F_2 folds. In Rivers'

(1976) study of rocks to the east of the map-area, he found that everywhere F_1 and F_2 folds are approximately coaxial. This appears to be true for the map-area as well, even into the areas dominated by plutons where the presence of these intrusive bodies has resulted in flattening and rotation of F_2 folds and transposition of coaxial F_1 structures into steeply plunging folds.

III.2.3 Third Phase Gently-plunging crenulations and kink bands with shallow axial surfaces and axes are documented outside the map-area to the south (Moore and Morton, m.s.) and to the east (Rivers, 1976). No folds of this generation were recognized within the map-area.

III.3 Faulting

Faults have been inferred where significant air photo lineaments indicate their possible presence. There appears to be at least two ages of faulting; early syntectonic shears and at least one late fault (post Precambrian) probably associated with formation of the Ottawa-Bonnechere graben.

Two early faults have been recognized, one cross-cutting the regional fabric with an associated recrystallized fault breccia zone in the vicinity of Little Long Lake (Fig. 3). The locus of this fault is a series of narrow linear depressions trending north northwest, north of Little Long Lake. These narrow valleys have a maximum relief of about 20 meters and in the northern part of the area, abruptly separate granite and metabasalt. One outcrop at this contact was observed to be a recrystallized breccia consisting of variably-sized, angular granite fragments in a matrix of fine-grained amphibolite.

The other possible early fault occurs along a northeasterly trending lineament south of Shabomeka Lake. The lineament is the locus of a series of narrow depressions at the contact between marble and meta-volcanic rocks on the southern limb of the Shawenegog Lake Synform (Fig. 3). Probably many other syntectonic faults have gone unnoticed because they strike subparallel to the regional foliation and have undergone metamorphism.

A very pronounced lineament along Mazinaw Lake has long been interpreted as the locus of a major fault. Meen (1944) interpreted this structure as a reverse thrust fault with upheaval of the eastern side of the lake. He also interpreted southerly extension of the fault 8 km south of Mazinaw Lake with a right-lateral horizontal displacement of 120 m. To the contrary, Moore and Morton (m.s.) could find no evidence of a southward extension of the fault and reinterpreted Meen's evidence of this horizontal displacement as offset, clearly the result of D_1 folding. Spectacular cliffs rising vertically 100 m above the water dominate portions of the eastern shoreline of Mazinaw Lake (Plate 6b). The maximum elevation difference of the highlands on the eastern and western sides of the lake is only about 30 m (N.T.S. 31 c/14, 1:50,000 topographic sheet); however on the western side the slope to the waterline is much more gradual. (In the northern half of the lake (north of the map-area) the relation is reversed, here the peak elevation on the west side is slightly higher and the slope to the waterline is greater. If these elevation differences can be used to gauge vertical displacement, then the movement was 'scissor-like' with uplift of the western side in the north and the eastern side in the south. The north northwesterly trend, overall topographic displacement and movement sense (east side

uplifted) of the southern portion of the fault are similar to those of the Plevna Fault located about 20 km to the east. Smith (p. 24, 1956) relates this normal fault to the formation of the Ottawa-Bonnechere graben in the Cretaceous to Tertiary period. The structural break along Mazinaw Lake probably occurred concurrently.

III.4 Metamorphism

One protracted regional metamorphic event resulted in peak conditions of middle amphibolite facies throughout the map-area. Considerable information has been published on the metamorphic grade and history of the region (Lumbers, 1964; Moore and Thompson, 1972; Sethuraman and Moore, 1973; Hutcheon and Moore, 1973). Mineral assemblages in rocks of the study area have been related to this data to ascertain the metamorphic conditions.

Three groups of rocks provide information on the metamorphic environment in the map-area. These are the mafic metavolcanic rocks, the semipelitic metasediments and the siliceous dolomite marbles. Sethuraman and Moore (1973) subdivided the mafic metavolcanic rocks south of the map-area (Fig. 6) into 5 zones of increasing metamorphic grade: chlorite, biotite, blue-green hornblende, green hornblende and diopside. The mineral assemblages within those zones are presented in Table 3. Typical assemblages found in the mafic metavolcanic rocks throughout most of the study area correlate with zone III (Table 10, Appendix 2). However, the mafic metavolcanic rocks in the northeastern part of the area contain hornblende crystals with darker green pleochroic colours, coarser hornblende porphyroblasts, plagioclase with a higher anorthite content and sporadic microcline poikiloblasts

Zone	Mineral assemblages
Chlorite	amph-olig-chl-cc $\pm$ qz (sph, py, hem) amph-olig-chl-cc-epi amph-olig-chl-epi
Biotite	amph-olig-chl-bio-epi-cc $\pm$ qz (sph, ap, opaque) amph-olig-chl-bio-ga-cc-qz amph-olig-chl-epi-cc $\pm$ qz amph-olig-chl-epi-bio amph-olig-epi-bio olig-bio-mic $\pm$ chl-qz
Blue-green Hornblende	hbd-olig, and-bio $\pm$ epi $\pm$ cc $\pm$ qz
Green Hornblende	hbd-and-bio-cc $\pm$ qz (ap, py, hem, rt) hbd-and-epi-cc-qz $\pm$ mic hbd-and-cc-qz-ga
Diopside	hbd-and-epi-di $\pm$ ga $\pm$ qz $\pm$ cc (sph, hem, py) hbd-and-bi-qz $\pm$ epi $\pm$ ga hbd-and-di-bi $\pm$ mic $\pm$ scp
NOTE: Abbreviations	
olig: oligoclase ga: garnet and: andesine mic: microcline amph: amphibole sph: sphene hbd: hornblende py: pyrite chl: chlorite hem: hematite bio: biotite ap: apatite cc: calcite rt: rutile qz: quartz scp: scapolite epi: epidote	

Table 3: Mineral assemblages of mafic metavolcanic rocks (Sethuraman and Moore, 1973, Table3).

Figure 6: Metamorphic zones in the Bishop Corners - Donaldson area. Chlorite zone (I); biotite zone (II); blue-green hornblende zone (III); green hornblende zone (IV); diopside zone (V). Disappearance of chloritoid (AA'); first appearance of sillimanite (BB'); disappearance of staurolite (CC') (Sethuraman and Moore, 1973, Fig. 6). Dotted line is the proposed extension of zone boundary into the study area.

(Chapter II.2.3). These features indicate this area is within zone IV (Fig. 6 and Table 3). It was not possible to draw a precise boundary between zones III and IV on Figure 3 because sampling was inadequate to define such a boundary, and the boundary is typically gradational over a distance of ± 2 km (Sethuraman and Moore, 1973). However, from observed thin sections, the boundary zone should run northwesterly along a line passing just east of Little Shabomeka Lake (the proposed extension is shown on Fig. 6 - dotted line).

Moore and Thompson (1972) located several metamorphic zone boundaries in the pelites of the Flinton Group (Fig. 7). The semipelitic rocks of the map-area are in general not sufficiently aluminous for metamorphic growth of aluminosilicates but in one locality (at the south end of Mazinaw Lake) the presence of staurolite crystals suggests that at least portions of the study area are within the Staurolite-Kyanite zone. This is also shown by the conjectural extensions of the zone boundaries in Figure 7.

Work on siliceous dolomite marbles south of the map-area resulted in location of a tremolite isograd based on the alternative assemblages dolomite-quartz (low grade) and tremolite-calcite (high grade) (Hutcheon and Moore, 1973). Dolomitic marbles in the southeastern part of the study area were found to contain tremolite-calcite but no quartz-dolomite assemblages, thus the map-area lies on the high grade side of this isograd. Figure 8 shows the position of this isograd as well as estimated minimum temperatures of metamorphism based on calcite-dolomite solvus geothermometry. This isograd is not parallel to the other established metamorphic zone boundaries (Figures 6 and 7) and it does not appear to be isothermal (indicated by the large variation in solvus

Figure 7: Distribution of metamorphic zones in the Flinton Group. Metamorphic boundaries are conjectural where broken (Moore and Thompson, 1972, Fig. 7).

Figure 8: Temperatures, the tremolite isograd (solid line), and mineral assemblages near Marble Lake (Hutcheon and Moore, 1973, Fig. 6).

temperatures along the isograd in Fig. 8). These features are best explained by the effect of variation in the composition of the fluid phase of the reaction responsible for the isograd (dolomite + quartz + $H_2O \rightleftharpoons$ tremolite + calcite + CO_2).

Metamorphic fabric was established during D_1 and was deformed during D_2 . However, locally the random orientation of hornblende porphyroblasts cutting across the S_1 fabric indicates metamorphism outlasted D_1 . This conclusion is substantiated by the attitude of metamorphic zone boundaries (Figures 6 and 7) which are highly discordant with the regional structural trend and clearly have not been folded by the major deformational phases. It is also apparent from these figures that the zone boundaries are not genetically related to the plutons as they do not conform to their margins.

In summary, the metamorphic grade appears to be increasing towards the north and northeast. Conditions within the map-area achieved middle amphibolite facies with temperatures in the range of 550 to 600°. The coexistence of kyanite and staurolite prograding to sillimanite (Fig. 7) and the absence of cordierite and andalusite in pelitic rocks in the vicinity of the map-area suggests an intermediate pressure series with load pressures in the range of 5 to 6 kb (Hutcheon and Moore, 1973).

IV: PETROCHEMISTRY

IV.1 Introduction

Classification of rocks in the study area into map-units was based primarily on field criteria. However, the subsequent identification of the composition of the rock-units was substantiated by chemical analysis of representative specimens. Some of the units were consistently misidentified in the field as being more siliceous than the subsequent analyses revealed (e.g. some metabasalt and meta-andesite units were classified in the field as meta-andesite and meta-dacite respectively). This type of error is common in amphibolite facies terrains because the metamorphic recrystallization results in a lighter colour for mafic metavolcanics than that of their premetamorphic parents.

Chemical analyses of the meta-igneous rock units are presented in Tables 4 to 8. Two major metavolcanic groups are recognized; a succession of tholeiitic basalt to rhyolite (the Mazinaw Lake formation), and a more mafic group of tholeiitic basalts (Tudor formation metabasalt). Chemical analyses of the intrusive rocks are presented in two categories; synvolcanic intrusions (Table 7) and postvolcanic granitic intrusions (Table 8).

IV.2 Sampling and Analysis

Localities of specimens selected for chemical analysis are shown as solid circles on Figure 3. The number beside the symbol corresponds with the analysis number in Appendix 2 (Table 12). A total of 58 specimens were analysed by X-ray fluorescence, emission spectroscopy, atomic absorption and wet chemical techniques in three analytical

laboratories. Details on the techniques used and the precision of the analyses from the various analytical laboratories are given in Appendix 2. The analyses in Appendix 2 represent the raw chemical data; tabulated analyses presented in this chapter are recalculated to totals of 100% on a volatile-free basis with total iron expressed as FeO (i.e. $\text{FeO}^* = \text{FeO} + \text{Fe}_2\text{O}_3 \times .899$).

