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Ontario Geological Survey
Open File Report 5537

Geology of Belmont, Marmora and Southern Methuen Townships Peterborough and Hastings Counties

1985

ONTARIO GEOLOGICAL SURVEY

Open File Report 5537

Geology of Belmont, Marmora, and Southern Methuen Townships, Peterborough and Hastings Counties

by

J.R. Bartlett and J.M. Moore, Jr.

1985

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V.G. Milne, Director
Ontario Geological Survey

FORWORD

Belmont-Marmora and Southern Methuen Townships

Until 1980 the geological map coverage of the Belmont-Marmora area was at a reconnaissance level. The present detailed mapping project was designed to encourage mineral exploration interests, to provide a mineral potential evaluation and to attempt to establish a detailed lithostratigraphic subdivision of the Grenville Supergroup of the area.

The work reported here was equally funded by the Federal Department of Regional Economic Expansion and the Ontario Ministry of Natural Resources under the Mineral Program of the Eastern Ontario Subsidiary Agreement.

The Precambrian bedrock of the Belmont-Marmora area hosts several metallic and non-metallic mineral deposits. The metallic commodities known to occur are copper, gold, iron, nickel, silver, and zinc. Non-metallic deposits include metabasalt, felsic intrusive rocks, and marble. Paleozoic limestone has been evaluated as a potential high-calcium carbonate deposit.

V.G. Milne

Director

Ontario Geological Survey

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ABSTRACT

Middle Proterozoic rocks in the area comprise metavolcanic and metasedimentary units of the Grenville Supergroup, which have been deformed, and metamorphosed and intruded by plutons ranging in composition from peridotite and gabbro to alkali-feldspar granite and syenite. In Belmont and southern Methuen Townships the succession is mainly of volcanic rocks, including submarine and subaerial basalt; andesite; and dacite to rhyolite pyroclastics and epiclastics. It results from four depositional cycles, each terminated by siliceous clastic, carbonate and/or volcanic-exhalative sedimentation. These rock units extend into northern Marmora Township, but much of that township is underlain by thin-

layered, mixed clastic and carbonate rocks representing marine sedimentation adjacent to a volcanic arc. Major plutons include the Cordova Gabbro, Gawley Creek Syenite and Deloro Granite. These plutons were emplaced at high levels in the crust and created contact aureoles that contain numerous skarn deposits.

At least two phases of regional deformation occurred, accompanied by metamorphism. Metamorphic grade rises westerly from greenschist facies in Marmora Township to mid- to upper-amphibolite facies in southern Methuen Township. Although the plutons are little deformed, they are partly to totally recrystallized and thus were present during the latest metamorphism. Metallic mineral occurrences of interest comprise stratiform base and precious metal deposits in volcanic-exhalative sediments; magnetite ironstones; magmatic Cu-Ni sulphides, contact skarns bearing magnetite and sulphides; precious-metal vein systems in hydrothermally altered rocks in the margins of granitic plutons; and late, probably syn-metamorphic auriferous veins in metagabbro. Industrial minerals include high-purity calcitic and dolomitic marble; granite dimension stone; trap rock and limestone aggregate.

The region has a long history of mineral exploration and development, and potential for future production.

Geology of
Belmont, Marmora, and Southern Methuen Townships, Peterborough and Hastings Counties

by

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This report was approved for publication by John Wood, Chief Geologist, Ontario Geological Survey, February 22, 1985.

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LOCATION MAP

Scale: 1: 1 584 000
or 1 inch to 25 miles

Figure 1. Key map of Belmont, Marmora, and Southern Methuen Townships.

INTRODUCTION

Belmont, Marmora and southern Methuen Townships of southeastern Ontario are underlain by a diversity of Precambrian and Paleozoic rocks. Many mineral occurrences are known, and the region has a history of exploration and production spanning over 150 years. Although it was until recently the site of one of the few producers in southern Ontario - the Marmoraton open pit iron mine - the area had not undergone systematic geological mapping since 1925.

Field work and much of the laboratory investigations were performed during 1980-1982 under contract equally funded by the Federal Department of Regional Economic Expansion and the Ontario Ministry of Natural Resources under the Minerals Program of the Eastern Ontario Subsidiary Agreement. The investigations formed the basis for the present report and an M.Sc. thesis by the senior author, at Carleton University, Ottawa. Therefore, much of the information inthis report is also included in the thesis (Bartlett, 1983). Some scientific information beyond the scope of this geological report is not presented here and to obtain it the reader is referred to Bartlett (1983). On the basis of additional data collected by the authors, parts of the thesis (Bartlett, 1983) have been improved upon, and are reported in this work. The reader is also advised that reference to the thesis is made only in some instances in the following.

Belmont Township was mapped in 1980, together with part of southern Methuen Township to enable correlation of the present work with previous studies by Hewitt (1960). In 1981 the field work continued with the mapping of Marmora Township. Subsequent independent mapping was carried out by the authors, mainly in Belmont Township, until the fall of 1983; the results of some of this work are reported herein.

Precambrian geology was the object of the present study; Paleozoic rocks have been mapped independently (Carson 1979), and were examined mainly near their contacts with the Precambrian basement.

Location and Access

The map-area lies halfway between Toronto and Ottawa. Highway 7 crosses the southern part, passing through the towns of Havelock and Marmora. County roads 44, 46 and 48 (Belmont) and 3 and 11 (Marmora) provide year-round access to the central and northparts, including the smaller centres of Cordova Mines and Deloro. In addition there are numerous, gravel-surfaced, township, concession, fire access, private farm and cottage roads which together provide excellent access to all of the area except the northeast part of Marmora Township. Lakeshores throughout the area, and an abandoned C.N.R. right-of-way in Marmora Township provide additional access; Beaver Creek and the Moira River are partly navigable by canoe or small outboard motor boat.

Mining and Exploration Activity

The history of mineral exploration and production in the map-area dates from 1820, when the Marmora Iron Works were established to treat iron ore from the nearby Blairton Mine (Miller and Knight, 1914). During the 1860s gold was the main target of exploration, with activity concentrated on the periphery of the Deloro Granite. Exploratory work increased in the next decade, and several mines went into production; recovery was small by today's standards. Minor silver production accompanied that of gold in the 1890s. The period around the turn of the century saw the greatest flurry of exploration and production, centred on the Deloro mining camp. Indigenous arsenic was produced from the 1880s to 1904; for the following ten years arsenic ores from Cobalt were processed at Deloro (Miller and Knight, 1914). Small deposits of iron and gold associated with the Cordova Gabbro were worked around the turn of the century; however, during the 1920s the search for gold waned; only sporadic exploration has occurred since then, with no notable production. The decline in gold exploration was coincident with an increasing interest in iron and copper-nickel, but, though exploration for these metals continued from the 1920s through the 1940s, no production ensued.

Although other areas in eastern Ontario hosted marble quarries prior to 1890 (Royal Commission Report, 1890), quarries in the map area were not established until the 1930s. Sporadic quarrying of relatively pure calcitic marble occurred near the Deloro Granite during the 1930s and 1940s, and peaked in the 1960s and early 1970s.

Base metals exploration was most intense during the 1950s. One of the first practical applications of aeromagnetics to mineral exploration resulted in the discovery, in the early 1950s, of the Marmoraton Iron Mine; high grade magnetite ore was extracted by open pit mining from 1955 to 1978.

In recent decades exploration activity has been directed toward base metals in volcanogenic sedimentary rocks, gold-bearing quartz veins in the Cordova Gabbro and several high-purity marble occurrences. Lasir Gold Incorporated and Minetek were, at the time of writing, experimenting with the recovery of gold from waste materials at the Cordova Mine in Belmont Township.

Granite has recently been quarried in northwestern Belmont Township. 3M Canada Ltd. presently operates a quarry for the production of roofing granules from metabasalt near Havelock.

Limestone aggregate from the waste piles of the Marmoraton Mine is currently being crushed and shipped by Armbro Limited.

Previous Geological Investigations

Parts of the area were examined in the nineteenth century by Logan, Murray and others of the Geological Survey of Canada. The state of knowledge to 1907 was summarized by Miller and Knight (1914) in their regional treatise on southeastern Ontario, which includes a 1:15,840 map of central Belmont Township. Much of the present area was mapped at 1:63,360 by M.E. Wilson during 1920-25 (Wilson, 1940) and also included in the Haliburton - Bancroft (1:126,760) compilation sheet of Hewitt and Satterly (1957); Methuen Township was later re-mapped by Hewitt (1960) at 1:31,680. More detailed maps are available for parts of northern Belmont and southern Methuen Townships (Heidecker 1963, Beavon, unpublished manuscript, 1967). Lumbers (1964) included much of the area in a compilation illustrating the distribution of mineral occurrences in relation to metamorphic grade. A mineral potential map of the region was compiled by Springer (1978). Paleozoic rocks in the area were mapped at 1:31,780 by Carson (1979).

The evolution of thought concerning the regional stratigraphy has been summarized by Moore and Thompson (1980). The volcanic rocks, termed "Keewatin" by early workers, are now assigned, along with most of the sedimentary units, to the Grenville Supergroup. The conglomerates cropping out mainly on the islands and shores of Belmont Lake have provoked considerable controversy, having been assigned by some geologists to the "Hastings Series" (believed by Miller and Knight (1914) to postdate most of the stratified rocks in the area) and to the Grenville "Series" (now Supergroup) by others. Moore and Thompson (1980) suggested correlation of these conglomerates with the Flinton Group, which unconformably overlies Grenville Supergroup rocks to the east of the map area. Evidence from the present mapping (see below) does not unequivocally confirm or preclude this view. However one of the authors (Bartlett, 1983) proposed that, rather than a major structural unconformity, one or more intraformational erosional unconformities separate the conglomerates from underlying rocks, thus establishing them as part of the Grenville Supergroup. Geochronological work in progress by the authors and D.W. Davis of the Royal Ontario Museum should resolve this issue.

The Deloro Granite in Marmora Township has been studied by Saha (1959), Wilson (1965) and Kuehnbaum (1973). The Cordova Gabbro is the subject of a current study by P.B. Thomas (M.Sc. in progress, University of Ottawa). Pilon (1981) studied some conglomerates at Belmont Lake. Bourque (1981, 1982) mapped in detail some carbonate rocks and associated stromatolites in Belmont and Marmora Townships in an attempt to determine paleoenvironment. Murray (1982) synthesized structural and metamorphic data of Belmont and southern Methuen Townships. Hulme (1982) studied some metabasalts in eastern Belmont Township.

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Assistance in drafting of figures for the final version of this report was provided by D. Hoffer. P. Chevalier assisted with the final compilation of properties and mineral deposits.

Regional Geology

The study area lies near the southwestern edge of the Central Metasedimentary Belt of the Grenville Province (Wynne-Edwards, 1972). The general region, termed the "Hastings Basin"[2] by Hewitt (1956) has been considered by Wynne-Edwards (1972) to contain the thickest succession of supracrustal rocks in the Grenville Province. The stratified rocks of the Central Metasedimentary Belt, collectively referred to as the Grenville Supergroup (Moore and Thompson, 1972; Wynne-Edwards, 1972), are mainly marbles, clastic metasediments (schists and/or gneisses in areas of higher grade metamorphism), and metavolcanics (typically amphibolites). These rocks are intruded by plutons of varied composition. The Grenville Supergroup is overlain unconformably by the Flinton Group, comprising clastic and carbonate metasediments (Moore and Thompson, 1980). Figure 2 illustrates the distribution of major rock types in the vicinity of the study area.

The rocks were deposited/emplaced, deformed and metamorphosed in Middle Proterozoic time, in the interval circa 1300-1050 Ma (Lumbers, 1964, 1967; Moore and Thompson, 1980).

Lumbers (1967) divided layered rocks of the Hastings region into two conformable groups, the predominantly metasedimentary Mayo group and the underlying, predominantly metavolcanic Hermon group. The Hermon group was considered by Lumbers (1967) to be concentrated in the eastern part of the Hastings region, around the Weslemkoon and Elzevir plutons. The present work by the

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[2] The geographic term "Hastings Basin" is used here for its historic value. Lumbers (1964) points out that the only feature of the region suggestive of a basin is the distribution of the metamorphic zones; that the Hastings Basin is not of basin shape with respect to structure, stratigraphy or topography. It is suggested here that the geographic term "Hastings Basin" be discontinued; "Hastings region" is preferred.

authors in Belmont, Marmora and southern Methuen Townships supports Lumbers' (1967) contention that some metavolcanic rocks of those townships are probably correlative with the Tudor formation of the Hermon group.

The Hastings Metamorphic "Low", centred around Millbridge (about 35 km northwest of Havelock; see Carmichael et al., 1978,, Figure 2), contains rocks of the lowest metamorphic grade in the Grenville Province. Metamorphic grade increases northwesterly from garnet-muscovite-chlorite zone (middle greenschist facies) to biotite-sillimanite-K-feldspar zone (upper amphibolite facies) southwest of Bancroft, and southeasterly to cordierite-hypersthene-K-feldspar zone (upper granulite facies) near Ganonoque.. Carmichael et al. (1978) suggest that most of the study area is within greenschist facies and that grade increases to middle amphibolite facies in northwest Belmont and southern Methuen Townships. A detailed treatment of the metamorphism of the rocks of the study area is presented in a later section (see Metamorphism).

The southwestern boundary of the Grenville Province is marked by the contact with Middle Ordovician sedimentary rocks, mainly limestone. These rocks cover much of the southwest half of Belmont Township and southern part of Marmora Township, and occur as outliers throughout the remainder of the study area.

GEOLOGY OF BELMONT, MARMORA AND SOUTHERN METHUEN TOWNSHIPS

Introduction

Metamorphosed Precambrian rocks occupy most of the northern and eastern parts of the map area; the contact with Ordovician sedimentary rocks is sinuous from southeast Marmora Township to southwest Methuen Township. Outliers of the Paleozoic rocks occur throughout the area.

Map (in back pocket) illustrates the distribution of lithologic units in the study area.

Although there is geologic continuity between Belmont and Marmora townships, there are differences between them in predominant lithology. Belmont and southern Methuen Townships are underlain mainly by metamorphosed volcanic and volcanogenic sedimentary rocks; Marmora Township by carbonate-rich metasediments. Areally significant plutons, ranging in composition from gabbro to granite, occur throughout the study area, and are most abundant in Marmora Township, accounting for many of the mineral occurrences there. In contrast, metal occurrences in Belmont Township are mainly volcanogenic.

The Precambrian stratified rocks of Belmont Township constitute the Belmont Lake Metavolcanic Complex, defined by Bartlett (1983). Rocks in southern Methuen and Marmora Townships are, in general, contiguous with those in Belmont Township; thus the Belmont Lake Metavolcanic Complex could be considered to extend into areas outside of Belmont Township. Extension of the complex into southern Methuen and Marmora Townships is addressed, albeit informally, in this report.

Within Belmont Township the complex comprises four mafic to felsic volcanic cycles. Sedimentary units are generally concentrated at or toward the top of each cycle, and are considered to be a part of the cycle they overlie or are intercalated with. Each cycle contains one or more formations as defined by Bartlett (1983); these will be described in the Lithologic Descriptions section.

Throughout this report emphasis will be on the geology of Belmont Township, as it received the majority of investigative attention and is thus best understood.

Structural Geology

The map area is considered here to consist of three structural domains, as illustrated in Figure 3. The boundary between the western and central domains is transitional, whereas that separating the central and eastern domains represents a major structural break.

In the central domain the rocks constitute an upright, moderately dipping, east-facing homocline. The north-trending regional planar fabric (S_1), expressed by orientation of micas and amphiboles, is subparallel to bedding, volcanic flow and lithological contacts (S_o).

The western domain is characterized by open to close macroscopic folds with near-vertical, east- to northeast-trending axial planes. In places a weak schistosity (S_2) is evident. The amplitude of map-scale D_2 folds increases westerly and northerly, paralleling an increase in metamorphic grade. D_2 folds generally plunge east-northeasterly; the only major reversal occurs at Oak Lake where a doubly-plunging fold describes a dome structure.

An assumed major fault separates the central and eastern domains (Figure 3). As in the central domain, S_i fabric in the eastern domain is close to S_o orientation, except where it parallels the axial surface of small tight to isoclinal D_1 folds; no megascopic D_1 folds are present in the map area. S_o and S_1 were refolded by D_2, which resulted in a locally strong S_2 fabric, axial planar to D_2 folds. Locally, as for example north of the Cordova Gabbro and east of Cordova Lake, S_1 is crenulated and deformed into open to tight D_2 folds. Map-scale D_2 folds in Marmora Township are open to close, with northeasterly striking axial surfaces; these are particularly evident along the northeast margin of the Cordova Gabbro.

An east-northeast-trending, moderately to steeply plunging lineation (L_1) is prominent in all domains within Belmont Township; it is defined by S_o/S_1 intersection, stretching of primary features, and mineral/mineral aggregate elongation. Outside of Belmont Township the orientation of L_1 is variable, due to D_2 folding.

No major faults could be mapped directly; one contact, however, is almost certainly a syn- to post-D_1 fault, based on the truncation of rock units along its eastern side. This surface, shown on Figure 3 as the boundary between the central and eastern structural domains, separates mafic metavolcanic rocks to the west from carbonate and clastic metasedimentary rocks, with minor metavolcanics, to the east. Non-bifurcating from south of Belmont Lake northward along the Crowe River to Cordova Lake, the fault appears to branch out into several splays in the Cordova Lake area. The main fault may connect with a major early structural discontinuity in Lake Township (Laakso, 1968). The possible splays extending into Marmora Township generally represent complex truncations of map units; striking subparallel to D_2 axial traces, these may be of a later generation than the main fault in Belmont Township. The main fault is discussed further in later sections describing the Vansickle, Marmora and Belmont Lake formations. The contact between marbles and mafic metavolcanics immediately east of Belmont Lake may be a fault, based on disharmony of structures across the contact.

Numerous outcrop-scale and smaller faults are present throughout the map area, as, for example, on Birch Island and Crowe River Point, Belmont Lake, where northeast-striking faults of at least a few metres displacement separate clastic metasedimentary rocks from siliceous dolomitic marble.

Fracture systems with northerly trend appear to control auriferous quartz veins and minor intrusions around the west contact of the Deloro Granite (see Map); a later joint set in the same pluton strikes east-southeast and contains both metamorphosed amphibolite dikes (along Highway 7) and post-metamorphic barite-fluorite veins. North- to east-trending shear zones in the Cordova Gabbro (see map) host gold-bearing quartz (± ankerite) veins (Thomas and Cherry, 1981).

The structural geometry of Precambrian rocks of the map area can thus be explained, for the most part, in terms of two, possibly three phases of deformation. The first phase (D_1) resulted in transposition of primary planar features, and development of pervasive schistosity subparallel to the north-striking, east-dipping axial plane of a tight to isoclinal fold having a wavelength of at least 50 km (Bartlett, 1983). During the second phase of deformation (D_2) these structures were refolded, with large variations in amplitude, about east- to northeast-trending axial planes. D_1 and D_2 structures were warped by open folds with northwest-trending axial traces. This phase could be a late stage of D_2, representing the time when northwest-southeast compression, which formed the D_2 structures, resulted in differential strain around the major plutons (Figure 2). The large variation in magnitude of D_2 strain across the map-area must be accommodated by flow in ductile units such as marble and/or slippage along major lithologic contacts.

Stratigraphy

The homoclinal arrangement of the volcanic-sedimentary succession in Belmont Township simplifies stratigraphic interpretation; only in the area north and east of Cordova Lake, where D_2 folds complicate the map pattern, is the stratigraphic order uncertain.

Many localities throughout Belmont Township yielded reliable information on stratigraphic top direction, based on pillow orientation, amygdule and flow breccia distribution in lavas, and grain gradation, cross-bedding, scour-and fill, and load structures in clastic rocks. The majority of these localities are concentrated in the Belmont Lake area where rocks have undergone minor recrystallization. Commensurate with an increase in metamorphic grade, top indicators are less abundant north and west of Belmont Lake. Except in areas where complex D_2 folding has produced local reversals in stratigraphy, all reliable primary facing criteria indicate that the succession is east-facing.

Stratigraphic facing data are lacking in southern Methuen Township, however extrapolation of rock units from northern Belmont Township suggests that the structurally lowest rocks in the Oak Lake area are also lowest stratigraphically.

Evidence of primary stratigraphic facing in Marmora Township is provided by graded bedding and load casts, mainly in interlayered carbonate and siliceous metasediments, and by pillow shape in metabasalts near the eastern township boundary. On these limited data the succession in northern Marmora Township "youngs" from north to south, in the order, mafic metavolcanics - siliceous clastic metasediments - carbonate metasediments.

The regional stratigraphic scheme proposed by Lumbers (1967) for rocks of the Bancroft-Madoc area is generally inapplicable to rocks of the present map-area. Instead of employing a type section based on primary facing data he constructed an hypothetical section based solely on major lithologic characteristics. Difficulties arise in trying to equate observed stratigraphy with this hypothetical section; thus a more practical stratigraphic scheme is required. The authors recommend that Lumbers' (1967) group and formation names be retained on grounds of precedent, but that they be re-defined to correspond to observed stratigraphy.

Bartlett (1983) assigned formation names to rock units in Belmont Township (see Figure 4) to facilitate greater ease in describing the lithology and to serve as a basis for correlating rocks of neighbouring areas with those of Belmont Township. In this report the authors have extrapolated Bartlett's (1983) formations to southern Methuen and Marmora Townships; this extrapolation, though tentative, has required re-definition of stratigraphic units employed by Hewitt (1960) and Laakso (1968). Bartlett's (1983) stratigraphic designations remain informal at the time of writing; the authors intend to formalize the stratigraphy in a future publication.

LITHOLOGIC DESCRIPTIONS

PROTEROZOIC ROCKS

Metamorphosed Volcanic and Sedimentary Rocks

The succeeding lithologic descriptions (see also Bartlett, 1983), begin with the structurally and presumed stratigraphically lowest rocks in the map area, in the Oak Lake antiform of Methuen Township, and proceed up-section to the youngest rock units, west of Crowe Lake. Meta-plutonic rocks are described after the stratified rocks.

Kosh Lake Beds

Within the map area the Kosh Lake beds, as defined by Hewitt (1960), occupy the centre of the Oak Lake antiform; they also occur immediately north of the map-area, along the south and east margins of the Methuen Granite body. Hewitt (1960) described the Kosh Lake beds as "epidotized amphibolite, paragneiss, feldspathic schist, and pink arkose"; the present authors consider the predominant lithology in the Oak Lake area to be medium-grained intermediate (colour index (CI) = 10-35) hornblende-biotite-plagioclase schist of volcanic origin. These rocks locally contain prominent spheroidal clots and lenticles, rich in garnet and epidote, from a few centimetres to a metre across.

Big Island Beds

Hewitt's (1960) placement of the contact between the Kosh Lake beds and the overlying Big Island beds is ambiguous. The inference from Hewitt's (1960) text is that these rocks are restricted to Big Island in Oak Lake; however, as he described the Big Island beds as being "interbedded schist and limestone", this rock unit would appear to crop out east of Oak Lake as well. The lower part of the Big Island beds consists of rocks essentially similar to those of the Kosh Lake beds, however they contain layers, tens of metres thick, of calcite marble and calcareous wacke. The upper part, exposed on the west side of Big Island, on the islands in the south part of Oak Lake and on the southeast shore of the lake, consists mainly of pyritic and garnetiferous mica schists, interpreted by the authors to be mudstones[3].