IV.3 Petrochemistry of Metavolcanic Rocks

Recalculated chemical analyses of metavolcanic rocks are presented in Tables 4 to 6. Chemical classification is on the basis of the observed range of SiO_2 content within individual map-units:

basalt	<54%	SiO_2
basaltic-andesite	54-58%	SiO_2
andesite	58-64%	SiO_2
rhyolite	>70%	SiO_2

All metabasalt analyses (Table 4) display relatively high total iron (FeO^*). However, the basalts can be subdivided into two groups on the basis of other oxides. Unit 1a basalts have higher MgO and CaO, and have lower Na_2O , K_2O , TiO_2 and P_2O_5 than the basalts of Unit 1b and 1c. The former group is also significantly higher in Cr and Ni (trace elements are included with the analyses in Appendix 2, Table 12). Unit 1a analyses are very similar to analyses of Tudor formation basalt from outside the map-area (Table 9, A & L), with which they are stratigraphically correlated (Chapter II.6). Unit 1b and 1c metabasalt analyses are strikingly similar to one another (Table 4) and this compositional similarity is taken as evidence for a common magma, despite apparent differences in texture and interpreted geological setting (Chapter II.2.2

Table 4: Basalts

Formation		Tudor			Mazinaw Lake					
Unit No.		1a			1b		1c			
Analyses No.	37	38	40		53	54	26	39	42	45
Oxide Wt. %										
SiO ₂	51.1	49.5	51.7		52.2	52.3	51.1	47.1	50.1	52.6
Al ₂ O ₃	16.2	16.2	14.6		16.8	15.6	17.5	16.8	17.9	17.3
FeO*	8.81	10.2	12.2		10.9	11.8	10.8	13.5	13.3	9.78
MgO	7.21	7.83	6.25		3.75	4.23	3.96	3.93	2.94	5.17
MnO	0.15	0.16	0.23		0.16	0.17	0.18	0.24	0.27	0.14
CaO	10.9	11.0	9.65		7.38	6.50	9.03	8.86	8.30	5.96
Na ₂ O	3.39	2.09	3.09		4.02	3.36	3.33	3.89	3.91	5.34
K ₂ O	0.55	1.08	0.67		1.84	2.75	1.40	2.17	0.91	2.27
TiO ₂	1.22	1.07	1.43		2.09	2.33	1.84	2.25	2.03	1.51
P ₂ O ₅	0.19	0.17	0.14		0.52	0.60	0.29	0.90	0.35	0.38
Norms (C.I.P.W. wt. %)										
Q	-	-	0.6		-	-	2.9	-	-	-
C	-	-	-		-	-	-	-	-	-
Or	3.3	6.4	3.8		10.9	16.2	8.3	12.8	5.1	12.9
Ab	28.7	17.7	25.1		34.0	28.4	28.2	23.7	31.7	33.6
An	27.3	31.8	23.1		22.4	19.3	28.6	21.9	27.4	14.8
Ne	-	-	-		-	-	-	5.0	-	4.2
Di	20.4	17.6	18.1		8.9	7.5	11.6	11.2	8.3	9.2
Hy	8.0	14.7	18.5		13.3	17.7	8.9	-	11.3	-
Ol	5.4	5.9	-		1.3	-	-	11.2	3.2	12.5
Mt	4.0	3.8	4.2		3.9	4.3	7.4	5.5	4.6	3.4
Il	2.3	2.0	2.6		4.2	4.4	3.5	4.3	3.7	2.8
Ap	0.5	0.4	0.3		1.2	1.4	0.7	2.1	0.8	0.9
Norm. C.I.	40.1	43.6	43.4		31.4	33.9	31.3	34.5	31.1	27.9

and II.2.3). Basalt analyses of these two map-units have lower MgO, CaO, Cr & Ni content and a consistently lower normative colour index than basalt of Unit 1a (Tudor formation basalt). They are thus considered to represent more highly fractionated parent magma.

Metavolcanic rocks more felsic than basalt, within the study area, are believed to represent a serial accumulation genetically related to Unit 1b and 1c basalt. Thus all rock-units of this series (ranging in composition from basalt to rhyolite) are defined as members of the Mazinaw Lake metavolcanic formation.

Analyses of basaltic-andesite (Unit 2) and andesite (Unit 3) are presented in Table 5. These mafic to intermediate members of the Mazinaw Lake formation are similar to Mazinaw Lake basalt (Table 4) in their generally high values of FeO*, alkalis, TiO_2 and P_2O_5 . Their higher SiO_2 is reflected in the common presence of normative quartz.

Analyses of rhyolite (Unit 4) are presented in Table 6. The rhyolites all possess SiO_2 values greater than 71%. Figure 10 depicts the range of SiO_2 values for the metavolcanic rocks. A continuum of SiO_2 values is present from Mazinaw Lake formation basalt through andesite, and a distinct compositional gap exists between andesite and rhyolite (between 64 & 71% SiO_2).

IV.4 Petrochemistry of Meta-intrusive Rocks

Analyses of synvolcanic intrusive rocks are presented in Table 7. They can be divided into 3 major categories; ultramafic and associated rocks, gabbro, and diorite.

Analyses of ultramafic group rocks (Unit 8) consists of two true ultrabasic rocks (low SiO_2 , high MgO) and an associated anorthositic gabbro

Table 5: Mazinaw Lake Formation Basaltic-andesite and Andesite

Unit No. Analyses No.	2 (basaltic-andesites)					3 (andesites)				
	5	8	44	48		3	19	24	25	31
Oxide Wt. %										
SiO ₂	55.4	57.3	57.6	55.0		63.1	63.7	63.6	61.3	59.4
Al ₂ O ₃	14.1	17.5	15.6	18.1		13.3	13.7	13.7	13.7	13.4
FeO*	11.7	6.98	9.59	7.44		9.7	7.21	8.66	7.89	12.2
MgO	3.32	3.42	4.07	3.76		1.71	1.73	1.64	2.65	2.62
MnO	0.34	0.14	0.17	0.07		0.26	0.16	0.18	0.22	0.13
CaO	5.15	5.17	6.95	5.98		3.79	4.57	3.04	5.55	3.51
Na ₂ O	4.38	4.93	3.27	4.66		3.82	4.86	4.53	4.14	3.12
K ₂ O	2.27	2.87	1.31	2.61		2.39	1.86	2.66	3.38	2.24
TiO ₂	2.47	1.31	1.21	1.69		1.26	1.45	1.31	0.67	1.88
P ₂ O ₅	0.47	0.25	0.27	0.51		0.40	0.49	0.43	0.20	0.80
Norms. (C.I.P.W. wt.%)										
Q	5.1	0.7	10.3	-		18.3	17.6	16.7	10.1	22.1
C	-	-	-	-		-	-	-	-	1.4
Or	13.4	17.0	7.4	15.4		14.1	11.1	15.7	20.0	13.2
Ab	37.1	41.6	26.6	39.4		32.3	41.1	38.4	35.0	26.4
An	12.1	17.1	23.0	20.7		12.2	10.0	9.0	8.7	12.2
Ne	-	-	-	-		-	-	-	-	-
Di	8.6	5.7	7.0	4.6		3.4	7.9	2.7	14.4	-
Hy	12.1	12.3	15.9	10.6		12.9	4.3	9.9	5.4	9.7
Ol	-	-	-	2.1		-	-	-	-	-
Mt	5.8	2.5	3.3	2.7		3.4	4.2	4.0	4.6	9.6
Il	4.7	2.5	2.2	3.2		2.4	2.8	2.5	1.3	3.6
Ap	1.1	0.6	0.6	1.2		0.9	1.1	1.0	0.5	1.8
Norm. C.I.	31.2	23.0	28.4	23.2		22.1	19.0	19.1	25.7	22.8

Table 6: Mazinaw Lake Formation Rhyolite

Unit No.	2	9	18	20	21	22	23	46
Analyses No.	2	9	18	20	21	22	23	46
Oxide Wt. %								
SiO ₂	73.4	73.0	72.1	73.2	75.6	73.6	71.1	73.1
Al ₂ O ₃	12.9	14.0	12.9	12.8	12.3	12.5	13.1	13.5
FeO*	3.39	3.66	4.2	4.03	3.62	5.47	4.84	3.56
MgO	0.10	0.44	0.64	0.52	0.33	0.66	0.82	0.31
MnO	0.06	0.03	0.05	0.04	0.05	0.03	0.07	0.19
CaO	1.25	0.94	1.06	1.02	0.94	0.93	0.65	1.74
Na ₂ O	4.31	4.28	4.24	4.47	4.96	4.67	3.85	4.17
K ₂ O	3.99	3.12	3.97	3.15	1.74	2.16	4.47	3.10
TiO ₂	0.37	0.31	0.57	0.44	0.28	0.59	0.63	0.28
P ₂ O ₅	0.02	0.07	0.16	0.12	0.05	0.14	0.16	0.00
Norms. (C.I.P.W. wt.%)	30.3	32.9	28.7	31.7	36.8	32.8	28.3	30.8
Q	-	2.0	-	0.4	0.6	1.1	1.2	0.1
C	23.6	18.5	23.5	18.7	10.3	12.8	26.4	18.3
Or	36.5	36.2	35.9	37.8	42.0	39.5	32.6	35.3
Ab	4.0	4.2	4.2	4.3	4.3	3.7	2.0	8.6
An	-	-	-	-	-	-	-	-
Ne	1.8	-	-	-	-	-	-	-
Di	0.3	2.8	3.2	3.1	2.6	5.4	4.7	5.0
Hy	-	-	-	-	-	-	-	-
Ol	2.7	2.7	3.0	2.8	2.6	3.1	3.1	1.3
Mt	0.7	0.6	1.0	0.8	0.5	1.1	1.2	0.5
Il	-	0.2	0.4	0.3	0.1	0.3	0.4	0.0
Ap	5.5	6.2	7.3	6.8	5.8	9.6	9.0	6.8
Norm. C.I.								

Table 7: Synvolcanic Intrusions

Unit No.	8				9					
Rock Name	Ultramafic		Anorthos. Gabbro		Gabbro			Diorite		
Analysis No.	35	57	58		10	12	49	51	1	7
<u>Oxide Wt. %</u>										
SiO ₂	48.6	49.1	45.8		51.9	52.6	48.6	50.4	57.6	59.2
Al ₂ O ₃	7.59	6.86	21.8		15.5	18.6	17.7	14.2	16.1	15.2
FeO*	11.2	11.9	6.4		8.94	6.82	9.91	9.41	10.9	8.68
MgO	23.6	18.4	10.9		7.97	6.44	6.98	10.2	1.73	3.47
MnO	0.22	0.31	0.10		0.13	0.11	0.16	0.16	0.22	0.14
CaO	7.13	11.3	11.4		10.3	10.3	11.6	10.9	3.92	5.20
Na ₂ O	0.25	0.97	1.67		3.18	3.32	2.86	2.79	5.52	4.14
K ₂ O	0.03	0.31	1.62		0.80	0.76	0.74	0.66	1.76	1.76
TiO ₂	0.80	0.47	0.09		0.91	0.61	1.02	0.89	1.38	1.63
P ₂ O ₅	0.16	0.03	0.01		0.13	0.12	0.10	0.11	0.29	0.23
<u>Norms: (C.I.P.W. wt.%)</u>										
Q	-	-	-		-	-	-	-	8.6	11.8
C	-	-	-		-	-	-	-	-	-
Or	0.2	1.8	9.6		4.8	4.5	4.4	3.9	10.4	10.4
Ab	2.1	8.2	6.3		26.9	28.1	23.0	23.6	46.7	35.0
An	19.5	13.5	47.2		25.5	33.6	33.3	24.4	13.8	17.7
Ne	-	-	4.2		-	-	0.6	-	-	-
Di	11.8	33.8	7.6		19.8	13.3	19.4	23.3	3.0	5.4
Hy	46.9	20.3	-		12.5	15.3	-	6.5	4.6	11.3
Ol	10.7	17.0	22.5		4.4	0.6	13.5	12.8	-	-
Mt	4.4	4.3	2.3		3.9	2.8	3.6	3.4	9.4	4.7
Il	1.5	0.9	0.2		1.7	1.2	1.9	1.7	2.6	3.1
Ap	0.4	0.0	0.0		0.3	0.3	0.2	0.3	0.7	0.5
Norm. C.I.	77.7	76.3	32.6		42.3	33.2	38.4	47.7	19.3	24.9

(low SiO_2 , high Al_2O_3). The ultrabasic rocks are compositionally similar to analyses of unmetamorphosed pyroxenite and websterite (Table 9, columns O & P respectively). Other affinities with fresh ultramafic rocks are the very high Cr and Ni values (Appendix 2, Table 12). The high Al_2O_3 and CaO values of the anorthositic gabbro reflects the high proportion of calcic plagioclase in the rock (Chapter II.4.1).

Analyses of gabbroic rocks (Table 7) are similar to those of Tudor formation basalt (i.e. high MgO and CaO, low alkalis, TiO_2 and P_2O_5); despite the fact that the specimens were collected from a gabbro body within the Mazinaw Lake formation and from gabbroic inclusions in the Mazinaw Lake Granite (Fig. 3). These gabbroic bodies are interpreted as subvolcanic cumulates of Mazinaw Lake formation magma. Thus the chemical similarity of Mazinaw Lake formation synvolcanic gabbro with underlying Tudor formation basalt (see also Fig. 10) may indicate a genetic relationship between the two formations. Perhaps the Mazinaw Lake formation volcanics were derived by some method of fractionation of the Tudor formation parental magma.

In general, diorite analyses (Table 7) correspond compositionally with Mazinaw Lake formation rocks which have a similar SiO_2 range. In fact, the average of two diorite analyses fits remarkably well into the small composition gap between basaltic-andesite and andesite (Fig. 10).

Analyses of postvolcanic, granitic rocks are presented in Table 8. These analyses are of samples collected from different phases of the Mazinaw Lake Granite. They are subdivided into three categories; granite ($\text{Na}_2\text{O} \approx \text{K}_2\text{O}$), trondhjemite ($\text{SiO}_2 < 72\%$, $\text{Na}_2\text{O} \gg \text{K}_2\text{O}$), and albite trondhjemite ($\text{SiO}_2 > 72\%$, $\text{Na}_2\text{O} \gg \text{K}_2\text{O}$). Although SiO_2 values of the granitic rock analyses are similar to those of the metarhyolite analyses

Table 8: Granitic Rocks

Unit No.	10				10a			
Rock Name	Granite				Trondhjemite			
Analyses No.	11	14	28		13	15	17	56
oxide wt. %								
SiO ₂	74.9	74.1	77.0		69.1	68.7	71.8	70.1
Al ₂ O ₃	14.2	14.1	13.1		17.0	15.5	15.3	15.0
FeO	1.61	1.79	1.29		2.19	3.71	1.35	2.75
MgO	0.40	0.36	0.20		0.86	1.23	1.20	1.03
MnO	0.02	0.02	0.01		0.03	0.04	0.07	0.05
CaO	0.70	0.83	0.32		3.58	1.85	1.81	2.46
Na ₂ O	3.97	4.83	4.09		5.13	6.36	6.43	6.52
K ₂ O	3.78	3.50	3.67		1.07	1.59	1.47	1.35
TiO ₂	0.25	0.27	0.17		0.61	0.72	0.41	0.52
P ₂ O ₅	0.08	0.07	0.05		0.12	0.17	0.10	0.12
Norms. (C.I.P.W. wt.%)								
Q	35.3	30.1	38.2		26.5	19.5	23.0	20.2
C	2.5	1.0	2.0		1.2	0.4	0.1	-
Or	22.3	20.7	21.7		6.3	9.4	8.7	8.0
Ab	33.6	40.9	34.6		43.5	53.8	54.4	55.2
An	2.9	3.6	1.2		17.0	8.1	8.3	7.7
Ne	-	-	-		-	-	-	-
Di	-	-	-		-	-	-	-
Hy	1.4	1.6	0.9		2.4	4.7	3.7	3.5
Ol	-	-	-		-	-	-	-
Mt	1.2	1.2	1.0		1.1	2.3	0.7	1.0
Il	0.5	0.5	0.3		1.2	1.4	0.8	1.0
Ap	0.2	0.2	0.1		0.3	0.4	0.2	0.3
Norm. C.I.	3.1	3.3	2.2		4.6	8.4	5.2	8.6
					3.7	3.5	6.2	7.2

(Table 6), they can be easily discriminated on the basis of the much higher FeO^* and FeO^*/MgO of the rhyolites (see also Fig. 13 and 14).

The Mazinaw Lake trondhjemite is chemically distinct from the Weslemkoon trondhjemite (Table 9, columns J and M, respectively). In general the Mazinaw Lake trondhjemite is more felsic (higher SiO_2 ,

lower MgO and FeO^*) and has a different alkali ratio (higher $\text{Na}_2\text{O}/\text{K}_2\text{O}$).

On the other hand the Mazinaw Lake granite and the Weslemkoon sodic granite (Table 9, columns N and I, respectively) bear a closer chemical resemblance.

IV.5 Alteration

In dealing with chemical data of rocks which have been metamorphosed, one must question what chemical changes (if any?) may have occurred as the result of metamorphism. Winkler (1974) stated that metamorphism is an essentially isochemical process for solid-state transformations, but the highly volatile components such as H_2O and CO_2 can be expected to move more readily in and out of the system. In some areas (Winkler, p. 16, 1974), it has been shown that even in high-grade gneisses the rock system was closed to potassium and calcium, thus making it highly probable that it was closed to the other elements as well. Contrasting opinions have been expressed from work in other areas. In a comparison of fresh and metamorphosed volcanic rocks, Pearce et al. (1974) concluded that alkalis tend to show progressive increases with increasing metamorphic grade.

In addition, the problem of the amount of pre-metamorphic metasomatism must be considered. This problem is compounded for the metamorphic rocks because originally altered rocks will tend to be disguised

by the subsequent mineralogical and textural changes. Because the alkalis are most readily moved by metasomatic processes, the analyses of all recognized metavolcanic rocks from the map-area have been plotted on an alkalis ratio diagram (Fig. 9). All but 4 of the analyses lie within the field of the 'igneous spectrum', the area in which samples of un-metasomatized volcanic rocks plot. Some of these show other criteria of alteration, such as very high $\text{Fe}_2\text{O}_3/\text{FeO}$ ratios and abnormally high volatile content. Through the use of this 'screen', the 4 analyses which lie outside the 'igneous spectrum' are considered altered and are not used in any figures or tables in this chapter. Although there is still some latitude for metasomatic change of rocks within the boundaries of the spectrum, it will be empirically demonstrated that the metavolcanic rocks of the map-area were not systematically altered before or during metamorphism. Rather, by comparison with analyses and trends in fresh volcanic rocks, it will be shown that the rock suite appears to have retained its original chemical characteristics.

IV.6 Chemical Affinities

Figure 10 is a SiO_2 -variation diagram. It shows a linear trend with variable scatter for analyses of the Mazinaw Lake formation metavolcanics (open symbols). The Tudor formation basalts plot as a separate group for most oxides (map-area analyses - solid triangles, average of 22 analyses from outside of map-area - solid diamond). The average of gabbro analyses (solid circle) shows a closer correlation with Tudor basalt than Mazinaw Lake basalt. On the other hand, the average diorite analyses (solid square) generally fits well into the linear trend of the Mazinaw Lake succession.

All oxides plotted of the Mazinaw Lake succession, except the alkalis, tend to

Figure 9: The alkali igneous spectrum (after Hughes, 1972 as modified by Stauffer et al., 1975).

Figure 10

LEGEND

TUDOR FORMATION

▲ BASALT

◆ average of 22 basalts from outside
map-area (Table 9, L)

MAZINAW LAKE FORMATION

○ RHYOLITE

□ ANDESITE

▽ BASALTIC-ANDESITE

△ BASALT

● average gabbro (4 analyses, Table 9, G)

■ average diorite (2 analyses, Table 9, H)

Figure 10: SiO₂-variation diagram for the metavolcanic and related intrusive rocks of the Mazinaw Lake area.

show a general decrease in value with increasing SiO_2 . K_2O increases with increasing SiO_2 , whereas Na_2O remains relatively constant.

The Tudor formation has been well established as consisting predominantly of tholeiitic basalt (Sethuraman and Moore, 1973; Moore, 1977; Condie and Moore, 1977; Morton and Moore, 1978). Figure 11 is an AFM diagram of metavolcanic analyses from the map-area. Also shown are the fields of 40 analyses of Tudor formation rocks (dashed line) and 48 analyses of a younger calc-alkaline succession (dot-dashed line, discussed below) from outside the area (Morton and Moore, 1978). Tudor formation rocks all lie within or close to the tholeiitic field. The majority of analyses from the Mazinaw Lake succession also plot within or close to the tholeiitic field. If one includes all analyses from the Tudor and Mazinaw Lake formations, the classical (but somewhat diffuse) trend of 'iron-enrichment' typical of tholeiitic volcanic rock series is outlined.

Figure 12 is a variation diagram which has been proposed to discriminate chemical trends in metavolcanic rocks (Jensen, 1976). This ternary diagram relates molecular percentages (cation-weighted) of Al_2O_3 , $\text{FeO} + \text{Fe}_2\text{O}_3 + \text{TiO}_2$, and MgO . The substitution of Al_2O_3 for alkalis (in the AFM diagram) provides a trend indicator which is less sensitive to metasomatic change, because aluminum is considerably less mobile than the alkalis. Map-area metavolcanic rock analyses show considerably less scatter, however a few points still fall within the calc-alkaline field. These four analyses came from different parts of the map-area, and appear physically similar to other rocks of their respective map-units. Thus the most likely explanation for their divergence from the normal trend is some metasomatic change before or during

Figure 11

LEGEND

TUDOR FORMATION

▲ BASALT

◆ average of 22 basalts from outside
map-area (Table 9, L)

MAZINAW LAKE FORMATION

○ RHYOLITE

□ ANDESITE

▽ BASALTIC-ANDESITE

△ BASALT

● average gabbro (4 analyses, Table 9, G)

■ average diorite (2 analyses, Table 9, H)

Figure 11: AFM diagram of the metavolcanic and related intrusive rocks of the Mazinaw Lake area. Solid line: the division between tholeiitic and calc-alkaline fields as proposed by Irvine and Baragar (1971). Dashed line: the field of 40 analyses of Tudor formation rocks from outside the map-area (Morton and Moore, 1978). Dot-dashed line: the field of 48 analyses of calc-alkaline rocks from outside the map-area (ibid.).

Figure 12

LEGEND

TUDOR FORMATION

▲ BASALT

◆ average of 22 basalts from outside
map-area (Table 9, L)

MAZINAW LAKE FORMATION

○ RHYOLITE

□ ANDESITE

▽ BASALTIC-ANDESITE

△ BASALT

● average gabbro (4 analyses, Table 9, G)

■ average diorite (2 analyses, Table 9, H)

Figure 12: Cation-weighted molecular percent diagram of the metavolcanic and related intrusive rocks of the Mazinaw Lake area, as proposed by Jensen (1976).

OF/DE

metamorphism. In this diagram (Fig. 12) the felsic members of the Mazinaw Lake formation are clearly tholeiitic; a feature which was not obvious on the AFM diagram (Fig. 11). Figure 12 also displays the compositional gap between rhyolites and andesites of the Mazinaw Lake formation; an interesting confirmation of this previously mentioned feature, when one considers the fact that SiO_2 is not represented on this diagram.

Final confirmation of the tholeiitic nature of volcanic rocks of the map-area is provided in Figure 13 and 14. These diagrams were proposed by Miyashiro (1974) to distinguish tholeiitic and calc-alkaline volcanic rock series. In both diagrams tholeiites have a higher FeO^*/MgO ratio for equivalent SiO_2 (Fig. 13) and FeO^* (Fig. 14) respectively. In Figure 13, the metavolcanic analyses display a scattered though essentially linear trend of increasing FeO^*/MgO with increasing SiO_2 . Figure 14 shows an iron enrichment trend in the Mazinaw Lake succession. A diffuse, curved trend line outlines an increase of FeO^* to a maximum, and then progressive decrease with increasing FeO^*/MgO .

Analyses of Mazinaw Lake granite and trondhjemite are also plotted on Figures 13 and 14 (small solid circles). These diagrams show that although the felsic metavolcanic rocks and the postvolcanic intrusives have similar SiO_2 values they are grossly different in FeO^*/MgO ratios. In fact, according to these diagrams, the Mazinaw Lake Granite has a calc-alkaline chemical affinity.

Figure 15 is a total alkalis versus SiO_2 diagram with the division between alkaline and sub-alkaline fields as proposed by Irvine and Baragar (1971). It shows that the Tudor formation basalts are clearly

Figure 13 & 14

LEGEND

TUDOR FORMATION

▲ BASALT

◆ average of 22 basalts from outside
map-area (Table 9, L)

MAZINAW LAKE FORMATION

○ RHYOLITE

□ ANDESITE

▽ BASALTIC-ANDESITE

△ BASALT

● average gabbro (4 analyses, Table 9, G)

■ average diorite (2 analyses, Table 9, H)

Figure 13: SiO_2 - FeO^*/MgO diagram of the metavolcanic, related intrusive and granitic rocks (small solid circles) of the Mazinaw Lake area.

Figure 14: FeO^* - FeO^*/MgO diagram of the metavolcanic, related intrusive and granitic (small solid circles) rocks of the Mazinaw Lake area.

Figure 15

LEGEND

TUDOR FORMATION

▲ BASALT

◆ average of 22 basalts from outside
map-area (Table 9, L)

MAZINAW LAKE FORMATION

○ RHYOLITE

□ ANDESITE

▽ BASALTIC-ANDESITE

△ BASALT

● average gabbro (4 analyses, Table 9, G)

■ average diorite (2 analyses, Table 9, H)

Figure 15: Alkali- SiO_2 diagram of the metavolcanic and related intrusive rocks² of the Mazinaw Lake area. Proposed division between alkaline and sub-alkaline fields (dashed line) after Irvine and Baragar (1971). The field of 78 Keweenawan volcanic rocks is enclosed by solid lines (Baragar, 1977).

sub-alkaline whereas the mafic members of the Mazinaw Lake formation lie within the alkaline field. However, the intermediate to felsic members of the formation transect the boundary and lie within the sub-alkaline field. Other indications of the alkaline character of the basalt members of the Mazinaw Lake succession are their relatively high TiO_2 (average 2.0%), and P_2O_5 (average 0.51) and a general tendency for higher Ba and Zr values (see Table 12, Appendix 2). In this respect they are similar to plateau basalt sequences which range from distinctly alkaline to sub-alkaline and in some areas with transitional chemical character (Baragar, 1977). The fields of 78 analyses of Keweenaw volcanic rocks are outlined in Figure 15 (solid line). In general, they occupy a similar field to that of the rocks of the map-area including a compositional gap (dacite-gap).