Oak Lake Formation

Hewitt (1960) defined the Oak Lake formation in Methuen Township; named for the excellent exposures around the shores of Oak Lake, the formation within that township consists of about 1500 m of "pink arkose, pink and grey quartzite and some interbeds of amphibolite schist and greenstone schist". The Oak Lake formation, as defined by Hewitt (1960) extends into Belmont Township, where its maximum exposed thickness is greater than

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[3] All Precambrian rocks of the map area are metamorphosed, however primary lithologic terms are used henceforth where they are reasonably well established and more concise than metamorphic names.

2,000 m. Although Hewitt (1960) referred to the Oak Lake formation as sedimentary, the provenance was probably wholly volcanic, with deposition controlled by volcanic, sedimentary and transitional processes.

The Oak Lake formation is, to the south (Figure 4), obscured by Ordovician limestone cover; to the north it is continuous through Methuen to Lake Township, and may correlate with volcanics in Wollaston and Limerick Townships (Hewitt, 1960).

The lower contact of the Oak Lake formation lies between the shoreline and marble-bearing islands (Big Island beds) of Oak Lake (Hewitt, 1960). Within southern Methuen Township the Oak Lake formation comprises felsic and intermediate volcanics, and siliciclastic rocks, disposed in alternating layers tens to hundreds of metres thick. Much of what Hewitt (1960) termed "arkose" in the Oak Lake area is considered by the authors to be felsic volcanic. Criteria used to distinguish between felsic volcanics and siliciclastic rocks in the map-area include well-developed thin layering, higher mica content and quartz: feldspar ratios and in some cases the presence of distinctive porphyroblasts such as garnet, cummingtonite and kyanite in the siliciclastic rocks. In addition, felsic volcanics commonly contain plagioclase phenocrysts showing no sign of appreciable abrasion.

Intermediate volcanics in Methuen Township are, in general, fine- to medium-grained quartz-biotite-plagioclase fels to schists, layered on the scale of centimetres to decimetres. These differ from felsic volcanics in their higher biotite and lower quartz contents.

The authors have re-defined Hewitt's (1960) original placement of the upper contact of the Oak Lake formation within Methuen Township. Originally it was placed at the first appearance of conglomerate, 60-90 m below the base of the Lower marble member (Little Whitney Lake formation of this report) of the Vansickle formation; in the view of the authors, the discontinuous nature of the conglomerate in Methuen Township, and its absence in Belmont Township requires that a more consistent datum be established, in this report the contact with the Little Whitney Lake formation.

Within Belmont Township the Oak Lake formation comprises three members, based on predominant composition - mafic, intermediate and felsic volcanics. The felsic volcanic member encloses both of the other members; the mafic member occurs low in the succession exposed in Belmont Township; the intermediate member occurs as lenses throughout.

In Belmont Township the upper contact of the formation is, in the north, at least in part transitional, over 5-10 m, with the Little Whitney Lake formation. Further south, the upper contact with the Whitney Creek formation is nowhere clearly exposed; however in places the change from felsic to mafic rocks can be delineated to within 10 m.

The mafic volcanics are largely confined to two stratigraphically distinct lentils, concentrated in the nose of the major syncline west of Little Whitney Lake (See Map). The lower lentil comprises black, dark grey-weathering, fine-grained, massive to schistose and lineated amphibolites; Color Index is

45-50. Plagioclase and hornblende are the major constituents, with minor magnetite[4]. Plagioclase-phyric varieties are common; phenocrysts average 3 mm, range to 15%, and are almost totally recrystallized. Rare relict twinning at one locality (UTM2671/493852)[5] yielded a plagioclase phenocryst composition of An_{29}. Quartz amygdules, averaging 1 cm long, are present locally to 10%.

The upper lentil consists of fine-grained, moderately schistose, lineated amphibolites, dark grey to green-grey on fresh and weathered surfaces. These rocks are typically quartz amygdaloidal and blastoporphyritic, with plagioclase phenocrysts up to 12 mm long composing 5-40% of the rock (Photo 1). Minor epidote is present in some rocks. Titanite typically occurs as an alteration product with magnetite. Colour index varies from 35 to 45. Primary mesoscopic features are generally well-preserved in these rocks; flow thickness varies from 2 to 10 m, or more. Elliptical rimmed structures, 15-100 cm long are interpreted to be pillows; these are plagioclase-phyric and amygdaloidal. Moderately deformed quartz amygdules within the pillows are up to 10 mm long and occupy 10-15% of the rock. Locally, hyaloclastites are present, containing varietal prograde chlorite and biotite.

Elsewhere, mafic volcanics occur only sporadically in the Oak Lake formation. One outcrop, 2 km northwest of Round Lake, comprises amygdaloidal mafic flows. Two kilometres north of Round

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[4] More Detailed petrographic descriptions and sample locations in Belmont Township are documented in Appendix B of Bartlett (1983); Murray (1982) provides similar documentation for southern Methuen Township.

[5] All universal transverse Mercator (UTM) coordinates refer to zone 18; reference grid is given in Appendix B, Figure B1.

Lake mafic flows grade into gabbro, demonstrating the subvolcanic nature of the gabbro. A fine- to medium-grained, centimetre-layered (hornblende-rich versus plagioclase-rich) rock, in which plagioclase is highly altered to sericite, lies directly beneath the Little Whitney Lake formation on the north limb of the major syncline (UTM 27026/493971). The scale and uniformity of layering, fineness of grain and the mineral composition suggests that this rock represents airfall tuff (cf. Williams and McBirney, 1979).

Two small, lenticular units of intermediate volcanics occur at, or close to, the lower contact of the upper lentil of mafic volcanics, one on each limb of the major syncline. Nearer the top of the formation a relatively thick, continuous intermediate unit occupies the major syncline and smaller anticline to the south. In the core of the syncline intermediate volcanics comprise massive flows, and tuff and pyroclastic breccias, layered on the scale of metres to tens of metres, containing angular to subrounded fragments. The unit pinches out on the north limb of the syncline; south of the syncline fragment size decreases to ash- and lapillus-size; here the rocks are mainly tuff and lapilli tuff layered on the scale of centimetres to decimetres.

Thin septa of intermediate volcanics occur within both lentils of mafic volcanics. The intermediate volcanics cropping out further south generally occur in thin lenticular units, or, as is the case toward the top of the formation, as centimetre-scale layers within felsic volcanics.

Intermediate volcanics are generally medium grey, brown-grey-weathering, fine-grained, granoblastic quartz-biotite-plagioclase fels to semi-schists. Hornblende is a common varietal mineral, occurring in amounts up to 15% in some rocks; magnetite is ubiquitous (1-4%), commonly with mantles of titanite. Colour index ranges from 10 to 25. Schistosity, where present, is typically weak, defined by biotite orientation. Rare hornblende (or biotite after hornblende) lineation is weak. Some rocks are typically massive on an outcrop scale and are considered to be flow rocks. Calcite-quartz lenticles in some rocks (eg. UTM 26878/493776) may represent amygdules.

Locally, fine- to medium-grained intermediate volcanics exhibit decimetre-scale layering, defined by variations in grain size and colour index. The scale and uniformity of layering, mineralogy, grain size, shape and gradation within layers and alternating grain size from layer to layer suggest that these rocks represent airfall tuffs (cf. Heiken, 1972; Sheridan, 1971; Sigurdsson, 1982a; Williams and McBirney, 1979).

The felsic volcanic member within Belmont Township consists of pyroclastic deposits with subordinate flow rocks and volcanically derived epiclastic rocks. The member is of relatively uniform thickness. Deformation and recrystallization have rendered determination of the origin of some rocks tenuous; however in many recrystallization has been incomplete, leaving original textures partially preserved.

The greatest diversity of rock types of this member occurs in the vicinity of the major syncline west of Little Whitney Lake. In this region strain is typically high and unidirectional. The lowest-exposed sections are dominated by fine-grained, pink-grey, pink-white-weathering, granoblastic quartz-alkali feldspar fels. For the most part the rocks appear to be megascopically uniform; millimetre- or weak centimetre-scale compositional layering is local.

Near the base of the lower mafic volcanic lentil felsic rocks are distinctly fragmental and are of two main types, distinguished by different matrix characteristics, and particularly by the great disparity in the amount of strain they have taken up. The two rock types are interlayered on the scale of metres to tens of metres; layer-to-layer contacts are commonly indistinct and possibly gradational. Poor exposure does not allow a reliable assessment of the relative proportions of these rock types.

The relatively unstrained type is characterized by ash- to block-sized, angular to sub-angular, commonly delicate fragments composing 40-60% of the rock; the fragments are generally of one type, with minor variations in colour. The rock is commonly matrix-supported. Comprising mainly fine ash, the matrix has a darker hue than the pale brown-grey fragments; in thin section distinction between fragments and matrix is commonly complicated by similar composition and texture. The coarse layering, poor sorting, felsic composition, uniformity of fragment type, and uniformity of texture of fragments (non-vesicular) and matrix suggests that this lapilli tuff represents either a pyroclastic flow deposit, possibly a Pelean-type block and ash flow (cf. Fisher, 1982a; Williams and McBirney, 1979), or a near-vent airfall deposit.

The other, more highly strained, rock type consists of up to four felsic fragment types, all quartzofeldspathic, that are variable only in the relative proportions of quartz and feldspars, and colour of the weathered surface. Length: width ratios of the fragments vary within each fragment family, and from type to type; ratios average 40:1. Fragment lengths average 30-40 cm; their terminations are typically round. Fragments predominate over the fine-grained matrix, and form the framework. In thin section the distinction between matrix and fragments is mainly one of texture - fragments are more complex-interlocking than the granoblastic matrix. The pronounced deformation of this rock precludes precise determination of its original character; fragments in this rock are obviously more susceptible to strain than fragments in neighbouring block and ash flows. Collapse of vesicles can lead to marked flattening of pumice fragments (Fiske, 1969); this may, in part, explain the highly deformed nature of the fragments described above.

Lapilli-tuff predominates in the area between the mafic volcanic lentils. Essential fragments, composing up to 60% of the rock are of two types - white- and dark grey-weathering. In addition, discontinuous quartzose septa probably represent flattened, silicified pumice fragments (cf. Thurston, 1980b; Fiske, 1969). The matrix consists of fine to coarse ash-sized grains and is similar to rocks in the area that do not have lapillus-sized or coarser fragments.

Throughout the felsic volcanic member north of UTM Northing 4937 are intercalations, metres to tens of metres thick, of coarse fragmental rocks with felsic (CI < 5) fragments in an intermediate (CI > 15), biotite-rich, strongly schistose matrix. Although the fragments, which include a minor intermediate type, are less strained than the matrix, precise determination of original size and shape is not possible; they are now mainly lenticular, average 10-30 cm, and occupy more than 50% of the rock. Stratification within these units was not observed. Strain renders definition of the original deposit tenuous; however, if the biotitic matrix represents original clay, the presence and abundance of this size fraction, along with the considerable thickness and lack of internal stratification of the units suggest a laharic origin (cf. Fisher, 1982b).

Overlying the upper mafic volcanic lentil, and concentrated in the nose and on the southern limb of the major syncline, one of the main rock types is a pink-grey-weathering, fine-grained rock, uniform on the scale of metres to tens of metres, with or without pervasive, dark grey quartz laminations, 0.5 mm thick, spaced 2-3 mm apart (Photo 2). The laminations are laterally continuous over metres to tens of metres; microscopic study reveals that these features consist of equant (recrystallized) quartz grains, 0.5 mm in diameter, and are locally accentuated by magnetite along the borders. By analogy with younger volcanic rocks (cf. Christiansen and Lipman, 1966; Wachendorf, 1973), these are interpreted to be felsic flow rocks, the laminations representing relict flow banding. Similar rocks in the Mazinaw Lake area (70 km to the northeast) have been interpreted by Ayer (1979) to be felsic flow rocks. Locally, the laminations are highly contorted, a feature the authors interpret as being primary flow folding, similar to that seen in younger rocks elsewhere (cf. Christiansen and Lipman, 1966; Wachendorf, 1973). The contorted nature was originally considered by Bartlett (1983) to have resulted from D_2 folding, however subsequent mapping has proved that the folding style is independent of regional D_2 structures.

Felsic flows can be traced laterally for 2 km in the nose and on the limbs of the major syncline.

Associated with felsic flows at some localities is the rock, described above, for which a laharic origin was suggested. In addition, centimetre-layered, locally graded felsic rocks composed of ash and lapilli crop out in the area of the felsic flows; the composition, grain size and gradation, and scale and uniformity of layering suggest that these are airfall tuffs and lapilli-tuffs (cf. Heiken, 1972; Sheridan, 1971; Sigurdsson, 1982a; Williams and McBirney, 1979). These rocks give way, on the north limb of the syncline, to fine-grained quartzofeldspathic semi-schists bearing varietal microcline, muscovite and biotite; 8% kyanite occurs at one locality (UTM 27026/493971) as lineated poikiloblasts. The aluminous and quartz-rich nature of some of these rocks suggest an epiclastic origin (cf. Ayres, 1982b). It is possible, however, that these rocks may have ben derived from altered volcanics.

On the south limb of the major syncline the middle to upper part of the felsic volcanic member contains layers, several metres thick, of granule to cobble volcanic conglomerate. Although bedding orientation in most units is uncertain, clast size variation within each unit is commonly gradational. In areas of low strain clasts are equidimensional to elongate, and are generally less than 35 cm in diameter. In the coarser rocks clasts occupy up to 70% of the rock - 30% in finer rocks. Clast and matrix characteristics are highly varied from area to area. One rock (UTM 27041/493758) contains nine rounded clast types - one is composed entirely of quartz, the others variations about a felsic lithic theme; the matrix is intermediate, and is composed of sand-sized grains; up to 7% magnetite is common in the matrix. Other conglomerates (eg. UTM 27044/493680) contain two varieties of siliceous carbonate clasts, one massive, the other with sub-millimetre-scale planar quartzose segregations (algal laminations ?). The rock is matrix-supported and bears clasts up to 15 cm long; clast outlines are commonly irregular. The sand-sized matrix is composed mainly of quartz and alkali feldspar, highly epidotized, with only minor carbonate. The heterolithic, in part non-volcanic, nature of the clasts, and size, texture and composition of clasts and matrix suggest that these rocks are epiclastic.

South of UTM Northing 4937 the abundance of conglomerates and coarse pyroclastic rocks diminishes. The lower, middle and some of the upper parts of the member comprise mainly pink-grey, pink-grey- to white-weathering rocks containing fine ash- to lapillus-sized particles. Bedding, evident in many rocks, is defined, on the scale of millimetres to decimetres, by interlayering with intermediate (CI = 10-15) beds; variation in the abundance of quartz, feldspar, biotite, muscovite and locally calcite within each bed; and grain size variation within beds.

Rocks at several localities exhibit normal size grading of ash- and (or) lapillus-sized fractions. A distinct lack of bedding is apparent in ash-sized rocks at several localities; massive sections range from metres to tens of metres thick. Lapillus-sized fragments, common in rocks north of Round Lake, rarely occupy more than 30% of the rock. Some rocks contain more than one type of lapillus-sized fragment; quartz and (or) plagioclase crystal fragments generally do not exceed 3 mm; quartzofeldspathic lithic fragments up to 10 cm long have length:width ratios of 5-10:1; wispy quartz-rich fragments 10-15 cm long probably represent silicified pumice (cf. Thurston, 1980b; Fiske, 1969). At one locality (UTM 26923/493377) both latter fragment types occur in the same rock; compositional grading on the scale of several metres is defined by a vertical increase of pumice fragments relative to lithic fragments. Another outcrop (UTM 26904/493232) contains elongate lithic or pumiceous lapilli up to 9 mm long deformed around crystal fragments. Photo 3 illustrates that the rock displays eutaxitic foliation.

The scale and gross uniformity of layering, grain size and composition, and grain size gradation in the well-bedded rocks described above suggest that these rocks represent airfall tuff (cf. Heiken, 1972; Sheridan, 1971; Sigurdsson, 1982a; Williams and McBirney, 1979). The lack of distinct bedding on a scale of metres to tens of metres, texture and composition of constituent grains, and compositional grading involving lithic and pumice fragments indicate that the non-bedded rocks were deposited by pyroclastic flows (cf. Fisher, 1982a; Sparks et al., 1973).

Felsic volcanics cropping out in close proximity to the many small gabbro bodies 3-4 km north of Round Lake have a CI of 10 or slightly less, in contrast to typical felsic volcanics in the general area, which have a CI of 5 or less.

Rocks forming the uppermost part of the felsic volcanic member between UTM Northings 4938 and 4936 include mappable units of rusty-weathering, highly cleaved, fine-grained siliceous rocks interpreted, on the basis of weathering characteristics and high quartzfeldspar ratios, to be epiclastic. Grey-weathering, commonly size-graded rocks containing ash-sized particles are layered on a scale of centimetres to decimetres north of UTM Northing 4935; scale of layering decreases southerly to millimetre- to centimetre-scale. The scale, uniformity and inferred continuity of layering, grain size and composition, and grain gradation suggest that these are airfall tuffs (cf. Heiken, 1972; Sheridan, 1971; Sigurdsson, 1982b; Williams and McBirney, 1979).

Chert is locally abundant as thin lenses and as millimetre-scale tops of tuff beds south of UTM Northing 4933. Near Round Lake the top of the felsic member is marked by a 5 m thickness of massive chert, containing a 2 m thick lens of massive pyrite. The coincidence of chert and massive pyrite in this lenticular unit suggests that this deposit may represent hydrothermal exhalation at a localized vent; the deposit may be loosely termed "sulphide facies iron formation" (cf. Fryer and Hutchinson, 1976).

Little Whitney Lake Formation

Rocks of the Little Whitney Lake formation (Figure 4) are concentrated in the nose of the major syncline in the area around Little Whitney Lake in Belmont Township (see Map). Complex fold patterns indicate that the unit has been considerably thickened tectonically in the nose, accompanied by attenuation along the north limb in Methuen Township.

The lower contact of the formation is exposed in one area in Belmont Township (UTM 27085/493800) where layered felsic tuffs of the Oak Lake formation grade upward, over 5-10 m, into dolomitic marble. Elsewhere the lower contact is traceable to within metres to tens of metres. The upper contact with mafic and intermediate volcanics of the Whitney Creek formation is less well-defined.

Calcitic and dolomitic marbles are the predominant rock types of this formation. Calcitic marbles are white or pale grey, fine- and medium-grained and granoblastic; centimetre-scale interlayers of calc-silicate rocks containing epidote, white mica and magnetite are common. Rare, centimetre-scale massive pyrite interlayers probably represent precipitation arising from fumarolic activity in the waning stages of volcanism (cf. Fryer and Hutchinson, 1976).

Dolomitic marbles are white, buff-weathering, medium-grained and saccharoidal. Tremolite is locally abundant in these rocks, forming sheaves up to 10 cm long. Centimetre-scale siliceous layers and lenses are local; laminated varieties are interpreted to be algal structures (M.S. Bourque, personal communication, 1982).

Biotitic, carbonate-bearing siliceous rocks are locally abundant, particularly west of Little Whitney Lake. These rocks include both massive and centimetre-layered varieties.

Whitney Creek Formation

The Whitney Creek formation comprises four members in Belmont Township - composite mafic and intermediate volcanics, rusty-weathering siliceous semischist, marble and felsic volcaniclastics. The lens-shaped siliceous semi-schist and marble members do not extend into Methuen Township, but rather pinch out south of Little Whitney Lake. The formation thickens from about 500 m east of Round Lake to about 1500 m at the north boundary of Belmont Township; thence it thins to about 500 m in southern Methuen Township.

The composite mafic and intermediate volcanic member is areally the dominant member of the Whitney Creek formation. Throughout the unit mafic flows and pyroclastics are intercalated with intermediate pyroclastics and rare flows; mafic rocks are generally more abundant, though in some areas, particularly northern Belmont and southern Methuen Townships (see Figure 4), the reverse is true. Laterally discontinuous intercalations are commonly on the scale of tens to hundreds of metres; mafic layers are generally thicker. Minor, thin felsic tuff layers are also present.

Mafic flow rocks are commonly fine- to medium-grained, uniform, dark grey, brown-grey-weathering, lineated and foliated; they are composed essentially of hornblende and plagioclase. Colour index varies from 35-60, averaging 45-50. In areas where flow contacts can be observed, the thickness of flows is about 10 m; some are 1 m thick. Most flows observed are massive; pillowed flows and hyaloclastites are only prevalent 3-4 km north of Round Lake. Amygdaloidal flows are not common; where present, amygdules occupy 10-20% of the rock.

Coarse mafic fragmental rocks occur mainly south of UTM Northing 4934 in the lower and middle parts of the member. The coarsest rock contains rounded and sub-rounded fragments, up to 15 cm long. The strong lineation in these rocks reflects the high degree to which fragments and other primary features have been stretched during D_1 deformation. Fragment dimensions quoted represent the long axis in cross-section; applying the principle of constant volume, the original dimensions are estimated to be at least double their present value. The rock is typically fragment-supported with less than 20% fine-grained matrix. Most fragments are of one type: amphibolite consisting of 30-40% hornblende porphyroblasts, up to 1 cm long, in a matrix of equigranular plagioclase. A small fraction of the fragment population differs mainly in the lower percentage of hornblende porphyroblasts (variable to as low as 10%); this feature may, however, reflect alteration rather than a primary difference. Some rocks contain scoriaceous (amygdaloidal) fragments up to 8 cm long with 30-40% matrix. Lack of sorting and stratification, degree of rounding, composition and, in general, monolithologic character of fragments suggest that these rocks are agglomerates (cf. Williams and McBirney, 1979).

Fine-grained mafic fragmental rocks occur in beds(?) several metres thick, and as centimetre-scale layers that alternate with quartzofeldspathic layers of similar thickness. The latter rock type is common in the area immediately north of Round Lake; fineness of grain, and scale and uniformity of layering suggests an airfall origin for these rocks (cf. Williams and McBirney, 1979).

Intermediate fragmental rocks are mainly fine- to medium-grained and bedded on a scale of centimetres to decimetres; bedding is defined by variations in CI and abundance of lapillus-sized fragments, generally more felsic than the matrix. These rocks are quartz-biotite-hornblende-plagioclase schists to semi-schists with CI = 10-25. An airfall origin is suggested, based on the scale and uniformity of bedding, composition, and grain texture and size (cf. Heiken, 1972; Sigurdsson, 1982a; Williams and McBirney, 1979).