In summary, on the basis of chemical trends, the volcanic rocks of the study area can be divided into two groups of tholeiitic rocks: a more basic succession of tholeiitic basalts (the Tudor formation); and a succession of tholeiitic basalt to rhyolite (the Mazinaw Lake formation). Iron-enrichment has been demonstrated in the Mazinaw Lake succession and the mafic members of this formation have a slightly alkaline character. It is suggested that the Mazinaw Lake and Tudor formation magmas may be genetically related. Two possibilities exist:

- 1) The voluminous Tudor formation basalts derived from the upper mantle were fed to the surface as great expanses of flood basalts and in the Mazinaw Lake area magma was emplaced at a high crustal level where it differentiated to form the extrusions of the Mazinaw Lake succession;

- 2) The parental magma to the Mazinaw Lake succession was derived directly from the upper mantle (from whence the Tudor magma came) and underwent fractionation as it rose to the surface, or at a high crustal level.

IV.7 Regional and Global Comparisons

Averages of chemical analyses of the major groups of meta-igneous rocks from the map-area are presented in Table 9 (columns A to K); also presented are analyses from the region (columns L to N) and from different localities around the world.

Comparisons of analyses of fresh tholeiitic andesites (Q) and calc-alkaline andesites (R) and the Mazinaw Lake andesite (D), indicate a striking similarity of Mazinaw Lake and average tholeiitic andesites. In general, tholeiitic andesite has significantly higher SiO_2 , FeO^* and TiO_2 and lower Al_2O_3 , MgO and CaO than calc-alkaline andesite. Carmichael (1964) classified the tholeiitic andesites as 'Icelandites' after the typical variety of andesite found in Iceland.

Icelandic rhyolites (Table 9, column S) are also chemically distinctive from typical calc-alkaline rhyolite (T). The average metarhyolite from the map-area (E) exhibits remarkable similarity with the average Icelandic rhyolite. Both averages have significantly higher FeO^* , FeO/MgO and are more sodic than calc-alkaline rhyolite. The origin of Icelandic rhyolite is debated (Walker, 1966). However, its close association with tholeiitic basalt and andesite, the similar isotopic ($\text{Sr}^{87}/\text{Sr}^{86}$) ratios of basalt and rhyolite (Singurdsson, 1967), and the tholeiitic character on

Table 9: Regional and Global Comparisons
Map--Area Analyses

Map Unit: No.	A	B	C	D	E	F	G	H	I	J	K
	1a	1b	2	3	4	8	9	9	10	10a	10a
No. of Analyses (3)	(6)	(4)	(5)	(8)	(2)	(4)	(2)	(3)	(4)	(4)	(4)
Oxide Wt. %											
SiO ₂	50.8	50.9	56.3	62.2	73.0	48.8	50.9	58.4	75.3	69.9	75.8
Al ₂ O ₃	15.7	17.0	16.3	13.5	13.0	7.2	16.5	15.6	13.8	15.7	12.7
FeO*	10.4	11.7	8.9	9.2	4.1	11.6	8.8	9.8	1.6	2.5	2.9
MgO	7.2	4.0	3.6	2.1	0.5	21.0	7.9	2.6	0.3	1.1	0.3
MnO	0.2	0.2	0.2	0.2	0.1	0.3	0.1	0.2	0.0	0.0	0.0
CaO	10.5	7.7	5.8	4.1	1.1	9.2	10.8	4.6	0.6	2.4	1.1
Na ₂ O	2.8	4.0	4.3	4.1	4.4	0.6	3.0	4.8	4.3	6.1	6.2
K ₂ O	0.7	1.9	2.3	2.5	3.2	0.2	0.7	1.8	3.6	1.4	0.6
TiO ₂	1.2	2.0	1.7	1.3	0.4	0.6	0.9	1.5	0.2	0.6	0.2
P ₂ O ₅	0.2	0.5	0.4	0.5	0.1	0.1	0.1	0.3	0.1	0.1	0.0

Regional Analyses				Global Analyses							
L	M	N		O	P	Q	R	S	T		
No. of Analyses (22)	(1)	(1)	(1)	(133)	(208)	(6)	(90)	(52)	(22)		
SiO ₂	49.9	66.6	73.6	48.0	49.7	62.4	60.5	73.5	74.2		
Al ₂ O ₃	15.2	17.4	15.4	6.8	6.2	14.4	17.4	13.3	13.6		
FeO*	12.8	3.3	0.9	11.6	12.0	8.2	5.9	3.1	1.9		
MgO	7.3	2.0	0.2	17.5	20.0	1.8	3.2	0.3	0.3		
MnO	0.2	0.0	0.0	0.2	0.1	0.2	ND	0.1	0.0		
CaO	9.4	2.6	0.6	12.7	9.7	5.1	6.1	1.6	1.1		
Na ₂ O	3.6	5.2	5.1	0.8	0.8	3.9	4.0	4.4	3.0		
K ₂ O	0.2	2.1	3.9	0.5	0.4	2.0	1.7	3.0	5.4		
TiO ₂	1.2	0.5	0.3	1.4	0.6	1.3	0.9	0.3	0.2		
P ₂ O ₅	0.1	0.1	0.0	0.4	0.2	0.3	0.2	0.1	0.1		

Source: L, Tudor basalt (Morton & Moore, 1978); M, Weslemkoon trondhjemite (Lumbers, 1976a)

N, Weslemkoon sodic granite (Lumbers, 1967a); O, pyroxenite (Lemaire, 1976);

P, websterite, (Lemaire, 1976); Q, tholeiitic andesite (Kuno, 1969);

R, calc-alkaline andesite (Chayes, 1969); S, Icelandic rhyolite (Walker, 1966);

T, calc-alkaline rhyolite (Walker, 1966).

discrimination diagrams strongly suggests the rhyolite can best be accounted for by fractionation of a tholeiitic parent magma. This conclusion would appear to be true for the Mazinaw Lake metarhyolite as well.

A 'dacite' compositional gap has been noted in Icelandic stratovolcanoes (Walker, 1963; Carmichael, 1964). This feature is also similar to the Mazinaw Lake volcanic succession. In fact, the interpreted original distribution of volcanic rocks in the area and surrounding region resembles eastern Iceland. There, localized accumulations (stratovolcanoes) of mafic to felsic volcanic rock rise above a vast plain of Tertiary flood basalts.

In the region to the south of the map-area, a succession of calc-alkalic metavolcanic rocks appears to overlie marbles which are younger than the Tudor and Mazinaw Lake formations (Fig. 2). The younger succession comprises calc-alkali basalt, andesite, dacite and rhyolite flows and pyroclastic rocks (Moore, 1977; Condie and Moore, 1977; Morton and Moore, 1978). The calc-alkaline nature of this succession is well defined in Figure 11 (dot-dashed line); the field of 48 analyses lie well within the calc-alkaline field on the AFM diagram. The trend of the group of analyses shows uniformly decreasing iron content (i.e. no iron-enrichment) for progressively more felsic members.

IV.8 Metarhyolite Petrochemistry

The rhyolites (Unit 4) appear to be very thick in certain portions of the map-area (Fig. 3). This is particularly true north of Semicircle Lake. Here the rhyolite horizon has an apparent stratigraphic thickness of 1000 m; the true thickness is probably considerably less because the

dip in this area is relatively shallow. The base and lateral extensions of the rhyolite horizon were truncated by the intrusion of the Mazinaw Lake Granite. Directly overlying the rhyolite (south of Semicircle Lake) is a thinner horizon of andesite (Unit 3) which is in turn overlain by another rhyolite horizon. These relations are shown in a schematic cross-section in Chapter III.1 (Figure 5).

Rhyolite in the lower half of the first rhyolite horizon is essentially aphyric; towards the upper portion of the unit relict phenocrysts are progressively more abundant. Alkali feldspar phenocrysts are very abundant near the top of the unit and in the upper rhyolite unit, south of Semicircle Lake.

Analyses of rhyolite samples selected across portions of the above rhyolite units display progressive chemical variation. Figure 16 shows the variation of the major oxides and selected trace elements with apparent stratigraphic height. SiO_2 and Na_2O decrease with increasing stratigraphic height; all other oxides and traces show a general increase, except CaO and Zr which do not show any consistent change. The most striking change is that of K_2O , which increases from about 2% at the base to 4.5% at the top of the sampled rhyolite succession.

Vertical chemical zonation is a common feature in many of the thick deposits of felsic ash tuff in the southwestern United States. A good example of vertical zonation within an ash flow sheet is the lower most member of the Paintbrush Tuff of southern Nevada (Lipman et al., 1966). The unit was estimated to have covered about $2,000 \text{ km}^2$ with a maximum thickness of 300 m. A typical section is characterized by crystal-poor rhyolite (1% phenocrysts) at the base and a cap-rock of crystal-rich latite (21% phenocrysts). In the crystal-poor rhyolite, plagioclase and alkali

Figure 16: Variation in metarhyolite chemistry with stratigraphic height. Analyses are from horizons north and south of Semicircle Lake (see Fig. 3).

feldspar phenocrysts occur in subequal amounts and there is an upward increase in phenocryst content to the quartz latite cap-rock, in which alkali feldspar is considerably more abundant than plagioclase. The chemical variation is very distinctive with progressive increases in all oxides excluding SiO_2 (which decreases) from the base to the top of the unit.

Similar chemical variation is described for the succession of felsic volcanic rocks related to the formation of the Creede caldera in southwestern Colorado (Ratte and Stevens, 1964 and 1967). The sequence shows a transition from alkali-rich rhyolite to younger quartz latite and rhyodacite. In this succession all oxides, excluding SiO_2 and K_2O , increase with stratigraphic height.

Many of the described examples of compositionally zoned felsic sequences indicate upward increase in phenocryst content and decrease in SiO_2 (Lipman et al., 1966; Smith and Bailey, 1966; Ratte and Stevens, 1967; Lambert, 1974). In the above examples the zoning is attributed to an original zonation in the magma chamber. The magmas were thought to have been reversely zoned; with the early phenocryst-poor silicic extrusions derived from a silica and volatile rich upper portion, and successively more mafic and crystal-rich extrusions tapped from progressively lower levels of the magma chamber.

Lipman et al. (1966) suggested that early crystallized feldspars could settle sufficiently rapidly to prevent reaction with the magmatic liquid in place, resulting in a compositional gradation towards the top of the magma chamber. Lambert (1974) suggested that gaseous transfer of volatiles could also result in a zoned magma chamber. Volatiles tend to concentrate in regions of lowest temperature and pressure. Certain

metals, such as alkalis and silicon, tend to co-ordinate with the volatiles and thus would also concentrate at the upper and outer margin of the magma chamber.

Chemical zonation in the metarhyolite succession in the map-area (Fig. 16) is complicated by an intervening unit of meta-andesite abruptly overlying the lower rhyolite horizon (Fig. 5). Composition of the andesite is not gradational with that of the rhyolite (in fact, a distinct gap is present, see Fig. 10). The chemical gradation appears to be continuous in the rhyolite above and below the andesite unit (Fig. 16). These features suggest the andesite was not extruded from the same magma chamber as the rhyolite; and that the rhyolite horizons represent successive extrusions from a compositionally zoned magma chamber.

As the observed chemical zonation displays a distinct increase in K_2O upward in the metarhyolite succession (i.e. decreasing K_2O towards the top of the magma chamber), it is thought to be unlikely that the zonation was the result of upward diffusion of alkalis. In order to test if the observed chemical zonation could be produced by crystal settling of feldspar, a method of graphical analysis developed by Pearce (1968) has been applied to the chemical data of the metarhyolite analyses. All rhyolites from Table 6 have been used; although for some of these analyses it is unsure what stratigraphic level they represent, still they should all be from the same magma chamber and thus fit somewhere into a zonation scheme.

Briefly, in a series of rocks related by crystal fractionation, the molar amounts of two chemical components in a series of chemical analyses are divided by the molar amounts of a component not involved in fractionation (i.e. a constant component), and the resulting points are

plotted on a molecular ratio diagram. Pairs of oxides occurring in a fractionated mineral will have a slope determined by their molecular ratio (stoichiometry).

Figure 17 is a molecular ratio diagram derived from analyses of metarhyolite in Table 6. TiO_2 was used for the constant component because it is unlikely that it would occur in significant quantities in phenocrysts formed from a rhyolitic melt. The linear variation of $\text{Al}_2\text{O}_3/\text{TiO}_2$ with respect to $\text{SiO}_2/\text{TiO}_2$, without any pronounced break or inflection from the most mafic to felsic variant, indicates feldspar fractionation is the best explanation for this variation. This is confirmed by a similar relationship between CaO/TiO_2 , $\text{Na}_2\text{O}/\text{TiO}_2$ and $\text{K}_2\text{O}/\text{TiO}_2$ with respect to $\text{SiO}_2/\text{TiO}_2$, and also indicates both alkali and plagioclase crystals were settling. The correlation coefficient (r) is excellent for Al_2O_3 and Na_2O , good for CaO and fair for K_2O . The scatter on the latter two plots is probably the result of metasomatic change. A good correlation between $\text{FeO}^*/\text{TiO}_2$ and $\text{SiO}_2/\text{TiO}_2$ can not be explained by feldspar fractionation. This feature, and the lack of variation in MgO/TiO_2 with respect to $\text{SiO}_2/\text{TiO}_2$ can be best explained by concurrent fractionation of crystals of iron-rich silicate. The most probable candidate was an iron-rich olivine (fayalite).

An important question concerning the crystal-settling hypothesis is whether settling velocities could be adequate in view of the high viscosity of rhyolitic melts. Lipman et al. (1966) has calculated that alkali feldspar crystals with a radius of 1 mm, in a rhyolitic melt with a viscosity of 10^7 poises would have settling velocities of 1 km in 30,000 years. Plagioclase and olivine, with their higher specific gravities, would settle more quickly.

Figure 17: Molecular ratio diagram of metarhyolite analyses (Table 6).

V: HISTORICAL SUMMARY AND CONCLUSIONS

V.1 Geological History

The earliest geological event in the region was extrusion of a thick succession of submarine flows of tholeiitic basalt. The lower portion of the sequence was extruded into deep water whereas the upper portion shows evidence of extrusion into a shallower marine environment.

Within the study area these basaltic flows are overlain by a localized accumulation of basalt, basaltic andesite, andesite and rhyolite flows and pyroclastic rocks. This accumulation represents a tholeiitic volcanic rock series with the members all genetically related to the same parent magma through fractionation. The deposits are thickest around the south end of Mazinaw Lake. Abundant coarse pyroclastic rocks, feeder dykes, and synvolcanic intrusions around the east end of Pringle Lake indicate proximity to the volcanic centre. Ultramafic and gabbroic intrusive bodies are thought to represent localized subvolcanic cumulates whereas dioritic bodies were emplaced as subvolcanic intrusions. The presence of relict eutaxitic structure in the rhyolites around Mazinaw Lake suggest that part of the succession was subaerial. These volcanic rocks were probably deposited at the site of an ancient stratovolcano which locally rose above the original sea level. Away from the central area volcanic deposits are thinner, and are locally intercalated with epiclastic and semipelitic sediments.

In the eastern part of the study area the volcanic rocks were succeeded by thickly bedded carbonate sediments deposited as chemical precipitates. Outside the map-area, south of Mazinaw Lake, stratigraphically equivalent carbonate sediments were deposited from turbidity currents,

perhaps derived from the collapse of unstable banks of precipitated carbonate around the flanks of the volcano. Further south the carbonate turbidites overlie the submarine basalt succession without any intervening horizons of volcanic rock related to the volcano around Mazinaw Lake.

Intrusion of granitic plutons resulted in removal of the northern portions of the volcanic pile. The plutons are predominantly granite but the Mazinaw Lake Granite in the north has a complex border zone with the volcanics which consists of abundant xenoliths and late trondhjemite. The last phase of igneous activity was intrusion of a swarm of thin gabbroic dykes.

The area was then subjected to intense deformation in two phases, an early phase with coincident development of a penetrative fabric and a later phase without any significant pervasive fabric. Metamorphism reached middle amphibolite facies throughout the map-area with somewhat higher temperatures in the east. Temperature reached 550 to 600°C and load pressure was 5 to 6 kb. Metamorphism outlasted deformation.

No further tectonism is recognizable in the map-area until Mesozoic to Tertiary time, when faulting related to formation of the Ottawa Valley graben system resulted in a large fault along Mazinaw Lake.

Pleistocene glaciation modified drainage and topography, and left a mantle of unconsolidated deposits over the region.

V.2 Conclusions

Map-units established in the field were largely substantiated by subsequent chemical analyses. On the basis of petrochemistry and field characteristics, the metavolcanic rocks have been subdivided into a lower,

more mafic group of tholeiitic basalts correlated with the Tudor formation and a younger serial accumulation of tholeiitic basalt to rhyolite defined as the Mazinaw Lake formation. Members of the Mazinaw Lake formation show an iron-enrichment trend and a distinct compositional gap occurs between andesite and rhyolite compositions. The mafic members of the formation appear to be slightly alkaline, however intermediate and felsic members do not show any alkaline characteristics.

The thick succession of metarhyolites on the east side of Mazinaw Lake display a physical and chemical zonation which appears to be the result of eruption from a zoned magma chamber. From a molecular ratio plot of rhyolite chemical analyses it appears that this zonation was caused by crystal-settling of phenocrysts of plagioclase, alkali feldspar and iron-rich olivine within the magma chamber prior to eruption.

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APPENDIX 1

Mode and texture of meta-igneous
rocks from the Mazinaw Lake area

Appendix 1 (continued)

AbbreviationsTextures

very fine-grained
fine-grained
medium-grained
coarse-grained
blastoporphyrific
amygdaloidal
fragmental
flow laminated

Abbreviation

v
f
m
c
bp
am
fr
fl

Minerals

actinolite
albitel
apatite
biotite
carbonate
chlorite
epidote
fluorite
garnet
hematite
hornblende
magnetite
plagioclase²
pyrite
quartz
scapolite
sphene
talc
tourmaline
tremolite
zircon

ac
ab
ap
bi
cb
ch
ep
ft
ga
hm
hn
mt
pc
py
qz
sc
sp
ta
to
tr
zr

- ¹ negative relief with respect to canada balsam
² positive relief with respect to canada balsam

General Notes

* slide stained for potassium feldspar

t mineral present in trace amount

Ps mineral present as a pseudomorph

An content determined by extinction angle method.

Appendix 1 (continued)
Table 10: Texture and Mode (visually estimated) of Metavolcanic Rocks

Name & Specimen No.	Texture	Quartz	Plagioclase	Microcline	Biotite	Amphibole	Muscovite	Opaque	Chlorite	Accessories	Relict Phenocrysts
Rhyolite											
ma207a*	v, bp, fr	30	45 (An10)	20	1		2	mt-2, hm-t, py-t	t-Ps-bi	sp-1, ap-t, ft-t	mi-5, qz-2, pc-t
ma207a*	v, bp, fr	32	43 (An2)	20	2			mt-2, hm-t	t-Ps-bi	sp-1, ap-t	mi-3
ma210a*	v, bp, fr	30	40 (ab)	20	1		2	mt-6, hm-t		sp-1, ap-1	mi-8, qz-2
ma225b*	v	32	40 (ab)	25	t		2	mt-t	t-Ps-bi	sp-t	
ma234a*	v, bp	23	42 (ab)	28	3			mt-2, hm-t	l-Ps-bi	sp-1	mi-4, pc-1
ma238a*	v, bp, fr	30	40 (ab)	25	3			mt-1, hm-t	l-Ps-bi	sp-1	mi-5, qz-t, pc-1
ma239a*	v, fl	35	30 (ab)	30	1		1	mt-3, hm-t	t-Ps-bi	sp-t, ap-t	
ma242a*	v, fr	30	45 (ab)	15	6		t	mt-3, hm-t		sp-t, ap-t, cb-t	
ma243a*	v, bp, fr	25	39 (An7)	26	7		t	mt-2, hm-t		sp-t, ap-t	mi-10, pc-3
Andesite											
ma207a*	f	20	52 (ab), 3	5	13	hn-7		mt-t		ap-2, ap-t	
ma216a*	f, bp	20	35 (An10)	20	15			mt-1, hm-t		cb-2, ap-t, sp-t	mi-2, pc-t
ma235a*	f, bp	15	50 (ab)	10	7	hn-15		mt-t		sp-2, ap-t, cb-t	pc-3
ma236a*	v, bp, fr	23	35 (ab)	25	4	hn-8		mt-4, hm-t		sp-2, ap-t	mi-2
ma246a*	f, bp	10	55 (An7)	10	20	hn-t		mt-t	5-Ps-hn	cb-t, sp-t	pc-1
ma246b*	f, bp, fr	12	50 (An13)	20	5	hn-10		mt-t, hm-t		sp-2, cb-t, ap-t	pc-t
ma246c*	f, bp	15	55 (An10)	7	13	hn-7		mt-t		sp-1, cb-1, ap-t	pc-2
ma247a*	f, bp	15	50 (ab)	10	20		t	mt-2, py-1, hm-t		cb-3, ap-t, sp-t	pc-t
ma254a*	f, bp, fr	15	52 (An10)	8	12	hn-7		mt-2		ap-1, cb-t	pc-2
ma256a*	f, bp	17	57 (An7)	3	20			mt-t, hm-t		sp-2, cb-1, ft-t	pc-2
Basaltic Andesite											
ma247a*	f	10	62 (An20)		10	hn-18		mt-t		sp-t, ep-t, cb-t	
ma253a*	f, bp, fr	15	55 (An21)	5	14	hn-7		hm-2		sp-2, cb-t, ep-t	pc-3
ma272b	f, am	10	50 (pc)		20	hn-10		hm-5, mt-t		cb-2, ga-2	
ma309	f	15	60 (pc)		5	hn-18		hm-t		sp-2, ap-t, ep-t	
ma314	f, am	20	45 (pc)	2	5	hn-22		py-3		sp-t, ap-t	
Basalt - Unit 1a											
ma289	v	t	40 (pc)		5	hn-45		py-1		sp-2	
ma312	f, bp	t	50 (pc)		5	hn-40		py-t		ep-5, sp-t, cb-t	pc-5
ma130	v, fl	t	50 (pc)			hn-45		py-5			
- Unit 1b											
ma109a*	f, am	15	50 (pc)		22	hn-5		cp-5, py-t, mt-t		ep-5	pc-25
ma124	f, bp, am	5	55 (An30)		15	hn-20		mt-5		sp-t, ep-t	
ma177*	v, am	5	45 (pc)		3	hn-27		mt-10, py-t		ep-5	
ga023b	f, bp, am	5	55 (An21)			hn-35		mt-3, py-t		ep-2	pc-20
ga042b	v, bp	t	46 (An22)			hn-50		py-2, mt-t		sp-t	pc-10
- Unit 1c											
ma301	f, am	5	60 (An30)		6	hn-25		py-4		ap-t	
ma302	f	5	53 (An35)		7	hn-26		mt-4, py-2		ep-2, sp-1, ap-t	
ma322b	f, bp	10	50 (pc)		15	hn-20		mt-2, py-t		sp-2, ap-t, cb-t	pc-t

Appendix 1 (continued)
Table 11: Texture and Mode (visually estimated) of Meta-Intrusive Rocks

Name & Specimen No.	Texture	Quartz	Plagioclase	Microcline	Biotite	Amphibole	Muscovite	Opaque	Chlorite	Accessories	Relict Phenocrysts
Granite											
ma206b*	f, bp	33	45 (An10)	17	2		1	mt-2, hm-t	t-Ps-bf	zr-t	pc-3, ml-1, qz-t
ma228c	f	35	30 (ab)	25	5		5	mt-t, hm-t	t-Ps-bf	zr-t	
ma231a*	f	25	50 (An12)	25	3		t	mt-t	t-Ps-bf	sp-t	
ma258a*	f	32	35 (An21)	30			2	mt-t, hm-t	l-Ps-bf		
ma265b	m	30	40 (An12)	25	2		1	mt-t, hm-t	t-Ps-bf	sp-t	
ma267	f	30	45 (An13)	15	8		2	hm-t	t-Ps-bf	sp-t	
Trondhjemite											
ma206a*	f	30	65 (An11)		t		5	hm-t		sp-t, ap-t	
ma230b*	f	35	60 (An21)	5	5			mt-1, py-t		sp-t, zt-t, ap-t	
ma231b*	f	30	60 (An21)	3	5		1	mt-1, hm-t		sp-t, cb-t, ap-t	
ma233d*	v	35	60 (ab)		3			mt-2, hm-t		sp-t, zt-t	
ma258d*	f, bp	30	60 (An8)	5			2	mt-2, hm-t	t-Ps-bf	sp-t	qz-10, pc-3
Diorite											
ma221a	m	25	50 (An5)			hn-20		mt-t, hm-t	2-Ps-hn	sp-2, ep-1, cb-t	
Gabbro											
ma227	m	10	50 (An30)		3	hn-30		hm-t		ac-5, sp-t, ep-t	
ma27-a	m	5	55 (An38)		10	hn-25		mt-2, py-t, hm-t		sp-2, ep-1, cb-t, ap-t	
ma264	m	t	49 (An30)		8	hn-40	t	mt-3	t-Ps-bf	ep-t	
ma273*	f	5	50 (pc)		5	hn-40		py-t		ep-t, cb-t	
Ultramafic Group											
ma288a	m					60		mt-10, py-t, hm-t	30		
ma293	f					45		mt-20, hm-t	35		
ma295b	f				5	ac-60		mt-5, py-5	20	ga-5	
ma175*	c				1	90	t	mt-t	8	ep-t	
ma176*	m		50 (An75)		t	ac-40	t	hm-t	10	tu-t, ep-t	
Late Mafic Dykes											
ma208c	f	10	41 (An30)	5	15	hn-22		hm-2, py-t	t-Ps-hn	sp-5, ap-t, cb-t	
ma215b	f, bp	5	53 (pc)		2	hn-35				ep-4, ap-1	pc-10
ma299b	f	5	55 (An30)		5	hn-30		py-5		cb-t	

APPENDIX 2

Chemical composition of rock specimens
from the Mazinaw Lake area

Appendix 2 (continued)

Abbreviations

<u>Rock Name</u> (prefix 'meta' omitted)	<u>Abbreviation</u>
Andesite	And.
Basaltic Andesite	Ban.
Basalt	Bas.
Diabase (unit 11)	Dia.
Diorite	Dio.
Gabbro	Gab.
Granite	Gra.
Rhyolite	Rhy.
Trondhjemite	Tro.
Volcaniclastic	Vcl.

note (A) after rock name indicates altered specimen as determined from Chapter IV - Fig. 9.