Occupying the middle of the south half of the Whitney Creek formation is a 3.5 km long lens of rusty-weathering siliceous schists and semi-schists; the maximum thickness of this member is 50-100 m. Compositional layering, occurring on a scale of metres to several metres, is distinct, defined mainly by the size and abundance of porphyroblastic garnet and cummingtonite, and, less commonly, by magnetite and pyrite. Some layers are gradational (UTM 27218/493392), with garnet-rich bases yielding upward to garnet + cummingtonite and thence to a cummingtonite-rich top. Most rocks of this member are porphyroblastic; 1-10 mm garnets occupy up to 80% of some layers; cummingtonite commonly occurs as radiating crystals up to 3 cm in diameter, and occupies more than 50% of some layers. Porphyroblasts typically overgrow and, in the case of garnet, incorporate D_1 schistosity as quartz inclusion trains. Quartz with or without plagioclase is the only other major constituent of the porphyroblastic rocks; minor biotite was observed in the field. Non-porphyroblastic rocks commonly contain, in addition to quartz and feldspar, 15-20% muscovite, up to 15% graphite, as much as 10% pyrite, and minor biotite. In some rocks magnetite porphyroblasts averaging 5 mm are present to 15%.

Minor layered magnetite chert is intercalated with the rocks in the north part of this unit.

Rocks of this member are interpreted, on the basis of analogy with similar rocks 40 km to the north (Hall, 1980), to be mainly chemical sediments derived from volcanic exhalations; they may be loosely termed "silicate facies iron formation" (cf. Klein, 1973). Although Figure 4 depicts the rocks of this unit as siliceous clastic metasediments, the epiclastic component is probably subordinate.

A thin unit of mafic and intermediate volcanics separates, in most places, the rusty-weathering schists from the overlying calcitic and dolomitic marble member. The lower contact of the marble member is exposed on the shores of Round Lake; here rusty-weathering, garnetiferous, amphibole-rich intermediate tuffs yield conformably to a 5 m thickness of well-bedded, muscovitic, calcitic marble. The member is exposed along strike for about 5 km; its average thickness is about 70 m, and thickens to 150 m in the south.

The dolomitic component is dominant in the northern part of the member, with white, buff-weathering, medium-grained marble commonly containing uniform or faintly laminated, centimetre- to decimetre-scale layers and lenses of fine white quartz. Some of these segregations are relict algal structures. A calcitic component is more evident to the south, occurring as fine- to medium-grained centimetre-scale layers with or without interlayers of dolomitic marble.

In most places an interval of mafic and (or) intermediate volcanics, 30-150 m thick, separates the marbles from the felsic volcaniclastic member. From a thickness of 500-700 m at the Belmont-Methuen Township boundary, felsic volcaniclastic rocks rapidly pinch out to the north, yielding to rocks of probable epiclastic origin. The unit thins gradually to the south and, in the vicinity of Seright Bay (see Map , back pocket), yields through a major facies change to epiclastic rocks. Epiclastic rocks are areally most extensive in the Seright Bay area, but also occur in a thin, continuous zone overlying and in part interlayered with the felsic volcaniclastic rocks.

Most of the member consists of aphanitic to medium-grained, grey, white- to brown-grey-weathering quartz-albite semi-schists. Primary clastic texture can be recognized locally. Well-rounded, flattened, lapillus-sized felsic volcanic fragments, locally composing up to 10% of the rock, are generally rare but more prevalent in the central to northern parts of the member. Rocks
ART 3A containing more plagioclase than quartz are considered to be
ART 3B tuffaceous. The rocks are increasingly more cherty and graphitic to the south. Bedding, defined by variations in grain size and

mica content, is typically millimetre- to centimetre-scale, locally decimetre- to metre-scale; normal and reverse grading are evident at several localities. In the upper parts of the member the rocks are increasingly rusty-weathering and pyritic toward the top; intercalations of layered felsic volcaniclastic and epiclastic rocks and, in some areas, chert gradually yield upward to graphite- and pyrite-bearing plagioclase-biotite (or muscovite)-quartz schists. Relict clastic texture in these rocks indicate that they were originally poorly sorted mudstones. Epiclastic rocks to the south are more pelitic; at one locality (UTM 27322/493176) garnet poikiloblasts in a chlorite-garnet-biotite-quartz schist are sigmoidal, having rotated during overgrowth of D_1 schistosity.

Post-D_1, possibly D_4 (see Table 4), cataclastic brecciation locally affected the rocks of this member.

The possibility exists that this member, on the whole, has undergone extensive alteration, including silicification (chemical analyses for rocks of this unit are presented in Bartlett, 1983).

Cordova Lake Formation

The Cordova Lake formation comprises two members, the lower composed of mainly mafic volcanic rocks including massive and pillowed flows, and hyaloclastites; intermediate and felsic flows and pyroclastic rocks form the upper member. The formation attains a maximum thickness of about 3000 m south of Cordova Lake; thence it thins drastically to the north, pinching out immediately north of the Belmont-Marmora Township boundary. It thins gradually to the south where the minimum exposed thickness is less than 1500 m. In most places the lower contact of the formation can be traced to within tens of metres; where mafic volcanics overlie pyritic siltstones of the Whitney Creek formation the transition is abrupt, though rarely exposed. The upper contact is marked in most places by the major fault, mentioned earlier, which separates mafic and intermediate volcanics from marble and siliciclastic rocks of the Vansickle and Marmora formations.

In the north the lower part of the formation consists largely of aphyric, massive and pillowed flows and breccias, and hyaloclastites; lenses of intermediate tuff and siliceous chemical sediments are subordinate. To the south, intermediate and felsic tuffs dominate. Rare mafic tuffs occur near the transition from essentially mafic to essentially intermediate rocks (Figure 3).

Plagioclase phenocrysts, absent in the lower third of the formation, increase in abundance in mafic flows and dikes to a maximum at about the middle part of the stratigraphic section; locally, phenocrysts up to 3 cm occupy more than 50% of the rock. In terms of lateral variation, rocks in the middle part of the formation are generally more replete with phenocrysts than those in the north and south.

Mafic dikes, also generally absent in the lower part of the formation, increase in abundance through the middle and upper parts; south of Cordova Lake mafic dikes account for about half of the outcrop area. Mafic and, more rarely, intermediate dikes are probably synvolcanic, as, at several localities, the transition from flow rocks to dikes (and in some cases from dikes to gabbro bodies) is gradational.

Flow morphology is best observed in exposures on and south of Cordova Lake, and on Belmont Lake. Flow units commonly include a gradational, upward progression from massive through pillowed flows to hyaloclastites; in many exposures pillow breccias, isolated pillow breccias and broken pillow breccias intervene between pillowed flows and hyaloclastites. This sequence corresponds well with those observed in Archean (Dimroth et al., 1978) and Triassic (Carlisle, 1963) volcanic successions. Flow units are 20-70 m thick.

Pillow lavas typically consist of closely packed, equidimensional to elliptical, unbroken pillows, generally less than 1 m in length; within any particular flow they have fairly regular shapes and sizes. Selvedges are commonly 1-3 cm thick. The gradation from pillowed flow to isolated pillow breccia is rapid. The unstratified, unsorted isolated pillow breccias (Photo 4) are composed of unbroken pillows varying greatly in size and shape, but generally becoming smaller upward until most are only several centimetres long. The unbroken pillows are generally not in mutual contact; rather they are separated by an hyaloclastic matrix. The isolated pillow breccias, and in places the pillow lavas themselves, pass upward into broken pillow breccias (Photo 5), composed mainly of fragments, up to 15 cm long, of pillows in a matrix of hyaloclastite. Pillow fragments are generally angular and elongate, with delicate terminations; they are dark grey, grey-brown-weathering, aphanitic and felty-textured to weakly schistose. Micro-amygdules and plagioclase microphenocrysts are common. Hornblende is the major constituent (up to 80%) with plagioclase subordinate. Some fragment boundaries are diffuse due to gradational transition from fragment to matrix. Hyaloclastite contrasts sharply with pillows and pillow fragments; it weathers to distinctive yellow- or grey-brown hues. It is fine-grained and moderately schistose; plagioclase is the main constituent, with up to 30% chlorite and varietal hornblende and calcite.

Amygdules are sparse in rocks of the Cordova Lake formation; where present they are typically small (1-2 mm) and rarely occupy more than 1-2% of the rock. Cherty space fillings are common throughout the formation, particularly in pillowed flows; some cherty lenses are 1 m long.

Massive mafic flow rocks, including pillow interiors are typically dark grey, medium brown-grey-weathering, fine- to medium-grained, uniform and massive to weakly foliated. Colour index varies from 45 to 85, averaging 60-70. Plagioclase and hornblende are the essential constituents; simple- to complex-interlocking plagioclase is generally interstitial to commonly coarser, more abundant hornblende. Up to 10% prograde chlorite occurs in some mafic flows, particularly in the southeastern part of the formation, and imparts a moderate schistosity to the rock. Plagioclase ubiquitously includes up to 10% epidote.

Mafic dike rocks are similar to the flow rocks, save for their medium grain and general lack of foliation.

Fine-grained mafic rocks displaying millimetre- to centimetre-scale layering defined by hornblende-rich versus plagioclase-rich beds are locally abundant in the lower part of the formation. The scale and uniformity of layering, and grain size and composition suggest that these rocks are tuffs, erupted subaerially or subaqueously, but probably deposited in a subaqueous environment (cf. Williams and McBirney, 1979).

Rocks in which chlorite, with or without biotite, is the predominant mafic mineral occur near the top of the mafic volcanic member of the Cordova Lake formation. Essential quartz in these rocks suggests that they are not primary mafic deposits. Although stratification in these rocks is commonly cryptic, they are tentatively interpreted to be deposits formed from reworked ash and (or) decomposed flows.

Rocks similar to the rusty-weathering siliceous schists of the Whitney Creek formation crop out in small lenses in the lower and upper parts of the Cordova Lake formation; they contain up to 30% chlorite, in contrast to the chlorite-poor rocks to the west.

Fine-grained, centimetre-layered intermediate volcanics occur with similar felsic rocks in small lenses throughout the formation. The fragmental nature of some of the rocks is borne out by the presence of fine lapillus-sized crystal fragments. Layering is typically uniform on a scale of several metres. The scale and uniformity of layering, and grain size, texture and composition suggest that these are airfall tuffs (cf. Heiken, 1972; Sheridan, 1971 Sigurdsson, 1982a; Williams and McBirney, 1979).

A lenticular unit in the Lost Lake area contains intermediate (CI = 30) tuff and lapilli tuff, and flow rocks, including hyaloclastites and flow breccias.

Magnetite-bearing cherts occur near the top of the formation, cropping out intermittently over a strike length of 3.5 km between Belmont and Cordova Lakes. They are fine- to medium-grained, centimetre-layered granular rocks consisting mainly of quartz, with about 10% magnetite overall. The maximum thickness of the interval containing magnetite-bearing chert is 30 m. Enclosing rocks are commonly chlorite schists, with garnet in places.

The upper member of the Cordova Lake formation is a composite unit comprising intermediate and felsic volcanics, occurring on the west shore of Belmont Lake; its maximum thickness is 200 m. Fine-grained, centimetre-layered biotite- or chlorite-bearing quartz-hornblende-plagioclase schists with CI = 20 are probably airfall tuffs, based on scale and uniformity of layering, and grain size and mineralogy (cf. Heiken, 1972; Sheridan, 1971; Sigurdsson, 1982a; Williams and McBirney, 1979). Associated, layered intermediate rocks containing more than 20% quartz probably represent locally derived reworked tuff. Biotite- and (or) chlorite-bearing quartz-plagioclase fels and semi-schist with CI < 10 are commonly uniform on a scale of several metres, and contain 1-2% amygdules. Partially preserved felty and intersertal to felty textures confirm a flow origin for these rocks; some (UTM 27498/493080) contain pillows exceeding 1 m in length. Rocks of this unit have been slightly to intensely epidotized.

At exceptionally low water levels of Belmont Lake, such as were afforded in the fall of 1983, pillowed mafic flows are exposed along the west shore of the lake, directly west of Mary's Island (see Map).

Vansickle Formation

Hewitt (1960) defined the Vansickle formation within Methuen Township; overlying the Oak Lake formation, it comprised about 1400 m of "schist, marble and some conglomerate". Its base was marked by a discontinuous conglomerate unit 60-90 m below the base of the marble unit that, in this report, is known to be the north part of the Little Whitney Lake formation.

The Vansickle formation is re-defined (see also Bartlett, 1983) to exclude the conglomerate base, the "Lower marble" and the "Lower schist" units (Hewitt, 1960) which correspond, respectively, to the Oak Lake, Little Whitney Lake and Whitney Creek formations of Belmont Township. Retained were the remainder of Hewitt's (1960) units; additions included siliciclastic rocks, pure and impure marbles, mafic and intermediate volcanics and rusty-weathering siliceous schists east of Cordova Lake. Stratigraphic analysis of the Vansickle formation in Belmont Township is hampered by the lack of primary facing information and by faults (see Figure 4) and complex D_2 folds; units were thus assigned member status by Bartlett (1983) on the basis of composition, rather than stratigraphic position.

As defined by Bartlett (1983), the Vansickle formation has limited extent in Belmont Township, occupying only the northeast corner of the township. According to Hewitt's (1960) original definition, the Vansickle formation occupied only a small area in the southeast corner of Methuen Township; Bartlett's (1983) re-definition constrained its areal extent even further in that township. Laakso (1968) emphasized the difficulties in attempting to extrapolate Hewitt's (1960) members north into Lake Township;

however, he proposed that the Vansickle Formation extended to the west-central and northeast parts of that township. Comparison with the geographic extent of the Vansickle formation in Belmont and southern Methuen Townships suggests that most of the stratified rocks in the northern one-quarter of Marmora Township could be considered to be part of the Vansickle formation, and are for the purposes of this report. The authors stress, however, that this assignment is tentative, and may change with further study; as a result, the rock units in northern Marmora Township will not be described as members, but rather according to lithologic type.

The nature of the contact between the Cordova Lake formation and the Vansickle formation is uncertain in the western Cordova Lake area due to limited mapping and poor exposure. The rapid thinning of the Cordova Lake formation west of Cordova Lake (Figure 4) suggests that the contact is not simply a primary facies transition; tectonic control is likely. A major fault is inferred to govern contacts along, and south of, the east shore of Cordova Lake. The main evidence for this fault is the apparent truncation of rock units in the Vansickle formation against the Cordova Lake formation to the west.

Carbonate rocks of the Vansickle formation in Belmont Township compose two discrete units, collectively referred to as member A by Bartlett (1983). Separated by an interval of siliciclastic rocks, these units comprise mainly centimetre-layered calcitic marble; dolomitic marble, commonly with thin siliceous segregations, is subordinate. Interlayered calcitic marble and fine siliciclastic or siliceous carbonate rocks are locally abundant. The east-trending carbonate unit in northwestern Marmora Township is essentially similar to the, in part, fault-separated units described above. In contrast, the carbonate unit in northeastern Marmora Township consists mainly of calcitic marble interlayered on a scale of centimetres to tens of metres with wacke or arenite; minor calcareous wacke also occurs in this unit. In many places in this unit the coarseness of intercalation results in designation of outcrops as either finely interlayered carbonate and siliceous clastic sedimentary rocks, or as relatively carbonate-free arenite or wacke.

Within Belmont Township four siliceous clastic units collectively constitute member B of the Vansickle formation (Bartlett, 1983). Two of these units, northwest of Cordova Lake, continue into southern Methuen Township. Another unit, east of Cordova Lake thickness considerably into northwestern Marmora Township, where its southeastern contact is a fault. Rocks of these units are typically fine-grained, dark grey, buff-grey- to rusty-weathering biotite-quartz-feldspar semi-schists containing subordinate muscovite, garnet and carbonate. A locally abundant rock type in the area around the village of Vansickle is volcanic cobble conglomerate, containing highly strained clasts (Photo 6). The northwesternmost rocks display little well-defined bedding, however to the southeast, particularly in the Cordova Lake area, centimetre- to decimetre-scale beds, some displaying grain gradation, are common.

The southeasternmost siliciclastic unit of the Vansickle formation is complexly folded in Belmont and western Marmora Townships; it continues across the north part of Marmora Township. The western part of this unit contains aphanitic to fine-grained quartzofeldspathic fels and semi-schists with minor or varietal calcite and accessory biotite, opaques, epidote and (or) garnet; quartz ranges from 70-85%. Millimetre- to centimetre-scale compositional layering, some graded, is common. Coarser clastic rocks are locally abundant in this unit. Some rocks contain fragments of aphanitic biotite-quartz-plagioclase semi-schist, derived from an intermediate volcanic source, in an aphanitic calcite-quartz-plagioclase semi-schist matrix; subhedral and euhedral plagioclase grains in the matrix indicate little reworking. Other rocks have muscovite-quartz-plagioclase, and minor calcite-rich sub-rounded fragments up to 8 cm long.

Intercalated with the fine siliciclastic rocks described above are black- and rusty-weathering siliceous schists similar to those of the Whitney Creek and Cordova Lake formations. Most display millimetre- to decimetre-scale compositional layering and contain poikiloblastic garnet and cummingtonite; some rocks also have actinolite poikiloblasts. Pyrite, magnetite and/or graphite are common varietal minerals. Pyritic and graphitic schists east of Cordova Lake contain disseminated chalcopyrite and sphalerite, and have been extensively prospected. These rocks are interpreted, on the basis of their mineralogy and layering characteristics, to have originated as exhalative sediments (silicate facies iron formation).

In north-central Marmora Township the siliciclastic unit contains rocks that are generally more massive, and locally alternate on a metre-scale with thinner, well-layered rocks. Felsic pyroclastic rocks may form part of the succession in this area. Further east, toward Beaver Creek (see Map), both massive and layered fine-grained wacke/siltstone and mica schist occur, displaying possible relict clastic texture. Biotite is common, though minor. Poikiloblastic garnet commonly occurs in thin muscovite-rich layers. The carbonate content of these rocks is generally low, though varies up to 30%. On the east side of Beaver Creek the most common rock type in this unit is very thinly bedded siltstone, with locally abundant centimetre-scale interbeds of arenite. Possibly overlying mafic volcanics in the northeast corner of the township are fine-grained, thinly to thickly bedded, dark grey, grey-weathering biotite-feldspar-quartz semi-schists. Fine-grained, fissile, rusty-weathering mica schists, bearing 2-3% pyrite, are locally abundant.

South of the Gawley Creek Syenite mafic volcanics are overlain by very fine-grained, centimetre- to decimetre-layered, dark grey, brown-grey-weathering wackes, and black- and rusty-weathering, pyritic, garnetiferous mica schist. The southwestern contact of this unit is gradational to interlayered carbonate and siliceous clastic sedimentary rocks.

The mafic volcanic unit east of Cordova Lake (Member C of Bartlett, 1983) consists of mafic hyaloclastites and chlorite (with or without amphibole) schists similar to and contiguous with the rocks of the Cordova Lake formation, with which it may be genetically related. Also similar to rocks of the Cordova Lake formation are mafic volcanics south of Thompson Lake (Figure 4), typified by a section between this lake and East Twin Sister Lake (Map). This unit includes the southerly continuation of Laakso's (1968) "Marmora volcanics" in Lake Township, and yields to a predominantly metasedimentary unit ("Thompson Lake beds" of Laakso, 1968) near the Marmora-Lake Township boundary. The mafic rocks south of Thompson Lake are mainly massive and pillowed flows and shallow intrusions; pillow breccias, isolated pillow breccias and hyaloclastites occur locally. Near Thompson Lake, siltstone, wacke and mica schists constitute thick intercalations with the mafic volcanics. Further south, thin lenses of siltstone, felsic tuff, chert and lithic (volcanic) wacke are enclosed by the mafic volcanics.

A smaller mafic volcanic unit east of Gawley Creek also comprises massive and pillowed flows, and shallow intrusions. Flows in the southern part of this unit contain bulbous, tightly packed pillows (Photo 7) that indicate a south-southwesterly facing direction.

Other small areas of mafic volcanics occur in northwestern Marmora Township; one of these constitutes the core of a fold, enveloped by pyritic mudstones that are continuous with similar rocks in Marmora Township.

Uniform and, more commonly, centimetre-layered intermediate rocks form the most southerly unit of the Vansickle formation (member D of Bartlett, 1983); this unit is confined entirely to Belmont Township. These rocks are interpreted on the basis of their mafic mineral content to be volcanically derived.

Structural relations along the upper contact, with marble of the Marmora formation, are uncertain.

Marmora Formation

Areally the most extensive unit in the map-area (see Figure 4), the Marmora formation extends from the Belmont Lake area, where it comprises mainly pure and impure dolomitic and calcitic marble, to the east, where, as predominantly intercalated calcitic marble and fine siliciclastics, it occupies much of the central part of Marmora Township.

The contact between Marmora formation marbles and volcanic rocks of the Cordova Lake formation is inferred to befault-controlled; the most northerly part of the contact may involve structural truncation of the Marmora formation. Along much of the contact structures across it are discordant, save in the central Belmont Lake area. Evidence in favour of a fault-controlled contact along the west side of Belmont Lake includes progressively stronger cleavage/schistosity in the marbles toward the contact and the strongly contrasting deformation styles on either side of the contact. The width of the zone of apparently fault-related planar fabric is 150-200 m. Tectonic brecciation of cherty layers in marble is evident 150 m from the contact and may be ascribed to brittle movement along it.

As mentioned above, the nature of the lower contact with intermediate volcanics of the Vansickle formation is uncertain, however within Marmora Township the contact between carbonate-rich rocks of the Marmora formation and siliciclastics of the Vansickle formation appears to be largely gradational. The upper contact of the Marmora formation is nowhere exposed in Marmora Township, as, to the south, Ordovician limestone covers much of the unit. Within Belmont Township the Marmora formation is interpreted (see also Bartlett, 1983) to be, in part, laterally equivalent to the Belmont Lake formation. The contact with the overlying Crowe River formation is nowhere exposed, and may, by virtue of the different deformation styles across it, represent a zone of tectonic dislocation.

Within Belmont Township, calcitic and dolomitic marbles are intercalated on a scale of decimetres to hundreds of metres throughout the Marmora formation. Calcitic marbles are commonly fine-grained, light grey or blue-grey and layered on a centimetre scale. Dolomitic marbles are fine- to medium-grained, white, grey- to buff-weathering and generally occur in beds 1 m or more thick. Both varieties contain thin, black, grey or white cherty segregations; dolomitic marble hosts centimetre-scale layers and lenses of laminated quartzose material (Photo 8) interpreted to be algal mats (Bourque, 1981). These features are abundant in the Belmont Lake area, and are well-exposed on the shores and islands. Columnar and domal stromatolites are also present, but less common (Bourque, 1981).

Several lenses of siliciclastic rocks occur throughout the Marmora formation in Belmont Township; these comprise mainly mudstones, with subordinate sandstones. Millimetre- to centimetre-scale layering is typical. Those rocks bearing metamorphic micas and (or) chlorite are commonly schistose. Primary structures, including slump folding and ripple marks, are locally well-preserved, and are best observed on the east side of Belmont Lake, 0.3-1.5 km north of Crowe River Bay.

Thinly laminated to medium-bedded, fine-grained hybrid sedimentary rocks occur, in some cases, at the interface between predominantly carbonate units, representing facies transitions. The rhythmic alternation between laminated, silica-rich, and uniform, calcite-rich rocks (Photo 9) may have resulted from chemical or biochemical processes. These rocks also occur in lenses not spatially related to predominantly siliceous units.

Intercalated with marbles northeast of Belmont Lake is a unit of clastic sedimentary rocks ranging from fine-grained to conglomeratic. Conglomerates are the most common rock type, with both matrix- and clast-supported varieties common; clasts are predominantly felsic volcanic, and are generally well-rounded with low to moderate sphericity.

From Belmont to Marmora Township a general facies transition occurs from dolomite-rich, relatively pure carbonate sedimentary rocks to dolomite-poor, interlayered siliceous and/or calc-silicate and carbonate sedimentary rocks. Relatively pure carbonate rocks occur in less extensive units in Marmora Township.

Throughout Marmora Township, alternation of siliceous, carbonate and/or calc-silicate layers occurs on a scale of millimetres to tens of metres; individual layers are commonly thinner than one decimetre. Where layers exceed several metres in thickness outcrops may consist of either siliceous or carbonate rocks. As outcrop designations are made on the basis of the predominant lithology, Map shows composite units consisting of subordinate siliceous and/or carbonate sedimentary rocks intimately associated with the predominant lithology.

The lower part of the Marmora formation, in the north-central part of the township, constitutes an extensive composite unit dominated by interlayered wacke/siltstone and calcitic marble; subordinate in areal extent is relatively pure calcitic marble, abundant west of Beaver Creek, and wacke/siltstone, abundant east of Beaver Creek. Near the lower contact with non-carbonate-bearing siliciclastics of the Vansickle formation the rocks are typically carbonate-rich (up to 90%), millimetre to centimetre-scale interlayered laminated calcitic marble and carbonate-bearing wacke. Locally predominant are centimetre- to metre-thick wacke beds that are typically massive and contain subrounded quartz and feldspar grains averaging 0.2 mm, and subangular and subrounded quartz grains up to 3 mm. These wacke beds are commonly separated by centimetre-scale calcitic marble layers. Further south from the lower contact of the formation, the rocks are dark grey muscovite-calcite marble with minor millimetre-scale layers of calc-silicate rocks, and thinly laminated calcitic marble interlayered with centimetre-scale wacke layers. Occurring locally are very fine-grained, massive siliceous calcitic marble, calcareous lithic arkosic wacke, and interlayered calcitic marble and mica schist.

In the central part of the township, and bordering the Deloro Granite body (see Figure 4), is a composite carbonate and siliciclastic unit dominated by calcitic marble, with subordinate dolomitic marble. Locally, layers of carbonate-bearing wacke and calc-silicate rock alternate with dolomitic and/or calcitic marble. The calcitic marble is typically dark grey- to blue-grey-weathering, and fine-grained. Centimetre- to decimetre-scale, buff-grey-weathering dolomitic marble alternates, in some locales, with centimetre- to metre-scale beds of finer-grained calcitic marble (Photo 10). Locally, as in the Malone area (see Map), high-purity, white, medium-grained calcitic marble occurs, rarely hosting brucite; coarse tremolite is a common constituent of marble in this area. In some areas light and dark grey-weathering dolomitic marble layers alternate in rocks having only minor calcitic marble or calc-silicate layers. Centimetre-scale interlayering of quartz arenite and calcitic marble, with minor dolomitic marble, occurs northwest of Malone; the quartz arenite commonly displays graded bedding, and contains 0.5 mm carbonate (ferrodolomite?) porphyroblasts.

Bordering the Cordova Gabbro in Marmora Township is a composite unit consisting of carbonate, siliceous and carbonate-bearing siliceous sedimentary rocks, interlayered on a scale of centimetres to metres. About 2 km east of Cordova Mines (see Map) the rocks are predominantly siliciclastics, with minor intercalations of calcitic marble. The main rock type is feldspathic wacke/arenite; locally, decimetre-scale beds contain euhedral to subhedral feldspar grains, and may represent tuffs. The feldspathic wackes/arenites are typically fine- to medium-grained and locally display graded bedding, cross-bedding and load casts; in most cases these criteria indicate southerly facing of the succession. Local thin calc-silicate layers contain up to 25%

fine tremolite and 10% epidote. Microcrystalline to fine-grained siliceous and relatively pure calcitic marbles occur as beds up to several metres thick. To the southeast the abundance of the carbonate component increases, and thicknesses up to 18 m of fine-grained, grey, micaceous calcitic marble occur with minor, thin siliceous interlayers, including wacke and chert. Regular centimetre-scale interlayering of siltstone, dark grey calcitic marble, and buff-weathering dolomite marble is common, with calcitic layers roughly five times thicker than siliceous and dolomitic layers.

North and east of the Cordova Gabbro is a 200 m thick unit of calcitic, and less abundant dolomitic marble. Grey, granular, commonly laminated calcitic marble locally displays centimetre-scale colour layering, and contains up to 10% black, buff-weathering cherty layers. Tremolite is an important constituent locally, occupying up to 20% of the rock. Together with elongate carbonate grains it defines a strong schistosity in some rocks.

In south-central Marmora Township the main lithology is intercalated calcitic marble and siliciclastic rocks, locally with minor layers of calc-silicate rock, dolomitic marble and/or carbonate-bearing wacke. The carbonate component exceeds the siliceous component by a factor of ten. Locally abundant in this area are dark grey calcitic marbles, in part laminated, interlayered on a millimetre to centimetre-scale with fine-grained carbonate- and non-carbonate-bearing siliciclastics, micaceous calcitic marbles, and very fine-grained, rare dolomitic marble.

Occurring inland from the east shore of Crowe Lake, and on an island in the lake is pure, white, fine- to medium-grained calcitic marble. Millimetre-scale cherty laminae, in part representing relict algal mat structures, are abundant locally; in one outcrop displaying these features (UTM 28431/493099), wollastonite selvedges separate quartz from calcite. Calcitic marble in the area east of Crowe Lake has been quarried in the past. Locally the marble has been converted to skarn.

South of the town of Deloro (see Map) calcitic marble borders the Deloro Granite body (see Figure 4), and is, in many places, partially or entirely converted to skarn. Pure, white, medium-grained calcite marble has been quarried locally immediately south of the Deloro Granite body. The eastern part of this unit bordering the pluton contains fine- to medium-grained calcitic marble displaying centimetre-scale medium grey and dark grey interlayers; some layers bear up to 10% pyrite.

The open pit of the Marmoraton Iron Mine exposes fine-grained, light grey, green-grey-weathering calcitic marble, locally layered on a millimetre-scale. This rock has been largely converted to skarn.

Belmont Lake Formation

Named for its areal restriction to the east shore and some islands of Belmont Lake, this formation comprises polymictic granule to cobble (rarely boulder) conglomerate with subordinate sandstone, mudstone and dolomitic marble. Rocks of the Belmont Lake formation were nowhere observed to overlie directly volcanic rocks of the Cordova Lake formation nor marbles of the Marmora formation. Previous belief (Bartlett et al., 1980, 1982) held that a major structural unconformity separated the Belmont Lake formation from underlying rocks. Further field work, however, has not confirmed the existence of a major unconformity; one or more intraformational erosional unconformities, instead, best explains the present configuration of rock units. Chert and felsic volcanic clasts of the Belmont Lake formation strongly resemble rocks of the Cordova Lake formation, the probable major provenance. Clasts were probably derived from the Marmora formation as well; some marble clasts contain stylofibrous cement, a feature observed in place in the Marmora formation (Bourque, 1982).

The Belmont Lake formation is intercalated with the Marmora formation, and, being laterally equivalent, was interpreted by Bartlett (1983) to be simply of a different facies. The upper contact with sandstones and mudstones of the Marmora formation north of Crowe River Bay (see Map) may be gradational. The coarse clastic rocks of the Belmont formation may be laterally equivalent to those of the Marmora formation, 1.5 km west of the town of Cordova Mines.

Restricted exposure and mesoscopic, open to close folding of some parts of the Belmont Lake formation render thickness determination of the formation tenuous in place. However, a section across Big Island (see Map) to the east shore of Belmont Lake traverses consistently east-facing strata, indicating a thickness in excess of 700 m.

Although the predominant clast type varies locally, the conglomerates share several characteristics; they are mainly polymictic and poorly to moderately sorted with sub-to well-rounded clasts having generally low to moderate sphericity. Graded bedding and scour-and fill structures are present locally. Thickness of conglomerate units, defined by alternation with units containing different particle size, is typically on the order of several metres.

Most conglomerates are clast-supported. Principal clast types include felsic and intermediate volcanic, chert and marble, mainly dolomitic; subordinate types are quartzose and feldspathic sandstone, quartz-feldspar porphyry and mafic volcanic (Pilon, 1981). Felsic and intermediate volcanic clasts are mainly fine-grained, felty-textured lavas. Some felsic clasts contain former pumice fragments and evidence of welding. Quartz-feldspar porphyry clasts are probably the eroded subvolcanic equivalent of the lavas. Massive and layered chert clasts are grey, red and (or) black; some bearing magnetite strongly resemble rocks west of the north end of Belmont Lake (cf. Pilon, 1981). Marble clasts are abundant at four stratigraphic levels in the formation. On Big Island they occur immediately overlying intervals of marble interstratified with siliceous clastic rocks (M.S. Bourque, personal communication, 1983). They also occur at two distinct stratigraphic levels near the top of the formation, on the east shore of the lake; here there are no underlying marble units associated with them. Whereas many marble clasts are massive, some contain algal structures; Miller and Knight (1914) recognized such "Eozoon" structure in clasts of the conglomerate on Crowe River Point of Belmont Lake (see Map). Sandstone clasts generally resemble layers interbedded with the conglomerates. Mafic volcanic clasts are typically highly amygdaloidal.

The matrix of the conglomerate varies from mudstone to quartz and (or) calcareous sandstone. Granule-size lithic fragments, generally felsic volcanic and subvolcanic, occupy up to 15% of the matrix. Magnetite and hematite are commonly abundant in the matrix.

Thin to thick bedded mudstone and sandstone units interstratified with conglomerates are grossly similar to the conglomerate matrix, although the lithic fragment component is generally minor or lacking. Primary sedimentary structures such as cross-bedding, scour channels and load features are locally abundant.

Cropping out at two distinct stratigraphic levels on Big Island, and on the east shore of Birch Island (see Map) are dolomitic marble units interlayered with mudstones and conglomerates. Characteristically massive in their lower parts, these units contain domal and laminar algal structures.

Near the top of the Belmont Lake formation, on the east shore of Belmont Lake, a 20 m thick unit of fine-grained felsic fragmental rock is exposed for a strike length of about 300 m (see Figure 4). The upper half of the unit is generally poorly exposed; the succeeding description draws mainly from observations on the lower half. The pink-grey, beige-weathering rock contains up to 15% each of plagioclase and blue and colourless quartz crystal fragments; some are euhedral and up to 5 mm across. Lithic fragments, some accidental, occupy up to 5% of the rock;

these include carbonate-rich (sedimentary ?), plagioclase-rich (subvolcanic) and scoriaceous intermediate lava fragments; lithic fragments are generally less than 5 mm long. A common alignment of elongated fragments is parallel to the base and strike of the unit. Some lenticular fragments several millimetres in length are here interpreted to be pumice; these are more easily seen in thin section. The matrix is roughly equigranular, and has been recrystallized to quartz and alkali feldspar; in thin section the originally vitric (now devitrified) nature of the matrix is revealed by the irregular, wavy distribution of minute magnetite grains that, in part, mimic original shards. Discrete shards are generally not recognizable, but have been flattened and partly transposed, probably due to moderate welding. The resultant eutaxitic foliation, parallel to fragment alignment, is also defined by pumice fragments, now flattened to wispy lenticles composed of quartz, alkali feldspar and up to 30% magnetite dust; these fiamme are commonly draped over crystal fragments.

Poor sorting, lack of stratification, composition of matrix and major fragment types, eutaxitic foliation and moderate welding in the lower parts of the unit indicate that this rock is an ash flow tuff (cf. Ross and Smith, 1961). The authors interpret the vesicles in the lower part of the unit as representing trapped gases, possibly steam incorporated into the ash flow as it overrode shallow water sediments.

Overlying the ash flow tuff is a 70 m thick unit comprising conglomerate, feldspathic sandstone and siltstone. The conglomerate is mainly clast-supported with pebble-sized clasts of felsic volcanic rock, including lavas with flow laminations, and rocks similar or identical to the underlying ash flow tuff; with local exceptions calcitic marble clasts are subordinate in amount, as are uniform cherty mudstone clasts. The matrix of the conglomerates is mainly feldspathic arenite, which also composes the predominant lithology of this unit. Commonly cross-bedded, these sandstones are bedded on a scale of centimetres to metres; where interbedded with siltstone, the sandstone beds commonly contain rip-up clasts of the finer-grained rock. Granular to pebble-sized clasts, similar to those in the conglomerates, locally occur to 10% in the sandstone. Siltstone is generally interbedded on a centimetre- to decimetre-scale with the sandstone; locally it possesses fine laminations. Convolute bedding surfaces, grain gradation, load casts and slump folding (Photo 11) are common structures in the interbedded sandstones and siltstones.

Bartlett (1983) proposed that the unit described above represented the top of the Belmont Lake formation. Detailed mapping by the authors in the fall of 1983, however, revealed that two thin, previously undiscovered clastic sedimentary units overlie the unit described above, and are each interstratified with mafic volcanics of the Crowe River formation (see Figure 5). These units are here assigned to the Belmont Lake formation. The lower unit, 10 m thick, contains conglomerates, sandstones and siltstones that are essentially identical to rocks in the clastic unit overlying the ash flow tuff. Bedding within the unit is concordant, in most places, to the upper and lower contacts of the unit, and to planar structures (eg. agglomerate/flow contacts) in the enclosing mafic volcanics. Sandstones are commonly cross-bedded, locally revealing that the unit is east-facing.

The upper clastic unit of the Belmont Lake formation is 10 m thick, and is traceable only for 275 m (see Figure 5). It comprises mainly feldspathic arenite, in beds up to 1 m thick, and is interbedded on a scale of centimetres to decimetres with dark grey-weathering siltstone. Graded bedding indicates stratigraphic top is to the east. The upper contact with mafic agglomerates is exposed at one locality (Figure 5); here grey-weathering sandstone yields upward to a pink-white-weathering fine-grained rock that may be altered (silicified) felsic tuff or epiclastic rock. This rock is about 60 cm thick and sharply abuts several centimetres of chlorite schist of the Crowe River formation; this contact may be fault-controlled despite concordance of structures across it.

One notable characteristic of both clastic units at the top of the Belmont Lake formation is that, although intercalated with mafic volcanic rocks, including agglomerate (which was probably unconsolidated when deposited), there is no mafic volcanic component in the clastic sedimentary rocks.

Crowe River Formation

The lower contacts of the Crowe River formation, with rocks of the Marmora and Belmont formations, have been discussed above. To the north and east the Crowe River formation is truncated by the Cordova Gabbro; to the south it is covered by Ordovician limestone. The maximum thickness of the formation is about 4500 m.

The Crowe River formation comprises two members. The lower, dominant member consists mainly of massive and amygdaloidal mafic lavas, agglomerates and tuff breccias; plagioclase-phyric lavas are locally abundant. Subordinate rock types include intermediate lavas and pyroclastics, and felsic tuffs. On the south side of Crowe Lake this unit is succeeded by a relatively thin member consisting of marble and derived skarn.

As stated above, rocks of the Crowe River formation and Belmont Lake formation are interstratified. The base of the lowermost mafic volcanic unit is exposed only at one locality (B, Figure 5); here the contact is sharp and conformable, with non-uniform lava directly overlying pebble conglomerate. The lower part of this mafic unit comprises mainly amygdaloidal flow rocks; agglomerates predominate in the upper part and in the next mafic volcanic unit to the east. The agglomerates are locally highly variable along strike in terms of their fragment: matrix ratio, the size and shape of fragments, and the composition of the matrix (probably related to the effects of hydrothermal alteration). Most agglomerates are non-sorted and contain 80-90% rounded fragments of variable shape (Photo 12); fragments generally range from coarse lapilli to small bombs, although some exceed 20 cm in maximum dimension. Light to dark grey-weathering for the most part, some fragments display white-weathering vesicle-rich parts; this is interpreted to have resulted from the passage of hydrothermal fluids through the more porous parts of the rock. Rocks containing fragments that are considerably longer in one dimension, or are complexly contorted, and commonly have diffuse fragment-to-fragment boundaries are agglutinates. These rocks indicate that eruption and deposition were subaerial. No rocks in the lowermost part of the Crowe River formation show evidence of secondary deformation; vesicle shape and orientation are a function of plastic deformation upon impact.

The matrix of the agglomerate is typically dark grey- or brown-weathering, and composed of coarse ash-sized particles; millimetre-scale stratification of the matrix is observable in some rocks. Less common rock types laterally equivalent to the type agglomerates described above have up to 70% matrix material (less than 2 mm), hosting subrounded to subangular, fark grey-weathering, vesicle-poor lapilli. These rocks may represent a reworked facies of agglomerate or explosion breccia.

Above the uppermost clastic sedimentary unit of the Belmont Lake formation the predominant rock type changes gradually, over a thickness of 200 m, from agglomerate to flow rocks. In general, the lower part of the Crowe River formation consists mainly of aphanitic to fine-grained, dark green-grey, red-brown-grey-weathering mafic flows, typically amygdaloidal and locally plagioclase-phyric. The rocks are generally uniform. Primary flow textures are partially preserved in the southernmost rocks of the lower section, however rocks of the central and northern parts are more recrystallized, with simple- to complex-interlocking plagioclase subgrains interstitial to hornblende blades or aggregates. The principal mineralogy is hornblende and plagioclase, with chlorite present only in the southernmost rocks. Where present, chlorite imparts a moderate schistosity to the rock. Colour index varies from 45 to 80. Amygdules show little deformation and consist mainly of quartz and (or) epidote and calcite.

Rocks of the middle part of the formation crop out mainly in a 7 km-long peninsular exposure indenting the Ordovician limestone (Figure 4). These rocks differ significantly from those of the lower part in that intermediate volcanics and flow breccias are more abundant; primary textures are generally well-preserved and hornblende is uncommon; amygdule size and abundance is generally greater than in rocks of the lower part; plagioclase phenocrysts are more common, particularly in the northeastern rocks of the middle part; disseminated magnetite and hematite are more abundant.

Mafic flow rocks of the middle part of the formation are similar to those of the lower part; they are aphanitic, medium green-grey, light beige- to dark brown-grey-weathering, uniform, massive to amygdaloidal with a CI of 35-75. Actinolite is the sole amphibole, occurring as prisms and blades; plagioclase is generally recrystallized to simple- to complex-interlocking subgrains interstitial to actinolite. Chlorite is a common varietal mineral, in some cases imparting, with actinolite, magnetite and titanite, a weak schistosity to the rock. Some rocks contain up to 50% chlorite, randomly oriented. Prograde epidote is present in some rocks, in varietal amounts.

Mafic rocks in the middle part of the formation also occur in fragmental deposits several metres thick; mafic felty-textured fragments up to 40 cm long, averaging 10 cm, are commonly elongate or irregular in shape and amygdaloidal; some have mutually conformable boundaries, with or without delicate outlines contacting a matrix composed of epidotized, aphanitic, possibly size-graded, plagioclase. The fragment: matrix ratio is commonly 2:1. The non-sorted nature of these rocks, lack of overall stratification, and composition, size and texture of fragments and matrix suggest that these rocks are agglomerates; further, those rocks containing fragments with mutually conformable boundaries are interpreted to be agglutinates (cf. Parsons, 1969; Macdonald, 1972). Similar rocks consisting of intermediate (altered mafic?) volcanic fragments in a mafic matrix are also common and are interpreted to be agglomerates; fragments are typically fine-grained, pilotaxitic to trachytic, amygdaloidal to cellular and consist essentially of epidotized plagioclase with up to 10% magnetite. The aphanitic matrix is composed of epidotized plagioclase and 25% actinolite, with 10% biotite defining a weak schistosity. Locally, as at UTM 27673/492784, tuff breccia containing mainly subangular fragments grades upward, over several metres, into agglomerate; this reflects a gradual change toward a less explosive eruption type with time.

The middle part of the Crowe River formation contains intermediate volcanics as flows, including flow breccias, and as agglomerate and rare lapilli-tuff and lapillistone. Flows are commonly fine-grained, medium green-grey, light green-brown-grey-weathering, uniform, massive to highly amygdaloidal and have a CI of 15-30. Flows are typically 5-10 m thick, and commonly exhibit amygdule gradation; flow bases are non-vesicular, but amygdules increase in size and abundance toward the top. The amygdules consist of quartz, epidote, calcite and (or) actinolite and range to 10 cm or more. Amygdule size, shape, abundance and distribution in many flows of the study area strongly resemble amygdule characteristics in the massive parts of typical aa flows (cf. Macdonald, 1972). These rocks are generally pilotaxitic or felty-textured; some contain minor plagioclase phenocrysts. Groundmass plagioclase (An_8) occupies 40-70% of the rock; actinolite varies to 25%. Chlorite and actinolite were not observed to be compatible in the same rock; whereas most rocks are actinolitic, some contain up to 20% chlorite. Ten to twenty percent epidote is disseminated throughout the rock, in part included in plagioclase grains. Up to 5% magnetite is typical, partly altered to titanite.

Some intermediate to mafic flow rocks are uniformily laminated on a scale of several millimetres. This texture is defined by an alternation of mafic mineral-rich versus mafic mineral-poor layers, and strongly resembles a texture present in modern aa flows that have become de-gassed (R.M. Easton, personal communication, 1983).

Coarse intermediate fragmental rocks consist of rounded to subrounded, medium grey, light green-grey-weathering fragments, averaging 10-12 cm, in a fine-grained matrix, medium brown-grey on fresh and weathered surfaces. Fragments are felty-textured to pilotaxitic and amygdaloidal; they are of identical composition to the lava described above; fragment type is variable mainly with respect to amygdule content. In contrast, the matrix consists of granular plagioclase, essential hornblende and epidote, and minor magnetite and chlorite. The CI of both fragments and matrix is generally about 30. On the basis of the general lack of stratification, poor sorting, and fragment and matrix size and texture, these rocks are interpreted to be agglomerates (cf. Parsons, 1969; Williams and McBirney, 1979).

In mafic and intermediate rocks the content of magnetite and, in particular, hematite generally increases east of UTM 277/4929. Bartlett (1983) considered that this might be related to the oxidation potential of the environment of deposition of these rocks; that is, the relatively sudden appearance of hematite may signify the change from predominantly subaqueous to predominantly subaerial deposition. Further detailed mapping (Figure 5) delimited abundant agglomerate and agglutinate in the lowest parts of the Crowe River formation, indicating that the environment of deposition was subaerial for those rocks, and thus probably subaerial for most of the rocks of the remainder of the formation.

Felsic volcanics and derived rocks are rare in the Crowe River formation. At UTM 27762/492922 a 2-3 m thick unit of millimetre- to centimetre-layered, aphanitic, highly epidotized quartzofeldspathic rock exhibits normal size grading. These characteristics suggest that this rock represents a waterlaid airfall tuff (cf. Williams and McBirney, 1979). The laterally discontinuous nature of this deposit, coupled with the close spatial relationship to agglomerates, suggests that this rock may have formed in a pond on the flank of the volcano.