General Notes

Fe_2O_3^*	total iron as Fe_2O_3
$\text{H}_2\text{O}-^*$	loss on ignition
ND	not determined
BD	below detection limit

Discussion

Chemical analyses of rock specimens from the map-area were performed at the following analytical laboratories:

- 1) Analyses 1 to 39, by the Ontario Geological Survey, Toronto;
- 2) Analyses 40 to 45, by Xray Assay Laboratories Limited, Toronto;
- 3) Analyses 46 to 58, by the Science Laboratories, Durham University, England, under the supervision of Dr. J.G. Holland.

Appendix 2 (continued)

Samples 1 to 37 (Table 12) had major elements determined simultaneously on a fused glass sample containing 15.3% rock powder, 75.5% lithium tetraborate and 9.2% lanthanum oxide by means of an Applied Research Laboratories 72000 XRF Quantometer. FeO, S, CO₂, H₂O⁺ and H₂O⁻ were determined by chemical techniques. Ba, Co, Cr, Cu, Li, Ni, Pb and Zn were determined by atomic absorption and the remaining reported traces by emission spectrography.

Each batch of 100 samples includes:

- a) 2 blanks
- b) 3 international reference standards
- c) 3 internal control standards
- d) 8 duplicate analyses

Results of reference and control standard analyses were not reported but duplicates were included. Table 13 shows the results of duplicate analyses (columns 1 to 3).

Totals of these analyses are good (98.1 to 99.8).

Samples 40 to 45 (Table 12) had major elements determined by an X-ray spectrometer on a fused glass button (the proportion of rock powder to other substances was not reported). Ba and Cr were determined by a nondispersive X-ray analyser. Co, Ni, Cu, Zn and Pb were determined by atomic absorption and Li by emission spectrography.

Total iron is reported as Fe₂O₃. Individual volatiles were not determined, however weight loss on ignition is reported. Totals from this laboratory are relatively low (97.0 to 97.9). Analyses of a sample also analysed by the Ontario Geological Survey Laboratory (Table

Appendix 2 (continued)

13, column 4) reveals good correspondence for most major oxides but Al_2O_3 is distinctly low. Some traces do not show significant differences, however Cr, Ni and Zn are discordant.

Samples 46 to 58 are analyses of specimens from the map-area which were included in a group of specimens submitted in connection with the report on the geology of the Clarendon Lake map sheet (Moore and Morton, m.s.). The analyses were performed mainly by multichannel X-Ray spectrography, and were reported recalculated to 100%, volatile free. The reported values of Fe_2O_3 are calculated as a constant proportion from the total iron determination, and thus should not be considered as representative of the actual oxidation state of iron.

Appendix 2, Table 12

Analysis No.	1	2	3	4	5	6	7
Specimen No.	ma127c	ma203a	ma203b	ma203c	ma217a	ma220b	ma221a
Rock Name	dio.	rhy.	and.	dia.	ban.	tro.	dio.
Oxide Wt. %							
SiO ₂	56.3	72.4	61.5	52.3	54.2	74.9	58.1
Al ₂ O ₃	15.7	12.7	13.0	14.6	13.8	12.5	14.9
Fe ₂ O ₃	6.36	1.96	2.29	1.66	3.93	1.84	3.18
FeO	4.90	1.58	7.40	10.4	7.90	1.25	5.65
MgO	1.69	0.10	1.67	3.88	3.25	0.10	3.41
MnO	0.22	0.06	0.25	0.25	0.33	0.03	0.14
CaO	3.83	1.23	3.69	3.28	5.04	0.81	5.10
Na ₂ O	5.40	4.25	3.72	3.55	4.29	6.53	4.06
K ₂ O	1.72	3.93	2.33	4.42	2.22	0.15	1.73
TiO ₂	1.35	0.36	1.23	2.15	2.42	0.21	1.60
P ₂ O ₅	0.28	0.02	0.39	0.59	0.46	0.0	0.23
S	0.06	0.02	0.01	0.02	0.01	0.04	0.05
CO ₂	0.16	0.32	0.10	0.70	0.16	0.08	0.28
H ₂ O+	0.27	0.0	0.53	0.69	0.57	0.0	1.04
H ₂ O-	0.36	0.34	0.41	0.42	0.42	0.34	0.42
Total	98.6	99.3	98.5	98.9	99.0	98.9	99.9
<u>Trace Element (PPM)</u>							
Ba	320	510	360	430	460	60	240
Be	3	4	4	3	3	3	2
Co	9	5	8	25	25	6	25
Cr	BD	6	BD	30	BD	BD	15
Cu	25	BD	6	5	BD	10	20
Ga	20	20	20	15	15	15	15
Li	15	5	10	10	9	3	15
Ni	BD	BD	BD	10	BD	BD	BD
Pb	25	25	BD	BD	BD	BD	BD
Sc	30	BD	9	25	30	8	25
Sr	500	40	40	200	300	400	700
V	15	15	60	200	350	20	250
Y	60	150	90	45	60	60	35
Zn	135	20	85	160	270	15	75
Zr	400	400	500	200	300	500	200
<u>CIPW Norms (Wt. %)</u>							
Qz	8.6	30.3	18.3	0.0	5.1	34.9	11.8
C	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Or	10.4	23.6	14.1	26.9	13.4	0.9	10.4
Ab	46.7	36.5	32.3	30.9	37.1	56.2	35.0
An	13.8	4.0	12.2	11.2	12.1	4.1	17.7
Ne	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wo	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Di	3.0	1.8	3.4	1.4	8.6	0.0	5.4
Hy	4.6	0.3	12.9	13.3	12.1	0.6	11.3
Ol	0.0	0.0	0.0	8.1	0.0	0.0	0.0
Mt	9.4	2.7	3.4	2.5	5.8	2.7	4.7
Hm	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Il	2.6	0.7	2.4	4.2	4.7	0.4	3.1
Ap	0.7	0.0	0.9	1.4	1.1	0.0	0.5
Normative CI	19.3	5.5	22.1	29.5	31.2	3.7	24.5
Normative An	17.2	9.0	27.4	26.7	24.6	6.8	33.6

Appendix 2, Table 12 (continued)

	8	9	10	11	12	DUP.	13	14	15
	ma225a	ma225b	ma227a	ma228c	ma230a	ma230a	ma230b	ma231a	ma231b
	ban.	rhy.	gab.	grn.	gab.	gab.	tro.	grn.	tro.
SiO ₂	55.4	72.0	51.0	73.8	51.8	52.0	68.0	73.4	67.8
Al ₂ O ₃	16.9	13.8	15.2	14.0	18.3	18.3	16.7	14.0	15.3
Fe ₂ O ₃	1.67	2.54	2.66	0.84	1.91	1.99	0.73	0.85	1.59
FeO	5.24	1.33	6.40	0.83	4.99	4.90	1.50	1.00	2.24
MgO	3.31	0.43	7.84	0.39	6.34	6.37	0.85	0.36	1.21
MnO	0.14	0.03	0.13	0.02	0.11	0.11	0.03	0.02	0.04
CaO	5.00	0.93	10.1	0.69	10.1	10.1	3.52	0.82	1.83
Na ₂ O	4.76	4.22	3.13	3.91	3.27	3.28	5.05	4.79	6.28
K ₂ O	2.78	3.08	0.79	3.72	0.75	0.76	1.05	3.47	1.57
TiO ₂	1.27	0.31	0.89	0.25	0.60	0.60	0.60	0.27	0.71
P ₂ O ₅	0.24	0.07	0.13	0.08	0.12	0.13	0.12	0.07	0.17
S	0.01	0.01	0.05	0.01	0.10	0.10	0.24	0.02	0.0
CO ₂	0.68	0.23	0.16	0.12	0.12	0.12	0.07	0.10	0.05
H ₂ O ⁺	0.35	0.26	0.44	0.12	0.46	0.46	0.14	0.06	0.16
H ₂ O ⁻	0.45	0.43	0.39	0.43	0.43	0.41	0.45	0.33	0.45
Total	98.2	99.7	99.3	99.2	99.4	99.6	99.0	99.6	99.4
Ba	320	810	130	800	150	140	170	380	180
Be	3	4	BD	2	BD	BD	2	3	3
Co	15	5	40	BD	25	25	15	BD	6
Cr	70	6	300	6	60	60	7	BD	BD
Cu	BD	BD	35	BD	30	30	105	10	BD
Ga	15	20	9	15	15	15	15	15	15
Li	8	4	5	4	6	6	5	6	9
Ni	30	BD	115	BD	55	55	20	BD	BD
Pb	25	BD	BD	BD	BD	BD	10	10	BD
Sc	15	BD	35	BD	25	25	6	BD	9
Sr	900	500	800	400	1000	1000	900	60	300
V	150	10	200	15	150	150	30	20	50
Y	45	150	20	10	20	20	25	45	45
Zn	110	25	75	15	55	55	30	25	40
Zr	200	400	100	100	80	80	350	400	200
Qz	0.7	32.9	0.0	35.3	0.0	0.0	26.5	30.1	19.5
C	0.0	2.0	0.0	2.5	0.0	0.0	1.2	1.0	0.4
Or	17.0	18.5	4.8	22.3	4.5	4.6	6.3	20.7	9.4
Ab	41.6	36.2	26.9	33.6	28.1	28.1	43.5	40.9	53.8
An	17.1	4.2	25.5	2.9	33.6	33.4	17.0	3.6	8.1
Ne	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Di	5.7	0.0	19.8	0.0	13.3	13.3	0.0	0.0	0.0
Hy	12.3	2.8	12.5	1.4	15.3	15.8	2.4	1.6	4.7
Ol	0.0	0.0	4.4	0.0	0.6	0.1	0.0	0.0	0.0
Mt	2.5	2.7	3.9	1.2	2.8	2.9	1.1	1.2	2.3
Hm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Il	2.5	0.6	1.7	0.5	1.2	1.2	1.2	0.5	1.4
Ap	0.6	0.2	0.3	0.2	0.3	0.3	0.3	0.2	0.4
Cl	23.0	6.2	42.3	3.1	33.2	33.3	4.6	3.3	8.4
An	29.1	10.4	48.6	7.9	54.5	54.3	28.1	8.1	13.1

Appendix 2, Table 12 (continued)