At UTM 27590/492470 a granule to boulder volcanic conglomerate unit, 1.5 m thick, contains sub- to well-rounded clasts, up to 30 cm long, of white and pink, aphanitic felsic rocks, and epidotized, amygdaloidal material in a medium brown-weathering matrix. On the basis of heterogeneity of clast types and degree of rounding of felsic clasts, the deposit is interpreted to be epiclastic. Low sphericity, poor sorting, relatively large clast size and lack of internal stratification suggest that this is a proximal deposit (cf. Blatt et al., 1980); the rounding does not preclude this conclusion (cf. Pearce, 1971).

Limited exposure of, and access to, the upper part of the Crowe River formation renders it poorly understood relative to lower parts of the formation. Rocks similar to those of the middle part were observed. Some mafic flows display ophitic and sub-ophitic textures.

An enigmatic, though common, feature of volcanic rocks of the Crowe River formation is the presence of epidotized, podiform bodies varying from several centimetres to more than 1 m in length, hosted by flows and fragmental rocks. Though epidote has extensively replaced much of the original rock, some primary structures are preserved; vesicles and fragment outlines within some pods indicate that replacement by epidote occurred without regard for differences in rock type or matrix-fragment transition. This suggests that the replacement process was not related solely to porosity and permeability of the host rock. The replacement appears to have been complete before D_1 deformation; a unit of lapilli-tuff (UTM 27673/492784) shows the D_1 deflection of primary structures around one epidote-rich pod (Photo 13). These podiform alteration features are similar to mottled quartz-epidote alteration features in andesite flows of the upper member of the Amulet Rhyolite formation, central Noranda volcanic complex.

Gibson et al. (1983) interpreted the latter features to have resulted from sea-water-rock interaction in highly permeable andesite flows.

Near Blairton (Map), a 70 m thick interval of calcitic marble and skarn separates the volcanic member of the Crowe River formation from gabbro. This unit, cropping out on the south shore of Crowe Lake, hosts the Blairton Iron Mine which yielded an estimated 300,000 tons of magnetite ore between 1820 and 1875 (Bartlett et al., 1982). Although now largely converted to skarn, marble occurs as vestiges; fine-grained, granoblastic calcite is the main constituent of the marbles; tremolite is a common essential mineral, occurring as euhedral prisms generally elongate parallel to a minor chlorite sheaf foliation.

Intrusive Rocks

Ultramafic Rocks

The only ultramafic intrusive rocks in the map-area occur in a small body, less than 200 m across, known as the Bonter Pluton (1.8 km southeast of Twin Sister Lakes). It was originally an olivine pyroxenite or peridotite, as evidenced by relict poikilitic textures, preserved in amphibole, typical of olivine granules in coarse pyroxene. The rock is coarse-grained, uniform, hypidiomorphic-granular, dark brown-grey and brown- to rusty-weathering. It now consists almost entirely of amphibole of two varieties; one pseudomorphs olivine and is partially replaced by chlorite; the other pseudomorphs large pyroxene grains. Relict clinopyroxene is present in some rocks. Minor epidote, plagioclase, chlorite and talc also occur. The body intruded wackes of the Vansickle formation. Cu-Ni mineralization is associated with this pluton.

Mafic and Intermediate Rocks

Introduction

Mafic rocks intrude all formations (Map). Small mafic bodies intrude the Oak Lake and Cordova Lake formations; mafic dikes are common only in the middle and upper sections of the Cordova Lake formation, and in part of the Vansickle and Marmora formations.

Apart from the Cordova Gabbro, nearly all mafic intrusive rocks are amphibolites composed of hornblende and plagioclase; the only exceptions are biotite and (or) chlorite lamprophyre dikes intruding rocks of the Belmont Lake and Crowe River formations. Several gabbro bodies of various size occupy the area north of Round Lake (Map); the northern gabbros are typically coarse- to very coarse-grained, with cumulate and (or) oikocrystic textures common. Further south, gabbros are generally fine- to medium-
ART 3B grained and contain up to 40% plagioclase phenocrysts, commonly
ART 3C heavily saussuritized and, locally, normally zoned. Colour index varies from 40 to 60. Some elongate map-scale gabbro bodies are oriented parallel to sinuous D_1 structures, suggesting that intrusion took place before D_1 deformation; that these gabbros were synvolcanic is demonstrated by gradational transition from mafic flows to gabbro north of Round Lake.

Cordova Gabbro

The Cordova Gabbro differs from other intrusive bodies in the map area in that the predominant amphibole is actinolite rather than hornblende, and layering, absent in all other plutonic rocks, is locally distinct. Rocks of the pluton are fine- to very coarse-grained gabbro and leucogabbro, with subordinate anorthosite; oikocrysts up to 15 cm across are present in some parts of the body. Generally uniform, these rocks are massive to moderately foliated; foliation is typically most pronounced within a zone 500-1000 m from the contact of the pluton, and is commonly parallel to it (Thomas and Cherry, 1981). Recrystallization mainly affected the mafic constituents of the gabbro, converting pyroxene to actinolite, and, locally, hornblende and chlorite; in some rocks former pyroxene grains have actinolite cores and hornblende rims. Original shape and size of plagioclase grains has been generally retained; despite partial alteration to chlorite, sericite, calcite and epidote in the northern rocks, and clinozoisite in the southern rocks, the composition of plagioclase is andesine (An_{32} to An_{51}). Magnetite, ilmenite, apatite and titanite are commonly present in minor amounts.

Compositional layering on a scale of centimetres to decimetres is evident locally near the north and west margins of the Cordova Gabbro; metre-scale layering is present in some parts of the body within Marmora Township. Layers vary from melanogabbro to anorthosite; some show grading from a mafic base to a plagioclase-rich top (Photo 14). These features are interpreted to represent primary gravity settling structures within the magma chamber.

Anorthosite, present locally within the Cordova Gabbro in Belmont Township, occupies a greater proportion of the intrusive body in Marmora Township; typically medium-grained, this rock is generally partly altered to epidote and white mica. One anorthosite sample (UTM 28180/493009) contains unaltered andesine (An_{40}); altered plagioclase in the same rock is An_{11}.

Within the gabbro body shear zones up to tens of metres in width host auriferous quartz-carbonate veins that have been exploited in the past (see Economic Geology section). Highly sheared rocks consist primarily of chlorite and biotite (Thomas and Cherry, 1981).

Associated with parts of the western margin of the Cordova Gabbro are coarse intrusive breccias (Photo 15), that have resulted from fracturing of fine- and coarse-grained gabbro and injection of fine-grained dioritic and tonalitic material. The felsic intrusive rocks are probably late differentiates of the gabbroic magma, based on the nature of the brecciation and the spatial restriction of this rock to the periphery of the gabbro body.

Horse Lake Diorite-Gabbro

The Horse Lake Diorite-Gabbro is an oval body in southern Methuen Township (see Figure 3); about one-half of the body is within the map-area. Hewitt (1960) described the entire body; the following description pertains mainly to the rocks exposed in the map area. The diorite is massive and fine- to medium-grained, with a CI of 30. Augite and oxides are successively mantled by greenish-brown hornblende and brown biotite, with wormy intergrowths of quartz. Plagioclase is partly in coarse relict laths, with andesine (An_{34}) cores and oligoclase rims; it is partly recrystallized to a mosaic of oligoclase.

Enveloping the Horse Lake intrusive body is a rim (see Figure 4) of granitic rocks; these grade from the diorite along the southern periphery through granodiorite to granite, including porphyritic granite. Myriad granite dikes cut the diorite. Inclusions of rocks from the Oak Lake formation commonly occur in the granitic rim rock (Hewitt, 1960).

Twin Sister and Shanick Diorites

The Twin Sister Diorite and the Shanick Diorite (Figure 4) are mainly composed of diorite, but are heterogeneous and vary from gabbro to syenite and granite. The diorite is pink to grey, medium- to coarse-grained, foliated, and contains both amphibole and biotite. Quartz diorite occurs throughout both intrusions; it is typically inequigranular, massive, uniform and hypidiomorphic-granular. Biotite granodiorite is leucocratic to mesocratic, medium- to coarse-grained, massive to moderately foliated and inequigranular with quartz in larger grains relative to the feldspars. Fine-grained leucocratic granite and massive medium- to coarse-grained syenite to quartz syenite occur in the Shanick Diorite body.

Unnamed Diorites

The Marmoraton open pit (Photo 16) exposes an unnamed diorite intrusion that has a discontinuous syenitic border against carbonate sedimentary rocks, now extensively replaced by skarn. This intrusive body, separate and distinct from the Cordova and Deloro plutons, lies on the trace of an arcuate aeromagnetic anomaly that also includes small exposures of diorite and leucocratic gabbro at

Marmora and south of Crowe Lake. These rocks may represent the northern periphery of a large intrusive mass beneath the Paleozoic cover; this mass may include the gabbro whose intrusion led to the formation of the Blairton iron deposit (see Economic Geology section). At the Marmoraton open pit biotite-hornblende diorite is massive, uniform, medium-grained, dark grey and light grey-weathering. The associated quartz-perthite syenite is pink to yellow-grey, massive, uniform, hypidiomorphic-granular, and locally contains xenoliths of fine-grained plagioclase-phyric mafic rocks.

Small discrete diorite bodies, similar in predominant lithology to the Twin Sister and Shanick Diorites, occur in the north part of Marmora Township, and about 5 km north of the town of Marmora, where the main rock type is fine- to medium-grained, massive, grey-green, buff-weathering biotite-amphibole diorite.

Mafic Dikes

Mafic dike rocks, best represented south of Cordova Lake, are typically medium-grained; in all other aspects they are identical to nearby extrusive rocks. In some places, particularly between Lost and Cordova Lakes, a gradational transition from fine-grained extrusive rocks through medium-grained to coarse gabbroic rocks indicates that the latter types are the hypabyssal and deeper equivalents of surficial flows. Dikes similar to those associated with volcanic rocks of the Cordova Lake formation cut marbles in the Belmont Lake and Cordova Lake areas. One 4 m wide dike on the west shore of Belmont Lake (UTM 27540/493168) metamorphosed the host marbles within 30-40 cm of the contact. Because all dikes observed have been metamorphosed, it is possible that their intrusion was a synvolcanic event. Indirect evidence supporting this includes the close spatial relationship, despite the proposed major fault, between intermediate volcanics and dikes of the Cordova Lake formation (Figure 4, Map), and intermediate dikes cutting the marbles of the Marmora formation.

Granitic and Syenitic Rocks

Belmont Granite

Straddling the Belmont-Methuen Township boundary is a granitic body, here named the Belmont Granite, that cuts, and intermingles with (Hewitt, 1960), deformed rocks of the Oak Lake formation (see Figure 4). The body consists mainly of fine- to coarse-grained biotite leucogranite, porphyritic granite, quartz monzonite and granodiorite. Microcline, sodic oligoclase and quartz are the essential constituents; orthoclase is rare; Hewitt (1960) noted the presence of microperthite. The rocks are typically hypidiomorphic- to allotriomorphic-granular and seriate, with simple- to complex-interlocking grains. Marginal granulation of coarse feldspar, and a weak mica fabric indicate a degree of strain considerably lower than that of the enclosing rocks, suggesting late tectonic emplacement of the intrusive rocks.

Deloro Granite

The Deloro Granite is a sub-circular body of predominantly massive, coarse, deep pink mesoperthite-bearing granite, containing 2-5% riebeckite and brown biotite; apatite and fluorite are accessories. Only the western third of the pluton is exposed in Marmora Township. Along the eastern boundary of the map-area the granite is mainly biotite-bearing and more heterogeneous, including "two-feldspar" granite with discrete microcline and oligoclase, and porphyritic granite with perthite phenocrysts. West of Jarvis Lake (Map), a small body of diorite is enclosed in the perthite granite. Most of the western contact is occupied by an arcuate mass, up to at least 1.2 km in width, that varies in composition from gabbro to syenite and quartz syenite. This border zone is heterogeneous, but there is a general succession toward more felsic composition as the granite is approached; the more mafic members are older than the felsic rocks. For example, east of Deloro (see Map) the border zone varies eastward from hornblende-plagioclase gabbro at the Moira River, through diorite to syenite, with an increase in perthite and a decrease in plagioclase and hornblende. A relatively abrupt contact with the granite is defined over about 20 m by an increase in quartz content and by a marked rise in elevation to the granite. Border zone rocks in the vicinity of Deloro and Malone (see Map) are hydrothermally altered, replaced extensively by carbonate, biotite and potassic feldspar and are cut by auriferous quartz-carbonate-arsenopyrite veins. The main body of the granite contains small dioritic xenoliths, and dikes of mafic and intermediate composition which have been deformed and metamorphosed. It is also cut by calcite-fluorite-barite veins in the southern part. Although the granitic rocks appear, superficially, to be unaltered, microscopic study reveals recrystallization of coarse mafic minerals to clots of fine grains, and marginal granulation of the feldspars. In the Deloro Granite coarse riebeckite is replaced by clots of fine riebeckite and biotite. Mafic dikes emplaced along a master joint in the granite (followed by Highway 7, see Map) are composed of locally schistose amphibolite; relict chilled margins show that the mafic rocks are not xenoliths, but that metamorphism outlasted dike emplacement. Toward the centre of the pluton, aplite and pegmatite dikes become prominent. These may be related to the emplacement of an inner ring of granophyric granite, exposed in Madoc Township to the east (Saha, 1959).

According to Kuehnbaum (1973), the ring-shaped geometry and "hypersolvus" (mesoperthitic) character of the granite, together with the presence of spherulitic, devitrified dikes in the body, argue for emplacement to less than 2-3 km depth, and perhaps subvolcanic intrusion.

Malone Pluton

The Malone Pluton consists mainly of very fine-grained, porphyritic alkali-feldspar granite, with phenocrysts generally 0.5-1 mm across, of anhedral quartz and subhedral plagioclase and microcline and/or orthoclase and/or perthite. This pluton may be a high level satellite of the Deloro Granite.

Gawley Creek Syenite

The Gawley Creek Syenite (see Figure 4) comprises mainly homogeneous, massive, medium- to coarse-grained, hypidiomorphic-granular, pink, grey-pink-weathering hornblende-biotite-perthite syenite. At its southernmost extremity it is poorly exposed and contains numerous bodies of amphibolite, probably xenoliths.

Granitic Dikes and Small Intrusions

As a general rule, felsic and intermediate dikes and small intrusive bodies are more prevalent in Marmora Township whereas Belmont Township contains mainly mafic intrusive rocks.

Microgranitic dikes and small intrusive masses up to 150 m across are prominent around the Malone and Deloro intrusions. Several of these are quartz- and plagioclase-phyric, in a very fine granular quartz-alkali feldspar matrix with only a trace of biotite. Leucocratic, fine-grained dikes with feldspar and quartz phenocrysts are also notable in wackes south of the Twin Sister Diorite body. A felsite sill of several metres width is enclosed by carbonate-rich sediments northeast of Crowe Lake (UTM 28384/493441).

Discussion

Like the Deloro Granite the Gawley Creek Syenite and the syenite at the Marmoraton open pit are also hypersolvus, and have prominent contact metamorphic aureoles. There is thus strong evidence of a high-level plutonic event that presumably post-dated at least part of the regional deformation and metamorphism (see Metamorphism section), but has been succeeded by a later metamorphism. The anhydrous nature of these plutons may have enabled them to remain rigid relative to the enclosing carbonate rocks, and hence little deformed. It is noteworthy, however, that a small granite body between the Deloro and Gawley Creek stocks, on the east boundary of the map-area, is strongly mylonitized.

CONTACT METAMORPHIC ROCKS

Carbonate-bearing sedimentary rocks adjacent to some of the major plutons have been partly converted to skarns. Carbonate-rich rocks of the Marmora formation were affected by the intrusion of the Cordova Gabbro. Within Belmont Township, skarn was observed within 80 m of the gabbro body at one locality (UTM 27794/493320), as an outcrop-scale xenolith within the body, and at the Belmont Iron Mine (see Economic Geology section). In the latter case diopside-garnet-epidote-carbonate skarn is enclosed in the intrusive body; iron was metasomatically concentrated to produce magnetite ore. Within Marmora Township, the Cordova Gabbro metasomatically altered carbonate rocks to produce schistose and decussate, fine- to medium-grained skarns having the typical assemblage tremolite-epidote-carbonate-quartz, with or without titanite, white mica and feldspar. Clinopyroxene, probably diopsidic, occurs at several localities. The width of this aureole is at least 900 m at the north side of the pluton and at least 800 m at the east side. Two kilometres southeast of Cordova Mines (Map) contact metasomatism has concentrated iron oxides and sulphides in rocks lying at or near the contact between the gabbro and the country rocks. On the east shore of Crowe Lake wollastonite is present in reaction zones between quartz and calcite.

The upper member of the Crowe River formation at the Blairton Iron Mine was largely converted to epidote-andradite-clinopyroxene-magnetite-pyrite-carbonate skarn by the intrusion of a body, at least in part gabbroic, that is interpreted as being separate from the Cordova Gabbro.

The Marmoraton contact metasomatic iron deposit has been studied extensively; the most detailed account of the geological setting is by Park (1966). Intrusion of calcite marble, presumably belonging to the Marmora formation, by a diorite/syenite pluton resulted in the formation of skarns with assemblages including andradite, clinopyroxene, hornblende, epidote, pyrite, pyrrhotite and magnetite; andradite is commonly zoned.

The Gawley Creek Syenite intruded intercalated carbonate and siliceous sedimentary rocks of the Vansickle formation to produce layered skarns; the originally siliceous layers have been epidotized, whereas the carbonate-rich layers have been converted to the assemblage epidote-clinopyroxene-quartz-plagioclase-pale actinolitic amphibole-calcite-titanite. The continuity of the contact aureole is not known; its width is greater than 50 m.

The Deloro Granite and its diorite border zone intruded pure and impure carbonate sedimentary rocks to produce contact metamorphic and metasomatic rocks. In the Malone area these rocks are tremolite-calcite skarns, pyrite-pyrrhotite-epidote-magnetite-carbonate rocks and others consisting of calcite-tremolite-serpentine-brucite: the latter two minerals probably formed at the expense of forsterite and periclase, respectively The rocks are locally layered and brecciated. North of the town of Deloro some assemblages include garnet and diopside. The contact aureole in the Malone area spans the breadth of the zone between the Deloro and Malone Granite bodies. Southwest of the Deloro Granite tremolite has developed in relatively pure carbonate rocks, which have been quarried in the past (see Economic Geology section). The width of the aureole is about 1 km in this area. Directly south of the Deloro pluton the contact aureole is about 800 m wide, and includes hornfels as well as skarn. Immediately adjacent to the intrusive body is a 100 m wide zone in which the common assemblage is hornblende-diopside-garnet-carbonate, with or without epidote, titanite, quartz and magnetite. The succeeding zone contains skarns with the assemblage garnet-alkali feldspar-vesuvianite-epidote-quartz-plagioclase-carbonate. Garnet and diopside do not occur in a third zone, containing the following characteristic minerals: hornblende, which decreases in abundance away from the granite, actinolite, biotite, epidote, microcline, carbonate, plagioclase and quartz. Locally present are clinozoisite, pyrite and magnetite.

The most distant indication of the effects of contact metasomatism is the presence of talc, which replaces tremolite in interlayered carbonate and siliceous sedimentary rocks. Relict layering is evident in many rocks within the aureole. Grain size generally increases toward the pluton. Decussate textures are present in most rocks.

PHANEROZOIC ROCKS

Ordovician Sedimentary Rocks

Except in local escarpments and cuts, the Ordovician sedimentary succession is not well-exposed and, in view of the prior work of Carson (1979), was studied only superficially by the authors.

In the south and west parts of the map area the Precambrian rocks are blanketed by flat-lying Ordovician limestone, which also occurs as outliers of up to 3 square kilometres size throughout the remainder of the area studied. The surface of the Paleozoic rocks constitutes a plateau that is locally below the summits developed in Precambrian rocks, indicating pre-Paleozoic relief on the Precambrian surface. Examples are the long, north-trending ridge of volcanic rocks that penetrates the Paleozoic outcrop west of Crowe Lake (see Figure 4), and summits in the Cordova Gabbro and Deloro Granite.

At the Marmoraton open pit mine, the basal 3-5 m of the Ordovician succession consist of unmetamorphosed red and green calcareous sandstone and siltstone; these rocks pass upward into uniform, medium-bedded grey limestone. Total thickness of the Paleozoic cover is at least 40 m at the mine, probably close to a maximum for the map area. The boundary of the Paleozoic rocks southeast of Crowe Lake is straight, suggesting fault or joint control. The chain of outliers trending northwesterly across the western part of Marmora Township is roughly parallel to structural trends in the surrounding Precambrian rocks, and may mark a pre-Ordovician topographic depression.

Metamorphism

The following section is derived mainly from Bartlett's (1983) study of metamorphism in Belmont Township; in addition, less detailed data from southern Methuen and Marmora Townships are presented.

Mineral assemblages and textures provide evidence, in general, of one major metamorphic event (M_1, Table 4) associated with and continuing beyond the first major deformation (D_1), and the formation of the regional fabric (S_1). Evidence of other metamorphic events: contact metamorphism, and later overprinting of M_1 assemblages, is local in extent. Accordingly, mineral assemblages and zonation discussed in this section are believed to be related to the main (M_1) metamorphic event, the timing of which will be discussed in further detail below.

Metamorphic Zonation

On the basis of the mineralogy of mafic and intermediate rocks, Bartlett (1983) divided Belmont Township into three zones, in order of increasing grade: actinolite, chlorite-hornblende and hornblende. The actinolite zone corresponds to the greenschist facies and the hornblende zone to the amphibolite facies of regional metamorphism; the chlorite-hornblende zone represents the transition from greenschist to amphibolite facies. The zones are ilustrated in Figure 6, and their stable mineral assemblages are tabulated in Table 2.

The actinolite zone within Belmont Township occupies the southeasternmost part of the area, encompassing most of the Crowe River formation. Actinolite[6] is the predominant amphibole; hornblende[6] is less common and is not compatible with actinolite. Chlorite occurs throughout the actinolite zone, commonly with actinolite or hornblende. The "actinolite-out" isograd is diffuse; it defines the upper boundary of the actinolite zone.

Hornblende, occurring locally in the actinolite zone and throughout the chlorite-hornblende zone may have, in part, arisen from the reaction:

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[6] Although there is probably a continuous range of compositions between the tremolite-ferroactinolite and the hornblende series, for the purposes of this study a qualitative distinction between actinolite and hornblende has been made on the basis of stronger pleochroism and birefringence of hornblende relative to actinolite.

actinolite + clinozoisite + chlorite + quartz = hornblende (Winkler, 1979). This reaction can occur over a range of P-T conditions, possibly explaining the stable occurrence of actinolite and hornblende in this zone.

The predominant mafic mineral in the chlorite-hornblende zone in Belmont Township is hornblende, which occurs with or without chlorite in mafic volcanics. Chlorite occurs without hornblende in intermediate volcanics and mafic fragmental rocks. In general, epidote is less abundant and plagioclase is more calcic toward the west (higher grade).