	16 ma232d tro.	17 ma232e tro.	18 am234a rhy.	19 ma235a and.	20 ma238a rhy.	21 ma240a rhy.	22 ma242a rhy.	23 ma245a rhy.	24 ma246c and.
SiO2	78.1	69.8	71.2	62.9	72.2	74.5	71.5	70.0	62.4
Al2O3	11.3	14.9	12.7	13.5	12.6	12.1	12.3	12.9	13.4
Fe2O3	0.90	0.45	2.76	2.84	2.47	2.48	3.50	2.54	2.72
FeO	0.91	0.91	1.66	4.57	1.75	1.33	2.24	2.49	6.07
MgO	0.46	1.17	0.63	1.71	0.50	0.33	0.65	0.81	1.61
MnO	0.01	0.07	0.05	0.16	0.04	0.05	0.03	0.07	0.18
CaO	0.32	1.76	1.05	4.52	1.01	0.93	0.92	0.64	2.98
Na2O	6.04	6.25	4.19	4.80	4.41	4.89	4.60	3.79	4.45
K2O	0.21	1.43	3.92	1.84	3.11	1.72	2.13	4.40	2.61
TiO2	0.12	0.40	0.56	1.43	0.43	0.28	0.58	0.62	1.29
P2O5	0.05	0.10	0.16	0.48	0.12	0.05	0.14	0.19	0.42
S	0.01	0.01	0.01	0.05	0.01	0.0	0.03	0.01	0.01
CO2	0.08	1.92	0.35	0.14	0.08	0.19	0.10	0.04	0.35
H2O+	0.0	0.16	0.18	0.38	0.0	0.0	0.02	0.10	0.49
H2O-	0.43	0.43	0.39	0.30	0.42	0.29	0.32	0.36	0.34
Total	98.9	99.8	99.8	99.6	99.2	99.1	99.1	99.0	99.3
Ba	40	80	550	200	480	370	500	660	440
Be	3	2	3	4	5	4	4	5	3
Co	BD	BD	BD	15	BD	BD	BD	7	6
Cr	BD	BD	6	8	BD	BD	BD	8	5
Cu	BD	BD	10	25	BD	BD	BD	BD	BD
Ga	15	15	15	15	20	20	20	20	20
Li	BD	3	4	5	6	3	5	8	10
Ni	BD	BD	BD	BD	BD	BD	BD	BD	BD
Pb	BD	BD	BD	BD	BD	BD	BD	BD	BD
Sc	BD	5	7	20	5	5	10	10	15
Sr	60	60	40	300	40	100	40	40	300
V	BD	15	20	100	25	BD	20	35	35
Y	80	30	100	100	100	100	100	100	90
Zn	8	6	50	80	35	15	15	105	165
Zr	250	200	450	700	600	900	800	800	600
Qz	41.2	23.0	28.7	17.6	31.7	36.8	32.8	28.3	16.7
C	0.7	0.1	0.0	0.0	0.4	0.6	1.1	1.2	0.0
Or	1.3	8.7	23.5	11.0	18.7	10.3	12.8	26.4	15.7
Ab	51.9	54.4	35.9	41.1	37.8	42.0	39.5	32.6	38.4
An	1.3	8.3	4.2	10.0	4.3	4.3	3.7	2.0	9.0
Ne	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Di	0.0	0.0	0.0	7.9	0.0	0.0	0.0	0.0	2.7
Hy	1.9	3.7	3.2	4.3	3.1	2.6	5.4	4.7	9.9
Ol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mt	1.3	0.7	3.0	4.2	2.8	2.6	3.1	3.1	4.0
Hm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Al	0.2	0.8	1.1	2.8	0.8	0.5	1.1	1.2	2.5
Ap	0.1	0.2	0.4	1.1	0.3	0.1	0.3	0.4	1.0
Cl	3.5	5.2	7.3	19.0	6.8	5.8	9.6	9.0	19.1
An	2.4	13.2	10.5	19.5	10.2	9.3	8.6	5.8	19.0

Appendix 2, Table 12 (continued)

	25 ma247a and.	26 ma248a bas.	27 ma252a vel.	DUP ma252a vel.	28 ma253a grn.	29 ma258d tro.	30 ma262b rhy(A)	31 ma263a and.	32 ma270a rhy(A)
SiO ₂	58.4	50.0	68.2	67.6	75.7	72.3	75.7	58.2	57.0
Al ₂ O ₃	13.4	17.1	12.5	12.6	12.9	13.5	12.5	13.1	17.1
Fe ₂ O ₃	2.99	4.97	2.59	2.57	0.67	3.28	1.86	6.47	5.64
FeO	4.82	6.15	1.50	1.50	0.66	1.75	0.80	6.15	1.58
MgO	2.52	3.87	2.72	2.75	0.20	0.30	0.68	2.57	0.83
MnO	0.21	0.18	0.10	0.10	0.01	0.02	0.09	0.13	0.16
CaO	5.28	8.83	5.16	5.14	0.31	0.50	0.49	3.44	4.06
Na ₂ O	3.94	3.26	4.08	3.99	4.02	5.94	1.74	3.06	5.52
K ₂ O	3.21	1.37	0.82	0.83	3.61	1.03	4.33	2.19	2.97
TiO ₂	0.64	1.80	0.52	0.52	0.17	0.29	0.26	1.84	0.56
P ₂ O ₅	0.19	0.28	0.15	0.15	0.05	0.09	0.06	0.78	0.16
S	0.01	0.01	0.01	0.01	0.01	0.0	0.02	0.02	0.0
CO ₂	3.56	0.05	0.35	0.38	0.09	0.08	0.12	0.16	2.25
H ₂ O+	0.35	0.64	0.12	0.12	0.34	0.17	0.53	0.36	0.24
H ₂ O-	0.31	0.32	0.34	0.33	0.32	0.37	0.32	0.37	0.34
Total	99.4	98.8	99.2	98.6	99.1	99.6	99.5	98.8	98.4
Ba	480	190	170	150	360	220	770	910	660
Be	5	BD	3	3	3	3	4	4	3
Co	10	35	15	10	BD	BD	BD	20	10
Cr	65	35	75	70	7	5	BD	BD	9
Cu	BD	50	20	20	BD	BD	65	10	BD
Ga	15	15	15	15	20	20	20	20	20
Li	15	10	10	10	4	15	15	15	15
Ni	20	15	25	25	BD	BD	BD	BD	BD
Pb	BD	35	15	15	BD	BD	25	BD	20
Sc	15	35	10	10	BD	BD	BD	25	6
Sr	300	1000	400	400	60	30	30	300	300
V	70	400	70	70	BD	10	BD	100	30
Y	70	40	45	45	40	100	100	60	70
Zn	130	260	80	75	10	10	710	125	115
Zr	450	200	250	200	100	900	600	300	300
Qz	10.1	2.9	29.6	29.4	38.2	32.8	47.8	22.1	2.5
C	0.0	0.0	0.0	0.0	2.0	1.9	4.3	1.4	0.0
Or	20.0	8.3	4.9	5.0	21.7	6.2	26.0	13.2	18.4
Ab	35.0	28.2	35.1	34.5	34.6	50.8	14.9	26.4	49.0
An	8.7	28.6	13.6	14.3	1.2	1.9	2.1	12.2	13.8
Ne	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Di	14.4	11.6	8.9	8.4	0.0	0.0	0.0	0.0	5.4
Hy	5.4	8.9	2.8	3.1	0.9	0.9	1.7	9.7	6.2
Ol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mt	4.6	7.4	3.6	3.7	1.0	4.8	2.0	9.6	3.1
Hm	0.0	0.0	0.1	0.1	0.0	0.0	0.5	0.0	0.0
Il	1.3	3.5	1.0	1.0	0.3	0.6	0.5	3.6	1.1
Ap	0.5	0.7	0.4	0.3	0.1	0.2	0.1	1.8	0.4
Cl	25.7	31.3	16.4	16.3	2.2	6.2	4.7	22.8	15.9
An	19.9	50.4	27.9	29.3	3.4	3.6	12.3	31.2	22.0

Appendix 2, Table 12 (continued)

	33 ma270b and(A)	34 ma287a vcl.	35 ma288a alt.	36 ma299b dia.	DUP ma299b dia.	37 ma310a bas.	38 ma312a bas.	39 ma319b bas.	40 ma289 bas.
SiO2	51.1	60.7	46.1	51.4	51.3	49.9	48.1	45.8	49.7
Al2O3	15.5	16.6	7.2	14.4	14.5	15.8	15.8	16.3	14.0
Fe2O3	8.11	1.72	2.86	2.09	2.08	3.10	3.16	8.05	13.0*
FeO	1.33	3.66	8.06	9.47	9.39	5.82	7.06	5.90	ND
MgO	1.30	2.30	22.4	5.04	5.05	7.04	7.98	3.82	6.0
MnO	0.23	0.11	0.21	0.14	0.14	0.15	0.16	0.23	0.22
CaO	8.12	4.21	6.76	7.49	7.49	10.6	10.7	8.62	9.27
Na2O	6.55	4.21	0.24	4.18	4.09	3.31	2.03	3.78	2.97
K2O	0.88	2.68	0.03	0.25	0.26	0.54	1.05	2.11	0.64
TiO2	1.27	0.80	0.76	2.28	2.28	1.19	1.04	2.19	1.37
P2O5	0.28	0.14	0.15	0.36	0.36	0.19	0.17	0.88	0.13
S	0.0	0.01	0.05	0.22	0.22	0.06	0.06	0.01	ND
CO2	4.32	0.85	0.10	1.08	1.08	0.04	0.07	0.43	ND
H2O+	0.13	0.31	3.74	0.30	0.40	0.52	0.35	0.32	ND
H2O-	0.44	0.45	0.46	0.39	0.42	0.32	0.34	0.32	0.55*
Total	99.6	98.7	99.1	99.1	99.1	98.6	98.1	98.8	97.9
Ba	110	220	50	50	50	110	150	260	100
Be	BD	2	BD	BD	BD	BD	BD	4	ND
Co	15	15	90	30	30	30	35	25	7
Cr	75	8	2980	70	70	240	330	8	380
Cu	15	25	30	30	30	45	30	45	4
Ga	15	15	7	15	15	15	15	20	ND
Li	8	15	6	15	15	5	7	20	15
Ni	75	6	780	20	20	65	70	BD	13
Pb	BD	BD	BD	25	25	BD	BD	20	15
Sc	25	10	15	30	30	30	30	20	ND
Sr	300	500	30	80	80	600	100	500	ND
V	200	100	150	350	350	200	250	100	ND
Y	30	35	15	45	50	30	35	70	ND
Zn	200	95	130	350	350	95	95	190	25
Zr	200	150	100	250	250	150	90	250	ND
Qz	0.0	12.7	0.0	1.8	2.1	0.0	0.0	0.0	0.6
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Or	5.5	16.3	0.2	1.5	1.6	3.3	6.4	12.8	3.8
Ab	44.6	36.7	2.1	36.4	35.7	28.7	17.7	23.7	25.1
An	10.9	19.0	19.5	20.4	21.1	27.3	31.8	21.9	23.1
Ne	7.7	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0
Wo	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Di	22.0	1.3	11.8	12.7	12.2	20.4	17.6	11.2	18.1
Hy	0.0	9.5	46.9	18.2	18.4	8.0	14.7	0.0	18.5
Ol	0.0	0.0	10.7	0.0	0.0	5.4	5.9	11.2	0.0
Mt	4.2	2.6	4.4	3.1	3.1	4.0	3.8	5.5	4.2
Hm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Il	2.6	1.6	1.5	1.5	1.6	2.3	2.0	4.3	2.6
Ap	0.7	0.3	0.4	0.9	0.9	0.5	0.4	2.1	0.3
Cl	28.8	14.9	77.7	38.5	38.2	40.1	43.6	34.5	43.4
An	19.6	34.1	90.3	35.9	37.1	48.8	64.2	48.0	47.9

Appendix 2, Table 12 (continued)

	41 ma295b ult.	42 ma302a bas.	43 ma312a bas.	44 ma314 ban.	45 ma322 bas.	46 mm021 rhy.	47 ma038 vcl.	48 mm053 ban.	49 mm064 gab.
SiO2	37.7	48.1	47.9	55.4	50.4	73.1	65.8	55.0	48.6
Al2O3	13.2	17.2	14.7	15.0	16.2	13.5	15.7	18.1	17.7
Fe2O3	23.2*	14.1*	10.8*	10.2*	10.3*	0.88	0.86	1.84	2.46
FeO	ND	ND	ND	ND	ND	2.77	2.70	5.78	7.69
MgO	9.19	2.82	7.82	3.91	4.96	0.31	2.09	3.76	6.98
MnO	0.31	0.26	0.16	0.16	0.13	0.19	0.05	0.07	0.16
CaO	7.08	7.96	10.4	6.68	5.74	1.74	4.91	5.98	11.64
Na2O	1.48	3.75	2.09	3.14	5.12	4.17	4.10	4.66	2.86
K2O	1.31	0.87	0.99	1.26	2.18	3.10	2.69	2.61	0.74
TiO2	3.10	1.95	1.03	1.16	1.45	0.28	0.51	1.69	1.02
P2O5	0.09	0.34	0.14	0.26	0.37	0.00	0.25	0.51	0.10
S	ND	ND	ND	ND	ND	0.01	0.70	0.03	0.04
CO2	ND	ND	ND	ND	ND	ND	ND	ND	ND
H2O+	ND	ND	ND	ND	ND	ND	ND	ND	ND
H2O-	0.43*	0.44*	0.96*	0.72*	0.81*	ND	ND	ND	ND
Total	97.0	97.7	97.1	97.9	97.7				
Ba	250	50	150	250	150	671	713	283	155
Be	ND	ND	ND	ND	ND	ND	ND	ND	ND
Co	39	21	20	18	15	ND	ND	ND	ND
Cr	600	140	420	180	120	9	15	196	104
Cu	7	32	37	100	4	1	47	3	14
Ga	ND	ND	ND	ND	ND	ND	ND	ND	ND
Li	20	10	10	10	10	ND	ND	ND	ND
Ni	95	20	36	36	35	11	16	68	14
Pb	10	5	10	20	5	ND	ND	ND	ND
Sc	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sr	ND	ND	ND	ND	ND	126	295	517	277
V	ND	ND	ND	ND	ND	ND	ND	ND	ND
Y	ND	ND	ND	ND	ND	51	14	33	26
Zn	105	71	28	52	70	25	34	62	109
Zr	ND	ND	ND	ND	ND	826	223	216	58
Qz	0.0	0.0	0.0	10.3	0.0	30.8	18.5	0.0	0.0
C	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Or	7.7	5.1	5.8	7.4	12.9	18.3	15.9	15.4	4.4
Ab	9.2	31.7	17.7	26.6	35.6	35.3	34.7	39.4	23.0
An	25.5	27.4	27.8	23.0	14.8	8.6	16.5	20.7	33.3
Ne	1.8	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.6
Wo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Di	7.4	8.3	18.7	7.0	9.2	0.0	5.1	4.6	19.4
Hy	0.0	11.3	15.3	15.9	0.0	5.0	6.1	10.6	0.0
Ol	29.5	3.2	4.1	0.0	12.5	0.0	0.0	2.1	13.5
Mt	7.6	4.6	3.6	3.3	3.4	1.3	1.2	2.7	3.6
Hm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Il	5.9	3.7	2.0	2.2	2.8	0.5	1.0	3.2	1.9
Ap	0.2	0.8	0.3	0.6	0.9	0.0	0.6	1.2	0.2
Cl	50.4	31.1	43.7	28.4	27.9	6.8	13.4	23.2	38.4
An	73.5	46.4	61.1	46.4	29.6	19.6	32.2	34.4	59.1