Accurate extrapolation of the actinolite and chlorite-hornblende zones into Marmora Township is inhibited by three factors. First, mafic and intermediate rocks occur only in the extreme north and northeast parts of the township. Secondly, data concerning mineral assemblages in rocks of Marmora Township are less detailed than those in Belmont Township. Thirdly, those mafic and intermediate rocks for which stable mineral assemblages are known contain both chlorite and hornblende; these minerals occur in both the actinolite and chlorite-hornblende zones in Belmont Township and thus cannot be used to distinguish between zones. Qualitative distinction between zones is possible, however, on the basis of textural preservation data. Volcanic rocks in the actinolite zone of Belmont Township generally exhibit well-preserved flow textures, as opposed to the recrystallized rocks in the chlorite-hornblende zone. As volcanic rocks in northern Marmora Township do not display well-preserved flow textures, they could probably be assigned to the chlorite-hornblende zone. The mesoscopically well-preserved pillowed mafic flows (see Photo 8) in the volcanic unit south of the Gawley Creek Syenite (Figure 4) may belong to the actinolite zone.

The hornblende zone in Belmont Township is marked by the disappearance of chlorite in most mafic and intermediate volcanics; the presence of prograde chlorite in mafic hyaloclastites and pyroclastics at three localities (Figure 6) is ascribed to higher attendant CO_2 activity. It is possible that chlorite is consumed by reaction with epidote to produce hornblende and more calcic plagioclase:

chlorite + epidote + quartz = hornblende + anorthite

(Sethuraman and Moore, 1973).

Data concerning mafic and intermediate volcanics in southern Methuen Township are insufficient to allow accurate extension of the boundary between the hornblende and chlorite-hornblende zones in Belmont Township.

Table 3 summarizes the distribution of minerals in mafic and intermediate volcanic rocks, quartzofeldspathic rocks (mainly felsic volcanics) and pelites (metamorphosed claystones), and siliceous carbonate rocks in Belmont Township as a function of metamorphic grade. Some isograds in the latter three rock types are illustrated in Figure 7, together with the distribution of relevant stable mineral assemblages. Table 3 and Figures 4 and 5 illustrate several salient features:

1) minerals common to all metamorphic zones include biotite and epidote in mafic and intermediate rocks; biotite, muscovite and sodic plagioclase in quartzofeldspathic and pelitic rocks, and

quartz and dolomite in carbonate rocks;

2) anorthite content of plagioclase in mafic and intermediate rocks increases from about 8 mol % in the actinolite zone to about 29 mol % in the highest-grade part of the hornblende zone;

3) the stability fields of chlorite-hornblende and actinolite overlap; thus the lower boundary of the chlorite-hornblende zone is not marked by the first appearance of chlorite-hornblende;

4) the "chlorite-out" isograds for mafic and intermediate, and quartzofeldspathic and pelitic rocks are coincident;

5) inappropriate bulk compositions inhibit the precise location of some isograds (eg. "kyanite-in"). The reaction-isograd "dolomite + quartz = tremolite + calcite" was located only to within 1-2 km;

6) although dolomite and quartz persist in carbonate rocks on the high grade side of the above mentioned reaction-isograd, they do not occur together;

7) low pressure indicators such as cordierite and andalusite, and high temperature minerals such as sillimanite do not occur in rocks of appropriate bulk composition.

Assemblages in mafic rocks of the lower grade (southeast) part of the actinolite zone are roughly consistent with the common assemblage for greenschist facies metamorphism (Moody et al., 1983). Definition of the beginning of the greenschist-amphibolite transition zone is tenuous in the study area; this zone may overlap with the actinolite zone.

The chlorite-hornblende zone of the study area probably represents the greenschist-amphibolite transition. The width of the model transition zone is strongly dependent on oxygen fugacity; in more reducing environments the isobaric temperature range may be as much as 150°C, whereas in more oxidizing environments the temperature range may be less than 50°C. The presence of epidote in the stable mineral assemblage of rocks of the chlorite-hornblende zone suggests that oxygen fugacities were, in general, relatively high, and that the temperature range across the zone was thus relatively low (Moody et al., 1983).

The coincidence of the two "chlorite-out" isograds in Belmont Township (Figures 6, 7) marks the beginning of amphibolite facies. This is in accord with the findings of Moody et al. (1983), who defined the end of the greenschist-amphibolite transition zone by the disappearance of chlorite in mafic rocks. Winkler (1979), however, stated that Mg-rich chlorite may persist into amphibolite facies in mafic rocks.

On the basis of stable chlorite in pelitic rocks 1.3 km southwest of the hamlet of Vansickle (Murray, 1982), the "chlorite-out" isograd can be extended into Methuen Township; the isograd must be to the west of this occurrence of chlorite, although data are insufficient to determine how far west. This placement of the isograd suggests that only the southeast corner of Methuen Township contains rocks metamorphosed to greenschist-amphibolite transition facies. Most of southern Methuen Township, then, can be assigned to amphibolite facies. Local migmatization of felsic rocks around, and to the west of Oak Lake is consistent with the onset of muscovite breakdown, signalling an approach to upper amphibolite facies conditions.

The disappearance of chlorite alone from pelitic rocks does not necessarily mark the beginning of amphibolite facies (Winkler, 1979). However, the onset of amphibolite facies conditions is marked by the appearance of staurolite or cordierite in rocks of appropriate bulk composition. In Belmont Township some quartzofeldspathic rocks close to, and on the low grade side of the "chlorite-out" isograd (Figure 7) have bulk compositions plotting on an AFM diagram mainly in areas where staurolite could form; the absence of staurolite in these rocks suggests that staurolite is not stable in the chlorite-hornblende zone. The absence of staurolite and (or) cordierite on the high grade side of the "chlorite-out" isograd is attributed to inappropriate bulk composition of the rocks.

The relative prevalence of the assemblage muscovite + K-feldspar (typically microcline) in rocks of the Oak Lake formation is due mainly to higher K content; other quartzofeldspathic rocks in the area have very low K contents and bear virtually no modal K-feldspar.

On the basis of present data, no regional metamorphic isograds can be drawn in Marmora Township. Stable mineral assemblages in quartzofeldspathic, pelitic and siliceous carbonate rocks correspond with those on the low grade side of the "chlorite-out" isograd in Belmont Township. The authors suggest (see earlier argument) that the rocks in northern Marmora Township have been metamorphosed to the greenschist-amphibolite transition facies, but that an unknown proportion of the remainder of the township contains rocks at greenschist facies.

Textural Changes

Table 3 summarizes the state of textural preservation of rocks of all metamorphic zones in Belmont Township. Generally, most textures are well-preserved, except in the highest grade areas. Felty, pilotaxitic and trachytic flow textures are best preserved in rocks of the actinolite zone. Welding features in ash flow tuffs are recognized with certainty well into the hornblende zone. In rocks having a strong mineral or aggregate lineation, primary features are commonly well displayed in sections perpendicular to the direction of principal extension. With increasing grade, grains become larger, more uniform in size and habit, and more equant, particularly in the hornblende zone.

Metamorphic Conditions

The change from actinolite to hornblende probably takes place at about 500°C, rising only slightly with increasing pressure (Winkler, 1979); this temperature must have prevailed throughout most of the actinolite zone. Assuming that garnets in quartzofeldspathic and pelitic rocks of the study area are almandine-rich, minimum pressures can be proposed for rocks of the chlorite-hornblende zone; Winkler (1979) stated that a pressure of 4 kb at 500°C must be exceeded to stabilize almandine-rich garnet with a very low content of spessartine component. Minimum pressures in the higher grade parts of the hornblende zone can be estimated from the presence of kyanite; at temperatures of 500-600°C, minimum pressures of 4.5-6 kb are required to stabilize kyanite (Winkler, 1979).

Comparison of the sequence of mineral assemblages in the study area (Table 3) with sequences of the Abukuma Plateau and the southeastern highlands of Scotland reveals several mineralogic similarities and contrasts. These regions are considered to typify, respectively, relatively low and intermediate pressures of regional metamorphism (respectively, "Abukuma" and "Barrovian" facies series of Winkler (1965).

The sequence of mineral assemblages and their stability fields suggests recrystallization under a P-T regime similar to that of the Barrovian facies series. The metamorphic zones in the mafic and intermediate rocks correspond, in pelitic rocks, to the interval between biotite zone and staurolite and kyanite zones.

Metamorphism and Timing of Emplacement of Major Intrusive Bodies

The Horse Lake Diorite-Gabbro has undergone only partial recrystallization, as pyroxene is still preserved. The dioritic to granitic rim enveloping the pluton is younger than the deformation and metamorphism of the surrounding Oak Lake formation rocks (because it contains random foliated xenoliths of them), and the diorite-gabbro body, which it intrudes. By virtue of its spatial restriction to the margin of the Horse Lake pluton, it may be a late differentiate of the diorite-gabbro.

The granitic body south of the Horse Lake pluton and rim is little-recrystallized relative to the surrounding rocks, and therefore may have been emplaced late in the tectonic history of the area. However, timing of emplacement remains uncertain, as Ordovician limestone cover masks its relationship to D_2 structures in the Oak Lake formation. Hewitt (1960) noted the similarities, including the microperthitic nature, between this granitic body and the rim enveloping the Horse Lake pluton; it is possible that they are synchronous.

The mafic mineralogy of the Cordova Gabbro is consistent with upper greenschist facies metamorphism. Pronounced disparity between plagioclase compositions in the Cordova Gabbro (An_{32-51}) and the adjacent basalts of the Crowe River formation (An_8) suggests that the intrusive rocks are less recrystallized. This may be due to the greater resistance to recrystallization of coarse-grained plutonic rocks relative to fine-grained rocks. It is also possible that the recrystallization history of the gabbro was different from that of the neighbouring basalts; the gabbro may have been emplaced after peak-M_1 (see Table 4), conditions resulting in incomplete metamorphic re-equilibration relative to the basalts. Emplacement was probably post-D_1, as the gabbro appears to truncate D_1 structures in the basalts. The general absence of obvious D_1 fabric within the gabbro is also evidence supporting post-D_1 emplacement. That the gabbro pre-dates D_2 deformation is demonstrable; D_2 fabric in marbles of the Marmora formation "wraps around" the pluton.

The Twin Sister and Shanick Diorites are foliated in part, possibly reflecting early (syn-D_1?) emplacement.

As stated above, metamorphism outlasted the emplacement of the Gawley Creek and Deloro plutons (see Lithologic Descriptions section).

There is strong evidence suggesting that at least some of the felsic intrusive rocks in the map area are late differentiates of mafic and/or intermediate plutons (eg. the felsic rim of the Horse Lake pluton the Felsic west margin of the Cordova Gabbro and possibly the Deloro Granite relative to its (parental?) mafic to felsic border zone). Lithologic similarities between these felsic intrusive rocks associated with mafic plutonic bodies and those with no such association (eg. Gawley Creek Syenite) suggests that all or most felsic rocks may be synchronous. If the felsic intrusive rocks are synchronous and derived from the differentiation of mafic magma that contributed to the emplacement of mafic plutons, then it is possible that both mafic and felsic intrusive bodies represent one plutonic event. This event is constrained in time to the period beginning during D_1 and ending before D_2, possibly coinciding with the peak of regional metamorphism (M_1, see Table 4). During D_2 all large plutons acted as rigid bodies about which more ductile rocks (eg. carbonate metasediments) were deformed. Figure 3 illustrates this "buttress effect" that the plutons had on adjacent stratified rocks.

Contact Metamorphism

The intrusion of the Cordova Gabbro, Gawley Creek Syenite, Deloro Granite and the diorite/syenite at the Marmoraton open pit mine produced contact aureoles of varying width and lithology. These have been described in the Lithologic Descriptions section.

In view of the evidence cited above, that regional metamorphism outlasted plutonic emplacement, the high-grade contact mineral assemblages have largely survived regional metamorphism. Low-temperature hydrous minerals such as talc and brucite, however, probably result from regional overprinting of he contact metamorphic rocks.

Metamorphism and Deformation History

Table 4 summarizes the relation between metamorphic and deformational events in the map-area. The salient aspects include:

(i) the development of a homoclinal succession by isoclinal folding (D_1) about north-striking, east-dipping axial surfaces;

(ii) a major regional metamorphic event (M_1) beginning in D_1 and persisting well into D_2;

(iii) a regional plutonic event, syn- D_1 and pre- D_2 that began with the emplacement of mafic and intermediate plutons; successive stages may have included differentiation to produce felsic derivatives;

(iv) NW - SE compression (D_2 and D_3) to produce close to gentle folding.

PHYSICAL VOLCANOLOGY

As data on volcanic rocks in southern Methuen Township are scarce, and as volcanic rocks occupy only a small part of Marmora Township, only those volcanics in Belmont Township are treated in detail here. For more information the reader is referred to Bartlett (1983). Some observations and interpretations presented in this report, however, have been modified after Bartlett (1983), on the basis of post-1982 field work.

Cyclical Volcanism

General Statement

In the context of this study cyclical volcanism refers to the repetition of generalized mafic to felsic volcanic sequences, with or without accompanying sedimentary units. This accords with the nomenclature used to describe the classic mafic to felsic volcanic sequences observed in Archean greenstone belts (Goodwin, 1967, 1977).

Cyclicity in the Belmont Lake Metavolcanic Complex

The rocks of Belmont Township group naturally into four distinct volcanic cycles on the scale of Anhaeusser's (1971) major-cycle. Although the cycles are generally defined by a progression from a mafic base to a felsic top, one end-member in each of two cycles is not well-represented. A mafic base to Cycle I, the lowermost cycle, is not exposed in the study area. Cycle IV, the uppermost cycle, does not have an exposed felsic top. Sedimentary units are generally concentrated toward or at the top of each cycle, and are considered to be part of the cycle they overlie or are intercalated with. Each cycle contains one or more formations; correlation between cycles and formations is outlined in Tables 5-8.

Cyclicity on the minor-cycle scale of Anhaeusser (1971) occurs in all cycles of the Belmont Lake Metavolcanic Complex, most commonly as the progression from mafic to intermediate and (or) felsic rocks; metres to hundreds of metres thick, these sequences occur throughout the major-cycles. Map illustrates many minor-cycles, the coarsest of which involve two mafic- (locally) intermediate-felsic suites in the lower to middle parts of the Oak Lake formation; each has a thickness of about 500 m.

Cyclicity on the mini-cycle scale of Anhaeusser (1971) was observed in millimetre- to centimetre-scale beds of felsic tuff with cherty tops, particularly in the felsic volcaniclastic member of the Whitney Creek formation. The Belmont Lake and Marmora formations contain numerous examples of greywacke-argillite-type couplets on the mini-cycle scale.

This study concerns mainly major-cycles; thus further mention of minor- and mini-cycles will be limited to specific examples as they apply to major-cycles.

Facies Analysis and Paleovolcanic Reconstruction

General Statement

Stratigraphic units have been defined on the basis of composition; facies variations are defined by textures, primary structures and structure sequences. Facies analysis is more meaningful in pyroclastic and epiclastic units than in units consisting only of flows because there are more measurable variables such as: nature of bedding, grain size, degree of sorting, angularity of clasts, composition, heterogeneity of clasts and matrix, and primary structures (Parsons, 1969; Buller and McManus, 1973; Heiken, 1972; all as quoted by Ayres, 1977). For flows the critical features to be observed are thickness and extent, primary structures including flow top (and bottom) characteristics, primary textures and alteration (Ayres, 1977). Facies analysis thus yields important information on the type of eruption, distance from and direction to source, method of transport, degree of reworking and depositional environment. Identification of depositional environment can be aided by the presence of indicators such as pillows and (or) hyaloclastites, amygdules (Moore, 1970; Jones, 1969), vulcanian pyroclastic rocks (McBirney, 1971), welded ash flow tuff (Rankin, 1960), and accretionary lapilli (Moore and Peck, 1962), among others (in part quoted by Ayres, 1977).

Facies in volcanic terranes are commonly cited as central, proximal and distal (cf. Williams and McBirney, 1979), relative to the vent that supplied the volcanic material. In the map-area, as in many deformed, ancient volcanic terranes it is commonly difficult or impossible to precisely delimit source areas due to several factors:

1) because most volcanic vents are small relative to the overall dimensions of the volcano, the present erosion surface is more likely to expose a flank section;
2) in most deformed shield areas vertical relief of the erosion surface is minimal, thereby allowing an observer only a two-dimensional view. Ayres (1977), however, pointed out that complex folding and faulting may allow extrapolation to a third dimension;
3) erosion may have completely removed the source area, thus "orphaning" the rocks being studied;
4) the source area may have been removed, in whole or in part, by subsequent intrusions, or unconformably overlain by rocks and (or) unconsolidated deposits.

Volcanic rocks emplaced close to vents are commonly easy to recognize in the field. The distinction between proximal and distal facies, however, is made on relative terms and is hence somewhat arbitrary.

Volcanic eruptions have been classified on several bases, but no classification so far devised is wholly satisfactory (Macdonald, 1972). Williams and McBirney (1979) discussed the advantages and disadvantages of attempts to rigidly classify eruptions, and concluded that old, firmly entrenched terms should be defined more clearly, and new terms introduced only where necessary.

Williams and McBirney (1979) described and illustrated, with case histories of examples, the following principal types of central eruptions: Hawaiian, Strombolian, Vulcanian, Pelean, Plinian (Krakatoan), phreatomagmatic (Surtseyan), and phreatic. They also described fissure eruptions. The classification used by Williams and McBirney (1979) is generally consistent with that of Macdonald (1972), and is used as the standard for this report. More recent studies by other workers (eg. Self, 1982) have defined further some types of eruption, particularly Plinian.

Cycle I

Cycle I comprises the Oak Lake and Little Whitney Lake formations. Figure 8 illustrates the distribution and general geology of Cycle I; Figure 9 consists of three stratigraphic sections through Cycle I and illustrates general facies relationships within the cycle. Table 5 summarizes the stratigraphy and evolution of Cycle I, based on facies analysis, and deduced types of eruption and depositional environment.

Facies Analysis

Deposition of central facies volcanic rocks is recorded in the nose of the major syncline west of Little Whitney Lake. Here thick, flow banded felsic flows have a lateral extent of 2 km; this is in accord with typical felsic flows, which rarely travel more than 1-2 km from source (Williams and McBirney, 1979).

Intermediate lavas, also present in and near the nose of the syncline, are nowhere longer than 800 m; they constrain the positioning of the volcanic centre, as andesite flows commonly come to rest close to the vent area (Dimroth and Rocheleau, 1979; Williams and McBirney, 1979). The occurrence of non-reworked pyroclastic and tuff breccia of intermediate and felsic composition also indicates central facies deposition (cf. Williams and McBirney, 1979) in the area of the syncline. The lower part of a section through the syncline (Figure 9, section A-A') contains rocks (tuff breccias, lapilli-tuffs) that cannot demonstrably be assigned to central facies deposition, yet are at least proximal (cf. Williams and McBirney, 1979). The significance of this observation cannot be evaluated without more data, however it may reflect the correlation of increasing distance from the conduit with decreasing height of the volcano that be brought about if the erosional surface exposed the volcano's western flank. Such a section through the volcano could also explain the minimal exposure of intrusive rocks in the central facies area.

North and south of the central facies area tuff and lapilli tuff are more abundant; bedding is commonly extremely thick (>3 m) to the north boundary of the township. Relatively distinct facies transitions occur directly south of the major syncline; laharic deposits, and volcanic conglomerate and wacke form mappable units up to 3 km south of the structure. Proximal facies tuff, lapilli tuff and ash flow tuff deposits are evident to the contact with Ordovician limestone south of Round Lake. A southerly increase in distance from the vent is indicated by the gradual fining of scale of bedding and grain size of airfall pyroclastic rocks.

Minor vent areas, possibly sites of eruptions on the flanks of the main volcano, occur north of Round Lake, in the middle and upper parts of the Oak Lake formation. A swarm of gabbro bodies (including sills?) occupies the area 4 km north-northwest of Round Lake (see Map); local gradation between gabbro and mafic flows indicates that the intrusive bodies represent feeders to mafic effusions that are presently minimally exposed. It is uncertain whether or not the mafic flows were deposited concurrently with associated felsic rocks. The close spatial relationship between the swarm of gabbro bodies, and rocks of higher CI (>10) than most felsic rocks in the area, suggests that minor intermediate to felsic volcanism may have been associated with this satellitic vent area, although there is no other evidence to support central facies deposition.

The lenticular unit comprising chert and sulphide facies iron formation 2 km north of Round Lake marks the site of fumarolic activity which may or may not have been related genetically to the gabbro bodies north of Round Lake. Deposition resulting from this activity was apparently local.

Eruption Types

The interstratified nature of mafic, intermediate and felsic flows and pyroclastics indicates the presence of a composite volcano occupying the area of central facies deposition. Varied deposit types in the area reflect different styles of eruption. The thin flows of the mafic volcanic lentils are certainly the products of mild effusive activity, probably Hawaiian-type; this type of eruption is, however, most commonly associated with shield volcanoes (cf. Williams and McBirney, 1979). Vulcanian and (or) Pelean eruptions were probably the most common types in the lower part of the exposed cycle, leading to the deposition of coarsely stratified airfall tuff to tuff breccia, possibly pyroclastic (including block and ash) flows, and felsic lavas. Sheet-forming pyroclastic flow and Plinian eruptions (Self, 1982) respectively accounted for most of the ash flow tuff, and airfall tuff and lapilli tuff deposits of the middle and upper parts of the cycle in the vent area, and most of the deposits in more distal areas.

Depositional Environment

The presence of pyroclastic rocks throughout the central facies area suggests that subaerial or shallow water (less than 500 m depth) conditions prevailed (cf. McBirney, 1963) while the volcano was active. The local occurrence of pillows and hyaloclastites demonstrates that there was at least minor subaqueous deposition; 10-15% large amygdules in pillows suggest depths considerably less than 500 m (Jones, 1969). Proximal facies volcanic conglomerates occur mainly in the middle part of the exposed stratigraphy; the abundance and heterolithic nature of these deposits indicates active erosion, suggestive of subaerial provenance and subaerial or shallow water deposition (cf. Ayres, 1977, 1982a).

Further from, and particularly south of the main vent, ash flow tuff dominates the lower and middle part of the cycle; features suggestive of moderate to strong welding constrain the environment of deposition. Although welding has been documented in subaqueous ash flow tuffs (Francis and Howells, 1973), the intensity of welding, shown by extreme flattening and silica replacement of pumice, indicates subaerial deposition (cf. Thurston, 1980a, b).

Tuffs forming the upper part of the cycle in proximal to distal areas display thin to very thin bedding and graded bedding, probably indicative of subaqueous deposition (cf. Ayres, 1977). Chert and sulphide facies iron formation at the top of the cycle are also suggestive of subaqueous deposition in a more distal area.

Marble of the Little Whitney Lake formation is restricted mainly to the area of central facies deposition of the volcanics. Lying above the volcanics it illustrates that subaqueous conditions prevailed in that area upon cessation of volcanism; although tectonically thickened in the major syncline, two major facies can be recognized. Calcitic marble predominates in the lower part of the formation, whereas dolomitic marble, bearing algal structures, is most abundant in the upper part. Presumably, this change reflects a transition in depositional environment from relatively deep to shallow water (cf. Blatt et al. 1980) with increasing stratigraphic height. The probable maximum depth for formation of Precambrian stromatolites was estimated by Playford et al. (1976) to be 100 m. Bourque (1982, unpublished data) concluded, on the basis of silt content and distribution in the carbonate rocks, that the carbonates occupying the syncline were deposited in a restricted basin.