Appendix 2, Table 12 (continued)

	DUP mm064 gab.	50 mm079 rhy.(A)	51 mm103 gab.	52 mm105 tro.	53 mm124 bas.
SiO2	49.2	74.2	50.4	74.6	52.2
Al2O3	18.1	13.2	14.2	13.1	16.8
Fe2O3	2.41	0.61	2.34	0.49	2.72
FeO	7.50	1.91	7.30	1.58	8.49
MgO	6.44	0.37	10.2	0.16	3.75
MnO	0.18	0.05	0.16	0.02	0.16
CaO	11.37	0.07	10.9	2.74	7.38
Na2O	2.93	3.11	2.79	6.07	4.02
K2O	0.71	6.09	0.66	0.93	1.84
TiO2	1.05	0.31	0.89	0.24	2.09
P2O5	0.13	0.02	0.11	0.01	0.52
S	0.04	0.01	0.07	0.02	0.02
CO2	ND	ND	ND	ND	ND
H2O+	ND	ND	ND	ND	ND
H2O-	ND	ND	ND	ND	ND
Total					
Ba	141	782	132	216	280
Be	ND	ND	ND	ND	ND
Co	ND	ND	ND	ND	ND
Cr	97	BD	603	8	52
Cu	15	1	33	23	6
Ga	ND	ND	ND	ND	ND
Li	ND	ND	ND	ND	ND
Ni	15	10	87	11	53
Pb	ND	ND	ND	ND	ND
Sc	ND	ND	ND	ND	ND
Sr	267	32	327	94	280
V	ND	ND	ND	ND	ND
Y	24	69	29	105	52
Zn	117	34	126	14	95
Zr	70	737	101	648	226
Qz		31.0	0.0	30.3	0.0
C		1.4	0.0	0.0	0.0
Or		36.0	3.9	5.5	10.9
Ab		26.3	23.6	51.4	34.0
An		0.2	24.4	5.7	22.4
Ne		0.0	0.0	0.0	0.0
Wo		0.0	0.0	0.7	0.0
Di		0.0	23.3	5.3	8.9
Hy		3.5	6.5	0.0	13.3
Ol		0.0	12.8	0.0	1.3
Mt		0.9	3.4	0.7	3.9
Hm		0.0	0.0	0.0	0.0
Il		0.6	1.7	0.5	4.0
Ap		0.0	0.3	0.0	1.2
CL		5.0	47.7	7.2	31.4
An.		1.0	50.8	10.0	39.7

Appendix 2, Table 12 (continued)

	54 mm126 bas.	55 mm130 bas.	56 mm168 tro.	57 mm175 ult.	58 mm176 gab.
SiO ₂	52.3	50.5	70.1	49.1	45.8
Al ₂ O ₃	15.6	12.7	15.0	6.9	21.8
Fe ₂ O ₃	2.95	3.80	0.68	2.97	1.58
FeO	9.10	11.8	2.13	9.26	4.96
MgO	4.23	5.25	1.03	18.4	11.0
MnO	0.17	0.26	0.05	0.31	0.10
CaO	6.50	8.95	2.46	11.3	11.4
Na ₂ O	3.36	3.51	6.52	0.97	1.67
K ₂ O	2.75	0.31	1.35	0.31	1.62
TiO ₂	2.33	2.58	0.52	0.47	0.09
P ₂ O ₅	0.60	0.34	0.12	0.03	0.01
S	0.02	0.01	0.05	0.02	0.02
CO ₂	ND	ND	ND	ND	ND
H ₂ O+	ND	ND	ND	ND	ND
H ₂ O-	ND	ND	ND	ND	ND
Total					
Ba	357	159	242	89	89
Be	ND	ND	ND	ND	ND
Co	ND	ND	ND	ND	ND
Cr	53	37	3	1417	100
Cu	1	51	3	10	5
Ga	ND	ND	ND	ND	ND
Li	ND	ND	ND	ND	ND
Ni	52	31	15	370	216
Pb	ND	ND	ND	ND	ND
Sc	ND	ND	ND	ND	ND
Sr	219	131	171	22	674
V	ND	ND	ND	ND	ND
Y	64	65	60	20	4
Zn	81	160	24	119	47
Zr	301	249	495	34	10
Qz	0.7	1.4	20.2	0.0	0.0
C	0.0	0.0	0.0	0.0	0.0
Or	16.2	1.8	8.0	1.8	9.6
Ab	28.4	29.7	55.2	8.2	6.3
An	19.3	17.9	7.7	13.5	47.2
Ne	0.0	0.0	0.0	0.0	4.2
Wo	0.0	0.0	0.0	0.0	0.0
Di	7.5	20.2	3.1	33.8	7.6
Hy	17.7	17.8	3.5	20.3	0.0
Ol	0.0	0.0	0.0	17.0	22.5
Mt	4.3	5.5	1.0	4.3	2.3
Hm	0.0	0.0	0.0	0.0	0.0
Il	4.4	4.9	1.0	0.9	0.2
Ap	1.4	0.8	0.3	0.0	0.0
Cl	33.9	48.5	8.6	76.3	32.6
An.	40.5	37.6	12.2	62.2	88.2

Appendix 2, Table 13

Pair No.	1		2		3		4	
Analysis No.	12	Dup.	27	Dup.	36	Dup.	38	43
<u>Oxide Wt. %</u>								
SiO ₂	51.8	52.0	68.2	67.6	51.4	51.3	48.1	47.9
Al ₂ O ₃	18.3	18.3	12.5	12.5	14.4	14.5	15.8	14.7
Fe ₂ O ₃	1.91	1.99	2.59	2.57	2.09	2.08	3.16	10.8*
FeO	4.99	4.90	1.50	1.50	9.47	9.39	7.06	ND
MgO	6.34	6.37	2.72	2.75	5.04	5.05	7.98	7.82
MnO	0.11	0.11	0.10	0.10	0.14	0.14	0.16	0.16
CaO	10.1	10.1	5.16	5.14	7.49	7.49	10.7	10.4
Na ₂ O	3.27	3.28	4.08	3.99	4.18	4.09	2.03	2.09
K ₂ O	0.75	0.76	0.82	0.83	0.25	0.26	1.05	0.99
TiO ₂	0.60	0.60	0.52	0.52	2.28	2.28	1.04	1.03
P ₂ O ₅	0.12	0.13	0.15	0.14	0.36	0.36	0.17	0.14
S	0.10	0.10	0.01	0.01	0.22	0.22	0.06	ND
CO ₂	0.12	0.12	0.35	0.38	1.08	1.08	0.07	ND
H ₂ O+	0.46	0.46	0.12	0.12	0.30	0.40	0.35	ND
H ₂ O-	0.43	0.41	0.34	0.33	0.39	0.42	0.34	0.96*
Total	99.4	99.6	99.2	98.6	99.1	99.1	98.1	97.1
<u>Traces</u>								
Ba	150	140	170	150	50	50	150	150
Be	BD	BD	3	3	BD	BD	BD	ND
Co	25	25	15	10	30	30	35	20
Cr	60	60	75	70	70	70	330	420
Cu	30	30	20	20	30	30	30	37
Ga	15	15	15	15	15	15	15	ND
Li	6	6	10	10	15	15	7	10
Ni	55	55	25	25	20	20	70	36
Pb	BD	BD	15	15	25	25	BD	10
Sc	25	25	10	10	30	30	30	ND
Sr	1000	1000	400	400	80	80	100	ND
V	150	150	70	70	350	350	250	ND
Y	20	20	45	45	45	50	35	ND
Zn	55	55	80	75	350	350	95	28
Zr	80	80	250	200	250	250	90	ND

MAZINAW

10

12, 13

35

10

9

9

Highway

41

10

14, 15

41

10

BON ECHO
LAKE

10

3 of

GEO

GEOLOGY OF THE MAZINA SOUTHEASTERN ON

MINAW LAKE AREA

FIG

ONTARIO

FIGURE 3

LEGEND

PRECAMBRIAN

GRENVILLE SUPERGROUP AND ASSOCIATED PLUTONIC ROCKS (HELIKIAN)

METAMORPHOSED INTRUSIVE ROCKS

11

MAFIC DYKES AND SILLS: Metadiabase, fine to medium-grained amphibolite, locally porphyritic.

10

GRANITOID GROUP: Gneissic granite,
IQa HYBRID GROUP: Granitoid intrusive breccias with numerous metavolcanic xenoliths

9

DIORITE AND GABBRO: Medium-grained, moderately foliated biotite-hornblende plagioclase and plagioclase-hornblende gneiss respectively

8

ULTRAMAFIC GROUP: Medium-grained, moderately foliated amphibole-rich rocks.

INTRUSIVE CONTACT

METAMORPHOSED SEDIMENTARY ROCKS

7

GREYWACKE: Fine-grained and well-laminated schists and psammites, locally tourmaline bearing

6

MARBLE: 6a CALCAREOUS, 6b DOLOMITIC

5

VOLCANICLASTIC SEDIMENTS: Intermediate to felsic, fine-grained and strongly laminated schists, intercalated with metavolcanics

METAMORPHOSED VOLCANIC ROCKS

4

RHYOLITE: Fine-grained, felsic, muscovite-feldspar-quartz schists, commonly quartz-feldspar porphyritic, locally fragmental.

3

ANDESITE: Fine-grained, hornblende-biotite-quartz-feldspar schists, commonly felsic porphyritic, locally fragmental.

2

BASALTIC ANDESITE: Fine-grained, biotite-hornblende-plagioclase schists, locally plagioclase porphyritic, amygduloidal and fragmental.

1

BASALT: 1a Fine-grained amphibolites and hornblende schists, predominantly flows

1b Fine-grained, biotite-rich amphibolites, commonly plagioclase porphyritic flows and pyroclastics.

1c Fine-grained, biotite-rich amphibolites, tuffs and flows, intercalated with numerous horizons of felsic to intermediate tuff.

Compiled by J.A. Ayer, 1978. Geology by J.A. Ayer, R.L. Morton & J.M. Moore.

Base map compiled from Ont. Min. of Nat. Res., E.R.I. map nos. 448772, 448771, 448770, 447771.

PLUTONIC

S

locally

xenoliths

blende

rocks.

KS

tourmaline -

ly laminated

quartz and

feldspar

locally

flows

pyritous

ated with

M. Moore, 1976 & 1977.

448771, 447772 &

90F

SKOOTAMATTA
LAKE

NORWAY LAKE

SYMBOLS

Area of bedrock outcrop

Small bedrock outcrop, area of small outcrops

Swamp covered area

Bedding, flow and tuff contacts, top unknown, (inclined, vertical)

Top direction indicated by arrow, (inclined, overturned)

Schistosity, foliation (inclined, vertical)

Lineation of elongate minerals or mineral aggregates

Minor fold axis

Geological boundary, observed

Geological boundary, interpreted

Fault, assumed

Minor fold axial surface (strike and dip), trend of fold axis (with plunge). Shape indicates vergence sense (indeterminate, dextral ('Z'), sinistral ('S')).

Axial surface trace of megascopic folds (antiform, synform)

Volcanic breccia, intrusive breccia

● 23, 24

Geochemical sample(s) location, numbers correspond to the tabulated analyses in the appendix.

Cu, Zn

Abandoned workings, (shaft and/or test pit), mineral occurrence.

140F14

END

06 03 80

FIN

LEGEND

TUDOR FORMATION

▲ BASALT

◆ average of 22 basalts from outside
map-area (Table 9, L)

MAZINAW LAKE FORMATION

○ RHYOLITE

□ ANDESITE

▽ BASALTIC-ANDESITE

△ BASALT

● average gabbro (4 analyses, Table 9, G)

■ average diorite (2 analyses, Table 9, H)