Large Scale Reconstruction

The most prominent feature of Cycle I is the composite volcano, here interpreted to have supplied most or all of the volcanic material of Cycle I, within Belmont Township. The exact coincidence of the vent area and the axial surface trace of the fold having the largest amplitude in the township is puzzling, however the restriction of central facies rocks, particularly felsic lavas, to the fold nose must reflect either a close primary spatial relationship among them, or capricious tectonism. The authors prefer the former, however allow that minor tectonic re-distribution of rock units in the central facies area may have occurred; structural data argue against mass migration of non-carbonate rocks to the fold nose; S_1 and S_2 planar fabric is, in general, not complexly folded in the nose. Certainly marble of the Little Whitney Lake formation has been thickened in the nose of the syncline.

The restricted lateral extent of mafic flows, the abrupt transition south of the syncline from vent-type to flank-type (volcanic conglomerate) deposition and the apparent restricted basin deposition of the marble suggests that at least the south side of the vent was a major factor in controlling depositional regimes, and may thus have been a wall of a major volcanic or volcano-tectonic subsidence feature (caldera). Such features are commonly formed by collapse following Plinian eruptions (Williams and McBirney, 1979). Subsidence in the vent area is demonstrable; from the lower mafic volcanic lentil, deposited at depths no greater than several hundred metres, to the base of the evidently subaqueous marble unit, about 1000-1500 m of stratigraphy are represented. Subsidence in more distal areas is also apparent; the lower and middle parts of the cycle are interpreted to have been deposited in a subaerial environment, in contrast to subaqueously deposited rocks at the top of the cycle.

The shape of the main volcano can be inferred, in part, from the distribution of ash flow tuffs assumed to have issued from it. Bond and Sparks (1976) studied ash flow deposits associated with the Santorini caldera in Greece and found that ignimbrites generally do not come to rest on slopes greater than 5°; they also noted that 10° is the maximum gradient of repose on Tenerife. That ash flow tuffs are apparently predominant only in more distal parts of Cycle I in the study area suggests that only there did the slope of the flank decrease to about 10° or less.

Cycle II

Cycle II comprises the Whitney Creek formation. Figure 10 illustrates the distribution and general geology of Cycle II; Figure 11 consists of three stratigraphic sections through Cycle II and illustrates general facies relationships within the cycle. Table 6 summarizes the stratigraphy and evolution of Cycle II, based on facies analysis and deduced types of eruption and depositional environment.

Facies Analysis

Central facies rocks associated with a major vent are not present in Cycle II. Minor vents are postulated for the area 2-3 km north of Round Lake, where agglomerates are most abundant. Agglomerate is generally considered to be a near-vent deposit

(Parsons, 1969; Williams and McBirney, 1979). These minor vents may have contributed all or most of the mafic and intermediate volcanic material in the south part of the exposed cycle.

The cycle gradually thickens northward to a maximum near the township boundary, whence it thins considerably and may pinch out in Lake Township. This suggests that, at least in relative terms, proximal facies rocks occupy the north part of the cycle in Belmont Township. Structural data indicate, however, that some of the thickening is tectonic. The presence of intermediate lavas, and their interstratification with pyroclastic rocks, suggests deposition on the proximal flanks of a composite volcano. A more distal environment in the south part of the cycle is indicated by the southward thickening of the marble of member C and the gradual fining of fragment size and bed thickness in rocks of member D; in addition, the relatively abrupt lateral transition from volcaniclastic to predominantly epiclastic rocks coincides with the thickening of the marble unit, and indicates a distal, predominantly sedimentary environment.

Eruption Types

The presence of thin mafic lavas, such as occur throughout member A of Cycle II, is characteristic of Hawaiian eruptions (Williams and McBirney, 1979). The interstratified nature of mafic lavas with intermediate tuff and lapilli-tuff may signify constantly alternating styles of eruption from one vent; it may, however, be due to mixing of material from separate vents.

The distribution of silicate facies iron formation was probably controlled by a fissure system and/or a series of fumarolic vents that may or may not have been associated with the composite volcano or volcanoes that produced the lavas and tuffs.

The agglomerates of the south part of the cycle were probably erupted during Strombolian activity (cf. Williams and McBirney, 1979). The relatively widespread occurrence of mafic tuff and lapilli-tuff, in part well-stratified, throughout the south part of member A may signify a change in eruptive style from Strombolian to phreatomagmatic (Surtseyan) (cf. Williams and McBirney, 1979).

Data are presently insufficient to estimate with accuracy the eruptive mechanism that led to the deposition of the felsic volcaniclastic member.

Depositional Environment

Subaqueous deposition of mafic volcanics can be demonstrated only in the lower to middle parts of member A in the central part of the cycle; pillows and hyaloclastites are restricted to this part of the cycle. The lack of pillows and hyaloclastites in other rocks does not necessarily indicate subaerial deposition, however the abundance of intermediate pyroclastics throughout member A constrains the maximum water depth to 500 m (cf. McBirney, 1963). The general paucity of amygdules thus does not necessarily represent deposition in deep water; instead it may indicate that the lava was largely de-gassed before coming to rest, or it may reflect a chemical peculiarity such as low K_2O content (Bryan and Moore, 1977). Where present, amygdules occur within thin flows.

Strombolian eruptions are generally considered to be subaerial phenomena (Williams and McBirney, 1979); deposition, however, may be subaqueous. Subsequent probable phreatomagmatic eruptions (see Eruption types section) suggest an increasing accessibility of water to the vent.

The silicate facies iron formation was deposited subaqueously by exhalative activity (cf. Klein, 1973). The subordinate amount of associated clastic deposits suggests that it was deposited in a basin restricted from major clastic sedimentation.

Algal structures in dolomitic marble limit the maximum depositional depth of the north part of member C to 100 m (cf. Playford et al., 1976); alternatively these rocks may have been deposited at intertidal to supratidal levels (cf. Hoffman, 1976). The southward decrease in dolomitic marble, with or without algal structures, relative to non-stromatolitic calcitic marble probably indicates a deepening marine basin to the south.

Thick bedding in the north part of the felsic volcaniclastic member may indicate subaerial or near-vent subaqueous deposition; small lenses of marble in this part of the unit, however, reflect subaqueous deposition. Very thin bedding and chert in the more southerly rocks are indicative of a subaqueous environment. The gradual increase in the amount of chert, pyrite and graphite in rocks toward the top of the member and to the south is interpreted to reflect a change in depositional environment from one in which active clastic deposition predominated to one in which conditions were more euxinic. The pyrite-rich rocks capping much of member D may have been formed by fumarolic activity.

Large Scale Reconstruction

Strata in the north part of the cycle are generally more steeply dipping than those in the south, possibly suggesting that the northern rocks constitute the east flank of the composite volcano. If this is the case the apex and central conduit have been eroded away, leaving few intrusive rocks exposed.

A restricted subaqueous basin separated the volcano from one or more cinder cones that controlled much of the deposition of mafic and intermediate rocks in the southern part of the cycle. A southward deepening sea dominated the distal area, where carbonates were succeeded vertically by mudstones, the distal analogue to the felsic volcaniclastics that lie at the top of much of the cycle.

Subsidence, probably manifested throughout the cycle, is most evident in the south where subaerial and shallow water deposits gradually yield upward through several hundred metres of stratigraphy to relatively deep subaqueous deposits.

A close spatial, if not genetic relationship exists between the mafic volcanics of the south part of Cycle II and the fumarolic vent(s) at the top of Cycle I: near-vent agglomerates directly overlie the exhalative deposit, suggesting that the fumarolic vent area(s) may have been re-activated to allow passage of magma to form the cinder cone(s) of Cycle II. The possibility, raised earlier, that the fumarolic activity was genetically related to the nearby gabbro bodies permits the conjecture that the intrusive rocks represent the feeders to the southern mafic volcanics of Cycle II.

Cycle III

Cycle III comprises the Cordova Lake, Vansickle, Marmora and Belmont formations. Figure 12 illustrates the distribution and general geology of Cycle III; Figure 13 consists of three stratigraphic sections through Cycle III and illustrates general facies relationships within the cycle. Table 7 summarizes the stratigraphy and evolution of Cycle III, based on facies analysis and deduced types of eruption and depositional environment.

Most of the volcanic rocks of Cycle III are in the Cordova Lake formation; therefore treatment here of facies analysis and eruptions types will centre on this unit. The predominantly sedimentary formations, however, provide valuable insights with respect to the prevailing depositional environments and paleogeography during and subsequent to major volcanism.

The fault separating the Cordova Lake formation from the rest of Cycle III restricts the certainty of the paleoenvironmental interpretations. This is especially true north of Belmont Lake, where correlation across the fault is largely conjectural. In the Belmont Lake area, however, the fault separates rocks that differ mainly in their respective modes of deposition, thus allowing at least qualitative correlation.

Facies Analysis

Rocks undoubtedly deposited close to a major vent are present on the west side of Belmont Lake, where locally intensely altered intermediate and felsic flows have a lateral extent of 2 km; the vent area is not exposed. This was probably the source area for much of the volcanics in the southern part of the Cordova Lake formation. However, the thickest part of the formation is 5 km to the north and thus may have derived from local fissures and (or) one or more major vents not exposed.

A minor (?) vent area is postulated in the area on and east of Lost Lake (Map); the abundant small gabbro and diorite bodies in this area represent feeders to mafic and intermediate volcanics. Intermediate flows, flow breccias and hyaloclastites support the interpretation that this is a near-vent area (cf. Dimroth and Rocheleau, 1979).

As stated in the Lithologic Descriptions section, the extreme, sudden attenuation of the Cordova Lake formation northwest of Cordova Lake is probably related to folding and (or) faulting rather than a primary facies change.

Detailed facies analysis of the predominantly sedimentary Vansickle, Marmora and Belmont formations is not attempted in this report.

General facies transitions in the Marmora formation in Belmont Township include a change from a predominantly dolomite-rich lower half to a predominantly calcite-rich upper half. In addition, the transition from marble to siliciclastic rocks at several places within the formation is marked by gradation through siliceous carbonate rocks. Erosion of the lower to middle part of the Marmora formation yielded clasts constituting some conglomerates of the Belmont Lake formation; this implies that on a gross scale these formations are, in part, time-equivalent. The distinction between them is interpreted to represent a facies change from, in general, low energy chemical/clastic deposition of the Marmora formation to moderate to high energy clastic deposition of the

Belmont Lake formation.

Eruption Types

The thick accumulation of massive and pillowed mafic lavas forming much of the Cordova Lake formation is consistent with eruptions of basaltic flood- and (or) Hawaiian-type (cf. Macdonald, 1972). The abundance of mafic dikes in the upper part of the formation may indicate that fissure eruptions were common during the latter period of mafic volcanism.

Deposition of finely bedded mafic tuff at the base of the central part of the formation may have followed phreatic, magmatic, or phreatomagmatic eruptions associated with structures such as fissures or ash cones (cf. Williams and McBirney, 1979) that are not presently exposed.

The presence of pillows in some felsic and mafic lavas on the west side of Belmont Lake indicates that relatively mild, effusive activity led to their formation.

Depositional Environment

The presence of pillows and hyaloclastites throughout the Cordova Lake formation indicates subaqueous deposition. Mafic, intermediate and felsic tuffs occur in abundance in the lower part, and, more rarely, in the middle and upper parts of the formation, indicating that the maximum depth of eruption was 500 m (cf. McBirney, 1963). Subaerially deposited rocks are not evident in this formation.

The paucity of amygdules, large or small, does not necessarily indicate excessive depth of subaqueous deposition; as noted for the mafic flows of Cycle II, the rocks may have been essentially de-gassed before coming to rest and (or) they may have had low initial K_2O values (Bryan and Moore, 1977).

Oxide and silicate facies iron formation occur at various levels throughout the Cordova Lake formation; their presence, together with the general lack of clastic sediments suggests that deposition occurred in a marine basin restricted from major clastic input. They were deposited during periodic, probably local, cessations in volcanism.

Deposition in the Vansickle formation was predominantly subaqueous, based on the abundance of marble, thinly bedded siliciclastic rocks, and hyaloclastites. Thinly laminated pyritic mudstones, commonly graphitic, and oxide and silicate facies iron formation indicate that much of the southeasternmost (uppermost?) siliciclastic unit was deposited under euxinic conditions.

The lower part of the Marmora formation was deposited for the most part, in shallow water as evidenced by the ubiquitous occurrence of algal mats and columnar stromatolites in dolomitic marble. By analogy with modern algal structures in Shark Bay, western Australia (cf. Hoffman, 1976), algal mats of the Marmora formation morphologically resemble stratiform cryptalgal sheets that form throughout the intertidal zone of protected embayments and in protected parts of the upper intertidal zone in bights; here, where wave or current action is too weak or impersistent to prevent mats from colonizing loose sand, mats form continuous undifferentiated sheets that grow without forming structures of significant relief. Discrete columnar structures, however, are common in the lower intertidal zone in places where wave and tidal scour are strong.

The upper part of the Marmora formation in Belmont Township, and most of the formation in Marmora Township consists mainly of calcitic marble with or without interlaminations of siliceous clastic material, suggesting a deeper water environment of deposition and (or) greater openness to a sea.

Most clasts in conglomerates of the Belmont Lake formation were derived from erosion and reworking of rocks of the Cordova Lake formation, with a minor component from the Marmora formation. Deposition occurred in a fluctuating subaerial to subaqueous environment, as indicated by the presence of ripple marks, soft sediment deformation structures, and mudcracks in fine-grained clastic rocks, and algal mats in dolomitic marble. These features, together with cross-bedding, and scour-and-fill structures several metres deep indicate that energy conditions were highly variable.

Moderate welding in the ash flow tuff near the top of the Belmont Lake formation suggests deposition in a subaerial (cf. Ross and Smith, 1961), possibly shallow subaqueous (cf. Francis and Howells, 1973) environment.

Large Scale Reconstruction

The interstratified nature of tuff units with flows, particularly in the lower half of the Cordova Lake formation, suggests that major edifices were associated with one or more composite volcanoes, possibly centred around the area east of Lost Lake. The thick accumulation of intermediate tuff at the base of the formation, west of Belmont Lake, may represent an ash cone (cf. Williams and McBirney, 1979). Lavas forming the upper part of the formation between Belmont and Cordova Lakes issued from fissures rather than one or more well-defined central vents. The general lack of intercalated pyroclastic rocks associated with these lavas may, in part, be due to extrusion at depths exceeding 500 m; oxide facies iron formation lying mainly above the fissure-erupted flows suggests that deposition occurred in a restricted basin.

The major vent area on the west side of Belmont Lake resembles a composite volcano in that felsic and intermediate pyroclastics are interdigitated with flows; the felsic and intermediate unit lies above mafic flows and mafic rocks of uncertain derivation which may or may not constitute part of a shield volcano.

Deposition of a subaerial to shallow subaqueous unit as thick as the Belmont Lake formation requires erosion of a largely subaerial unit considerably thicker than Member B of the Cordova Lake formation, the inferred provenance. On this basis it is here proposed that Member B was more voluminous, before erosion and faulting, than present exposure suggests. Some clast types allow inferences to be made regarding volcanic and subvolcanic rocks not presently exposed in outcrop; minor quartz-feldspar porphyry clasts were probably derived from rocks formed beneath the vent and subsequently brought to or close to the surface in the form of domes or spines, or as fragments ejected with or without juvenile magma; alternatively erosion and (or) explosive processes may have exposed the roots of the volcano. Clasts containing extremely flattened pumice probably were derived from subaerial ash flow tuffs no longer exposed in the Cordova Lake formation.

The relative contributions of erosion versus reworking subsequent to volcanic fragmentation (eg. explosions and destruction of spines and domes) is difficult to establish, however may be largely academic. Certainly erosional fragmentation yielded chert and iron formation clasts, probably derived from Member A of the Cordova Lake formation; this requires uplift of the source area to subaerial or shallow subaqueous conditions, possibly accomplished by regional tumescence and (or) syn- or post-volcanic faulting. Some, if not most of the material re-deposited to form the Belmont Lake formation may have composed large accumulations of debris in the area of the vent; talus deposits formed by the crumbling of spines and domes, for example, are commonly voluminous (cf. Williams and McBirney, 1979).

The erosional unconformity that separates the Cordova Lake formation from the Belmont Lake formation does not require the passage of appreciable geological time. By analogy with erosion rates determined for the active volcano Fuego in Guatemala (cf. Davies et al., 1978), the probably exaggerated volume estimate of 15 km^3 for the Belmont Lake formation (derived from a strike length of 2 km, an average thickness of 0.5 km and a generously estimated deposit length, in profile, of 15 km) could have been eroded/reworked from the Cordova Lake formation in about 7000 years. This estimate does not take into account the fact that erosion in Precambrian times was more pronounced due to a lack of vegetation. Quiet sedimentation of limestone and fine clastic sediments, however, suggest that erosion was not continuously tumultuous, and thus probably occurred over a greater period of time.

The presence of abundant hematite in fine clastic sediments and in the matrix of some conglomerates could be construed by some to have been derived from the diagenetic alteration of brown colloidal iron released from minerals in warm, moist upland soils (Van Houten, 1973, quoted by Blatt et al., 1980). This would require a protracted time period from the initial (subaqueous) deposition of the parent rock to the final deposition as a sediment, during which occurred uplift to expose the rock to weathering, soil formation and erosion. Walker (1967, 1974, quoted by Blatt et al., 1980), however, believed that most, if not all, ferric oxide pigment in sedimentary rocks is formed by diagenetic alteration of sand- and silt-size mineral grains, not brown colloidal iron, after deposition; this process does not require uplift and laterization, and carries no paleoclimatic connotations.

The authors' data are presently insufficient to determine the exact nature of sedimentary processes responsible for the deposition of most of the Belmont Lake formation. Fluvial processes were important, as evidenced by cross-bedding and scour channels, however lahars may have contributed significantly, as may have alluvial processes. Whatever the mechanism, the spatial distribution of the Belmont Lake formation relative to the Cordova Lake formation suggests that material was primarily transported down the east flank of the source volcano.

Spatial relations suggest that deposition of dolomitic limestone of the Marmora formation occurred before deposition of the Belmont Lake formation, and synchronous with it mainly in marginal and less proximal areas.

Active subsidence accompanied deposition in both the Belmont Lake and Marmora formations. Throughout both formations more than 700 m of stratigraphy were deposited at, or within several tens of metres of wave base. Calcitic marble in the upper half of the Marmora formation in Belmont Township, and throughout most of Marmora Township, may have formed in a deeper basin and (or) may have been part of a relatively open sea.

The interstratified nature of the contact between the Belmont Lake and Crowe River formations may have a bearing on the determination of their temporal relationship, and, therefore the temporal relationship between volcanism of Cycles III and IV. If the intercalation of the formations represents a depositional relationship, then, following the argument presented above, a time difference between the last major stage of volcanism of Cycle III, and the initial stage of Cycle IV could be relatively small.

If the intercalation of the formations is controlled by deposition rather than tectonics, then felsic volcanic rocks, and carbonate and siliceous sedimentary rocks must have occupied upland areas relative to the site of eventual clastic deposition. Original relief, regional or local tumescence and/or syn- or post-volcanic faulting could have accounted for this. Special mechanisms must be invoked to account for the absence of mafic volcanic detritus in the uppermost clastic rocks of the Belmont

Lake formation. For example, all loose debris may have been washed away prior to deposition of the clastic rocks. The lowermost metre to several metres of each clastic unit is generally not exposed, allowing the possibility that all basaltic detritus is concentrated in that interval.

Cycle IV

Cycle IV comprises the Crowe River formation. Figure 14 illustrates the distribution and general geology of Cycle IV; Figure 15 consists of two stratigraphic sections through Cycle IV and illustrates general facies relationships within the cycle. Table 8 summarizes the stratigraphy and evolution of Cycle IV, based on facies analysis, and deduced types of eruption and depositional environment.

Facies Analysis

The original lateral extent of the Crowe River formation is unknown; the Cordova Gabbro truncates the northern part, and Ordovician limestone covers the unit in the south.

Deposition in central facies is evident throughout the lower and middle parts of the formation, and to an unknown extent in the upper part. Near-vent deposits such as agglomerates and agglutinates (cf. Parsons, 1969; Williams and McBirney, 1979), and intermediate lavas (cf. Dimroth and Rocheleau, 1979) attest to eruption from two or more vents in the middle part of the formation; in addition, locally intense epidotization in these areas is potentially consistent with close proximity to vents. Mafic flows of the lower part of the formation are, by virtue of their close spatial association to the near vent deposits, assumed to be relatively proximal.

The felsic volcanic conglomerate interpreted earlier (see Lithologic Descriptions section) to be relatively proximal deposit cannot be traced to a source given present exposure.

Eruption Types

The lower and middle parts of the formation comprise a thick accumulation of mafic agglomerates and lava flows, the product of combined Hawaiian-Strombolian-type eruptions. This type of eruption probably continued until volcanic activity ceased. Agglomerate and agglutinate may have formed spatter cones in the lowest parts of the formation, and in the middle part, where they were probably built on a linear fissure system that supplied much of the mafic and intermediate lavas.

Depositional Environment

The conformable contact between mafic flows of the Crowe River formation and subaerial or shallow subaqueous deposits of the Belmont Lake formation, and the presence of large amygdules in the basal lavas of the Crowe River formation indicate that deposition occurred in a subaerial or shallow water environment. Agglutinates in the lowest part of the formation indicate that both eruption and deposition were subaerial. In general, this conclusion applies for most, if not all, of Member A of the Crowe River formation. The complete absence of pillows throughout the member also argues in favour of subaerial deposition. Local subaqueous deposition, probably in ponds, is documented by the presence of finely laminated, normally graded felsic airfall tuff. The felsic volcanic conglomerate was probably deposited by fluviatile proccesses; the degree of reworking shown by the clasts is an indication that the source area was subaerial.

The deposition of marble (Member B) was subaqueous; that it occurs atop at least 2500 m of subaerial deposits suggests that either subsidence led to submergence of the entire formation, or, more likely, the marble formed in a lake on the volcano (possibly in a crater).

Large Scale Reconstruction

The Crowe River formation documents the growth of one or more composite volcanoes predominantly, if not entirely founded on land. From a base of agglomerates and fluid mafic lavas erupted from one or more spatter cones, the volcano(es) was (were) built up by further accumulations of mainly fluid lavas. Erosion of unexposed felsic upland areas yielded material that was fluvially deposited as conglomerate on the volcano. Limestone formed at the top of the volcanic succession, either as a consequence of extreme subsidence of the volcano to near sea level conditions, or in a crater lake, possibly at the summit of the volcano.

GEOCHEMISTRY OF VOLCANIC ROCKS AND SELECTED INTRUSIVE ROCKS

The geochemistry of the Belmont Lake Metavolcanic Complex within Belmont Township is based on major and trace element analysis of fifty-five volcanic and hypabyssal rocks and two synvolcanic gabbro samples (see also Bartlett, 1983). In addition, two granitic rock samples from Methuen Township were analyzed. One felsic volcanic and six intrusive rocks from Marmora Township were analyzed for the purposes of this report. All analyses are presented in Table C_1 Appendix C. For some more detail on the chemistry of volcanic rocks from Belmont Township and description of analytical methods (Geoscience Laboratories, Ontario Geological Survey, Toronto and Department of Geology, University of Ottawa, Ottawa) and the precision and accuracy of these methods the reader is referred to Bartlett (1983, Appendix D).

The salient aspects concerning the geochemistry of rocks in the map area are:

1) application of a rigid set of criteria designed to distinguish between altered and relatively unaltered rocks shows that about half of the volcanic rock samples can be considered to be "unaltered"; some of the remaining samples are useful, as they show general trends, despite having been altered; in diagrams of this report altered samples are distinguished graphically from "unaltered" samples by the use of open versus closed symbols, respectively;

2) with the exception of two highly plagioclase-phyric (>25% phenocrysts) samples, volcanic rocks are subalkaline;

3) the majority of basalt (SiO_2 = 47-54%) samples are "unaltered", even at amphibolite facies metamorphic rank; most andesite (SiO_2 = 54-63%), dacite (SiO_2 = 63-68%) and rhyolite (SiO_2 = >68%) samples are altered;

4) a strong correlation exists, in all "unaltered" and most altered volcanic rocks, between modal CI and composition according to SiO_2 content. With few exceptions, basalts have a CI > 35, andesites 10-35, and dacites and rhyolites < 10. This correspondence should thus allow one to classify, in the field,

all but the most altered rocks as basalt, andesite, or dacite/rhyolite on the basis of visual estimation of colour index alone;

5) on the basis of the AFM diagram of Irvine and Baragar (1971), almost all basalts, andesites and dacites are tholeiitic (Figure 15), whereas rhyolites are calc-alkaline;

6) basalts are variably olivine- or quartz and hypersthene-normative; the latter type is more common;

7) REE patterns and discriminant diagrams involving Ti, Zr and Sr illustrate that, in general, basalts of the Belmont Lake Metavolcanic Complex closely resemble modern ocean floor and back-arc basin basalts.

ECONOMIC GEOLOGY

Introduction

Mineral deposits in the map-area comprise both metallic and non-metallic types.

Table 9 summarizes information on major mineral occurrences in Belmont, southern Methuen and Marmora Townships. Table 10 reports assay data collected by the authors on mineral occurrences in Belmont and southern Methuen Townships. Similar data for Marmora Township are presented in Table 11.

On the geological map that accompanies this report (No.) the mineral deposits are listed in alphabetical order under the headings "Producer", "Past Producer", and "Occurrence".

In this section of the report much of the information presented on past exploration activity, including assays, has been derived from the Assessment Files Research Office, Ontario

Geological Survey, Toronto. This information is augmented by property descriptions by the authors, based on data collected during this survey.

Metallic Mineral Deposits

Metallic mineral deposits in the map area include the following types:

a) Gold ± arsenic ± silver-bearing quartz ± carbonate veins in altered mafic, intermediate and felsic intrusive rocks;

b) stratiform zinc-copper-silver sulphide mineralization in volcanogenic metasedimentary rocks;

c) contact metasomatic iron ± iron-titanium oxides and/or sulphides in altered carbonate and gabbroic rocks;

d) contact metasomatic arsenopyrite ± magnetite ± pyrite-chalcopyrite in altered carbonate rocks;

e) disseminated copper-nickel sulphide mineralization in ultramafic intrusive rocks;

f) magnetite ironstone and magnetitic chert.

a) Gold ± arsenic ± silver-bearing quartz veins

Most documented gold mineralization is in quartz-carbonate veins associated with the western border of the Deloro Granite and shear zones in the Cordova Gabbro. Most of the veins (nos. 9, 12, 13, 19, 42 and 53, Table 8) are hosted by highly altered metadiorite or metasyenite converted to a light grey pyrite- and carbonate-bearing mica schist in the immediate vicinity of the veins. Further from the veins the wallrock is massive but is impregnated with pyrite, biotite and carbonate. Arsenopyrite is abundant in most veins; pyrite is also present, but in smaller amounts. some deposits have abundant arsenic, but are low in gold and very low in silver. Arsenopyrite also occurs as disseminations in the altered plutonic rocks. Some vein deposits contain anomalously high silver, but low gold, as in the two small quartz veins hosted by a muscovite granodiorite plug northwest of the Deloro pluton.

As a group, the Deloro vein deposits appear to have been precipitated in an extensive hydrothermal system generated by the high-level Deloro pluton, which leached metals from the marginal plutonic rocks. As the original plutonic rocks were relatively anhydrous (containing alkalic amphibole in lieu of biotite), much of the water involved may have been of meteoric origin.

Precious metal-bearing veins, composed mostly of quartz and iron-rich carbonates with pyrite occupy chlorite and/or biotite schist zones in the Cordova Gabbro at the Cordova and Ledyard Gold Mines (respectively nos.3 and 16, Table 9). These "shear" zones vary in width from 0.5 m to over 10 m, averaging 2 m; they are steeply-dipping and strike easterly to southeasterly. Cordova Mines operated intermittently between 1891 and 1941, yielding 22,774 oz of gold, at an average grade of 0.19 oz/ton Au, and 687 oz of silver. Workings involved at least ten shafts and extended to at least 270 m depth over a strike length of about 400 m. At the time of writing pilot project of gold recovery from existing tailings was being carried out by Lasir Gold Incorporated and Minetek. The occurrence at the Ledyard Mine is similar but much smaller; only 55 tons of ore were milled in 1893-94. An M.Sc. thesis study of the Cordova Gabbro and its contained vein system is presently being carried out by P. Thomas, University of Ottawa. Further data on the deposits are reported by Carter (1980). Quartz veins, some associated with schistose zones bearing pyrite were also found in the mafic volcanic rocks. Vein quartz from Cycle III chlorite schist at Munn Bay, Belmont Lake (see Map) and from Cycle I amphibolite north of Little Whitney Lake assayed 200 ppb and 24 ppb Au respectively (assays by Geoscience Laboratories, Ontario Geological Survey, Toronto). The association of discordant, relatively planar auriferous veins with schistose, altered metagabbro, implies deposition from circulating fluids late in the metamorphic history, the most obvious source of gold being the mafic rocks themselves.

b) Stratiform zinc-copper-silver sulphides

Stratiform sulphides occur in the upper parts of Cycles I, II, and III, within dark, siliceous and graphitic fine-grained, rusty-weathering mica schists derived from mudstones. Pyrite is the principal sulphide, and occurs with or without pyrrhotite and very fine-grained sphalerite and chalcopyrite. The typically associated rocks are fine-grained lithic wackes and/or tuffs with numerous cherty layers and lesser amounts of pyrite. At the Round Lake sulphide occurrence (No.51, Table 9) there are 5 m of quartz-pyrite rocks at the top of Cycle I, including 3 m containing 30-40% barren pyrite. These are underlain by cherty wacke and overlain by mafic fragmental rocks of Cycle II. Sulphidic schist within Cycle II, 2 km south of Little Whitney Lake, assayed 1.24% Zn, 0.1% Cu, and is also anomalously rich in gold, arsenic, mercury, nickel and antimony (assays by Geoscience Laboratories, Ontario Geological Survey, Toronto). Pyritic schists at the top and bottom of the felsic volcanic clastic tuff unit of Cycle II are also anomalously high in base and precious metals, as are similar rocks within Cycle III basalt immediately south of Lost Lake. The Young-Cumming II property (No.56, Table 9) east of Cordova Lake contains the largest amount of sulphide-rich schist in the map-area, which attains thicknesses of 300 m in the hinge of a D_1 fold. These rocks lie between mafic metavolcanics and less sulphide-rich, cherty wackes and felsic tuffs. Although the assemblage appears to be in tectonic contact with Cycle III rocks, it is probably equivalent to the top of that cycle. Pyrrhotite is typically more abundant than pyrite; the rock is continuously mineralized over drill intersections of 80 m or more, with total sulphides typically reaching 25% over 8 m intervals. Zinc, copper, gold and silver are the principal metals concentrated (Carter, 1980; C.R. Young, personal communication, 1980). One surface sample collected by the writers assayed 3% Zn (assay by Geoscience Laboratories, Ontario Geological Survey, Toronto). At this property and also within Cycle III basalt, there are garnet and garnet-cummingtonite schists which are also sulphidic and anomalous in metal content. These probably represent mudstones and volcanic exhalative sediments.

The "Deer Lake rusty schists" extend into Marmora Township where two properties have been drilled (nos. 25 and 55, Table 9) revealing sections, at least 120 m long, that are continuously mineralized with sphalerite and chalcopyrite; significant silver values are not uncommon. Similar, but less strongly mineralized rocks extend easterly at least to the Twin Sister Lakes area.

c) Contact metasomatic iron and iron-titanium

The large, open pit of the Marmoraton Iron Mine (no. 18, Table 9) exposes the most notable example of contact metasomatic iron oxide deposits in altered carbonate rocks. Here relatively pure carbonate rocks and minor impure carbonate rocks have been intruded by a diorite-syenite pluton of variable character to produce skarn rocks typically rich in magnetite with subordinate carbonate, epidote, garnet, pyroxene, amphibole, pyrite, pyrrhotite and chalcopyrite. The intrusive rocks are generally massive biotite-hornblende metadiorite, with minor leucodiorite and pink and yellow-grey medium-grained metasyenite; several early mafic dikes have been cut by granitic dikes. The border zone between the intrusion and the carbonate metasediments is discontinuously syenitic, and in places appears to be sheared. The intrusive body, formerly covered by limestone, is separate and distinct from the Cordova and Deloro plutons. It lies on the trace of an arcuate aeromagnetic anomaly (ODM-GSC, 1957) which also includes small exposures of metadiorite or leucogabbro at Marmora and south of Crowe Lake; these rocks may represent the northern periphery of a large intrusive mass beneath Paleozoic cover.

Contact skarns have developed where gabbro has intruded carbonate metasediments, as at the Belmont (no.5, Table 9), and Blairton (no.6, Table 9) iron mines. These are dense, fine-grained rocks composed mainly of andradite garnet, green clinopyroxene, amphibole, epidote, magnetite, pyrite, pyrrhotite and carbonate;

chalcopyrite is a minor constituent. At Blairton the skarn zone is 70 m wide and traceable for 400 m between Crowe Lake and Paleozoic cover to the south. The Blairton is one of Ontario's oldest mines; two open pits are estimated to have yielded 300,000 tons of ore between 1820 and 1875. Reserves (depth unspecified) were estimated in 1914 at 2.3 million tons grading 52-54% Fe. The mine has not produced since the nineteenth century; more recent diamond drilling and magnetic surveys indicate that the magnetite-bearing zone does not extend significantly into the lake.

The Belmont Iron Mine (No.5, Table 8) includes underground workings and two pits in a similar skarn zone about 200 m long by 15-45 m wide and 80 m deep. Mining, carried out between 1899 and 1914, produced about 8,500 tons of ore; a sampling program in 1970 proved nearly one million long tons grading 31.5% magnetite.

At the Crowe River iron occurrence (no.28, Table 9), massive hematite is found within the margin of the Cordova Gabbro, and martite occurs in float immediately to the west.

Although the Belmont deposit is clearly related to the Cordova Gabbro, the Blairton skarn appears to be separated from the Cordova intrusion by a septum of calcitic marble and is probably related to a more southerly gabbro-diorite body now concealed beneath Paleozoic cover. Further support for this interpretation is a discontinuity between the aeromagnetic anomaly at Blairton and the concentric magnetic pattern of the Cordova Gabbro; the anomaly at Blairton has a north-northeasterly trend, parallel to the east edge of the main exposure of Cycle IV basalts (ODM-GSC, 1949). Southwest of Blairton two anomalies on the same trend beneath Paleozoic limestone have been investigated. A ground magnetometer survey of the Dominion-Gulf claims (no. 32, Table 9) confirmed an anomaly suggesting the occurrence of magnetite at 150 m depth or less. Drilling was recommended, but does not appear to have been carried out. On the Pershing occurrence (no.49, Table 9) drill holes intersected magnetite skarn at 40 m depth directly below Paleozoic cover. Associated rocks include marble, chlorite schist, "greenstone" and mafic intrusions. Average grade (17 samples) was 27.7% Fe, 0.12% TiO_2, 0.53% S, 0.29% P, 0.125% Cu and 0.24% Mn. It is probable that these two occurrences, and the Blairton deposit, are related to a tabular gabbroic intrusion roughly concordant with Cycle IV basalts.

Iron oxide, iron-titanium oxide and iron sulphide deposits, believed to be at least in part contact metasomatic in origin occur on the northern periphery of the Cordova Gabbro southeast of Cordova Mines. Although carbonate rocks occur in direct association with only one of these deposits, most mineralization occurs in close proximity to the assumed metagabbro-marble contact. The Maloney property (no.44, Table 9) consists of several small deposits, in part connected, which are characterized by altered metagabbro containing magnetite in variable amounts; locally the rock is nearly massive magnetite. Pyrrhotite and pyrite are common, and ilmenite may be abundant in the more westerly deposits.

d) Contact metasomatic arsenophyrite, magnetite, pyrite and chalcopyrite in altered carbonate rocks

Contact metasomatic deposits having arsenopyrite and/or magnetite and/or pyrite-chalcopyrite mineralization commonly occur in altered carbonate rocks in the contact zone of the Deloro pluton, particularly south of Highway 7. Extensive replacement by potassic feldspar, arsenopyrite, magnetite, diopside, garnet, tremolite, pyrite and pyrrhotite has produced skarn rocks which bear up to 25% arsenopyrite, 10% pyrite, and massive magnetite in zones up to 1 metre thick.

e) Copper-nickel sulphides in ultramafic rocks

The Bonter copper-nickel deposit (no.26, Table 9) is in a small metamorphosed pyroxenite-peridotite body within siliceous clastic metasedimentary rocks southeast of Twin Sister Lake. Chalcopyrite, pyrrhotite (+ pentlandite?) and pyrite occur as disseminations (up to 15%) in the pyroxenite-peridotite and, more rarely, in veinlets.

f) Magnetite ironstone and magnetitic chert

Magnetite-bearing cherts occupy the upper part of the submarine basalts of Cycle III, within 0.5 km of the top. They occur intermittently over a strike length of at least 3-4 km, at the north end of Belmont Lake. They are fine to medium-grained, centimetre-layered granular rocks consisting mainly of quartz, with about 10% magnetite overall. Laminae up to a few millimetres thick may consist entirely of magnetite, with subordinate hematite. The enclosing rock is a chlorite-rich schist, with garnets in places. One kilometre north of Belmont Lake, an interval of 30 m contains a magnetite ironstone layer 0.5 km thick, underlain by mafic flow(?) breccia and overlain by mafic epiclastic sediments with disseminated magnetite and lenses of chert averaging 50 cm long by 15 cm thick. At the Young-Purdy magnetite occurrence (no.58, Table 9), 0.5 km west of Belmont Lake, a 15 m layer of magnetite-quartz rocks with subordinate hematite can be traced for about 400 m on surface and has been intersected by drill holes a further 60 m south. A sample assayed 24.06 % Fe, 0.024 % S, and 0.126 % P (Miller and Knight, 1914, p.26) but average grade at surface is much lower. The deposit shows signs of having been quarried in the distant past.

Smaller magnetite ironstone layers, generally less than 0.5 m thick, occur elsewhere in Cycle III. At the Young-Phillips occurrence (no.57, Table 9) west of Breckenridge Bay, Belmont Lake, three diamond drill holes intersected at least 1.5 m of magnetite ironstone below hematitic, siliceous rocks which are overlain by 27 m of Paleozoic cover (C.R. Young, personal communication, 1981). Hematite-quartz ironstone was also reported in the same vicinity, on Lot 15, Con.5 (Miller and Knight, 1914), but was not located during this survey. Another ironstone was reported by Miller and Knight (1914) southwest of Lost Lake, in Lot 25, Con.6, where it would probably lie close to the base of Cycle III; magnetite-bearing chert was mapped in this area.

Other magnetite-bearing metasediments are less pure, containing garnet, amphibole and/or carbonate. Such rocks are found at the top of the mafic part of Cycle III, between Belmont and Cordova Lakes.

Layered quartz-carbonate-magnetite ironstone occurs on the south shore of Thompson Lake, and probably, based on a strong ground magnetic attraction, east of Twin Sister Lakes as well, in the same rock succession.

Unlocated Occurrences

A galena occurrence within carbonate rocks in southeastern Methuen Township (No.46, Table 9) was reported by Vennor (1870) and a pit was marked on the geologic map by Hewitt (1960), but the occurrence could not be located by the writers. The vein was said to be 50 cm wide and to comprise two carbonates plus galena, in a calc-schist host. It was also reported by Vennor (1870) to extend southeasterly nearly 5 km into Marmora Township: as this direction is strongly discordant to the metamorphic fabric the vein may be a late fissure filling. Galena, said to be from a pit in marble just east of Belmont Lake, one kilometer north of Rockdale, was shown to one of the writers, but the pit could not be located.

Low-grade chalcopyrite mineralization associated with calcite and magnetite was reported by Wilson (1940) from Lot 8, Con.5, Belmont Township, north of the 3M quarry. The locality was not discovered, but the occurrence probably lies within volcanic rocks of Cycle IV.

Non-metallic Mineral Deposits

Non-metallic mineral deposits in the map-area include the following types:

a) metabasalt;

b) felsic intrusive rocks;

c) marble;

d) Paleozoic limestone

a) Metabasalt

Metabasalt of Cycle IV is quarried by 3M Canada Incorporated near Preneveau (no.4, Table 9) for the production of roofing granules. A plant on the site crushes, sorts and applies various colours to the material. Medium-grained metagabbro along the west contact of the Cordova Gabbro (Crowe River Trap Rock, no.29, Table 9) has been sampled and found suitable for road metal, but has not been developed.

b) Felsic intrusive rocks

The Belmont granite quarry (no.2, Table 9) in northwest Belmont Township is located in a uniform, massive to slightly foliated medium-grained biotite granite. Although only intermittently active now, it produced excellent dimension stone during the 1970s. Systematic diamond drilling of massive diorite near Horse Lake in southwest Methuen Township near the C.P. Rail line to Nephton was carried out in 1965 and 1970 (no.43, Table 9). The rock, which is cut by about 25% granitic dikes, forms part of the core of a major concentrically-zoned intrusive complex situated largely north of the map-area.

c) Marble

Marble has seen detailed exploration in Belmont Township but no deposit has yet come into production there. On the Belmont Calcite (Whitney) property (no.23, Table 9) west of Little Whitney Lake, coarse pure dolomite and calcite marbles are interlayered on a scale of 2-40 m. Systematic drilling has been carried out to delineate a high-purity carbonate deposit suitable for use as a chemical reagent and white pigment. The same unit, where it extends as a thinner layer into southeast Methuen Township, has also been extensively drilled (Vansickle property, no.54, Table 9). Pure dolomite marble in Cycle II near the power line north of Seright Bay has also been drilled (Round Lake Dolomite occurrence, no.50, Table 9).

In Marmora Township, quarries, mainly located in relatively pure, white calcitic marbles near the Deloro Granite (nos. 7, 15, 21 and 52, Table 9), have produced dimension stone, and crushed stone for terrazzo and other industrial uses. Associated with these marbles, in places (eg. south of town of Malone), are brucite, tremolite and serpentine. One deposit (no.47, Table 9) that was quarried in the past was reactivated in 1981. Another quarry (no.52, Table 9) was being developed in 1983.

d) Paleozoic Limestone

In Belmont Township, Paleozoic limestone near Beloporine Creek (no.24, Table 9) has been evaluated as a potential high-calcium carbonate deposit by drilling to a depth of about 35 m.

The 40 m thick limestone capping that was removed to expose the Marmoraton iron deposit (no.1, Table 9) has been and is currently being exploited for use as aggregate (no.1, Table 9).

Recommendations for Future Exploration

Prospecting and detailed geological mapping are warranted in areas within the mafic to felsic intrusive border zone of the Deloro Granite that have not received much attention in the past. In areas that have received active geological exploration, geophysical prospecting, particularly electromagnetic surveys, should be employed to delineate possible continuations of productive arsenopyrite-bearing quartz vein systems. The tailings dump at Deloro should be regarded as a significant deposit, derived from processing of local and imported ores. Arsenic, copper, cobalt, nickel, antimony, silver and possibly other metals may be worthy of extraction by existing technology (see Carter, 1981 for assay data).

The prospect of new discoveries of vein gold in the Cordova Gabbro, other mafic intrusions, or mafic metavolcanics warrants consideration.

One of the most promising deposit types appears to be base and precious metal occurrences in volcanic-exhalative units situated at or near the tops of volcanic cycles. The pyritic, graphitic mudstones and exhalative metasediments exhibit anomalies in one or more of copper, zinc, lead and silver at most localities sampled; the best values, on the Young-Cumming properties I and II (no. 55 and 56, Table 9) and Beninger (no. 25, Table 9) deposits are disseminated in pyrite-pyrrhotite-rich schists in close stratigraphic association with mafic metavolcanics. The easterly continuation of these rocks is not well-exposed; areas with coincident magnetic and electromagnetic anomalies would be good exploration targets. An exploitable deposit would either be of substantially higher grade than hitherto discovered (to permit underground mining), or a large-tonnage, near-surface mass.

The strong correlation between volcanic centres and mineral deposits, particularly involving massive sulphides, in many volcanic mining camps should encourage exploration in the area of central facies deposition in Cycle I. Reconnaissance airborne geophysical surveys should be applied in addition to detailed geological mapping.

Known contact-metasomatic or magnetic deposits associated with metadiorite and gabbro are unlikely to yield economic iron ores in the near future; however associated metals such as vanadium and titanium may be of interest. The margin of the Cordova Gabbro, and the arcuate plutonic belt in the southern part of the township which includes the Marmoraton deposit, are of principal interest.

Two areas where significant deposits of high-purity calcitic marble occur are east of Crowe Lake and, especially, surrounding the Deloro Pluton. Excellent access to the deposits and their proximity to urban centres makes them favourable targets. The occurrence of brucite at the Moira River deposit suggests a potential for production of refractory materials in the area.

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APPENDIX A

Nomenclature

Volcanic rocks were classified in the field and in hand specimen and thin section studies according to colour index, for which the following parameters apply:

Compositional group	Colour index
mafic	>35
intermediate	10-35
felsic	<10

Mineral modes were estimated; in addition to percentages, qualitative terms were used throughout the text to define the abundance of minerals. The qualitative terms used, and their corresponding percentages are as follows:

essential	>15%
varietal	5-15%
minor	1-5%
accessory	<1%

Grain size of phaneritic rocks is described as:

very coarse-grained	>10 mm
coarse-grained	5-10 mm
medium-grained	1-5 mm
fine-grained	<1 mm

The terminology used to define grain size of epiclastic and pyroclastic fragments is that proposed by Fisher (1961); and is outlined in Table A1. Mixture terms and end-member terms used for rocks composed of pyroclastic fragments (Figure A1) are those proposed by Fisher (1966). Fisher (1966) did not propose precise percentage boundaries for the mixtures; the present study considers the boundaries to mark thirds.

The terminology adopted by Lajoie (1979, after Fisher, 1961, 1966) is used in this study to define volcaniclastic, pyroclastic, and epiclastic rocks. Volcaniclastic rocks include all fragmental volcanic rocks that result from any mechanism of fragmentation. Epiclastic fragments result from the weathering of volcanic rocks. Pyroclastic rocks are deposits of fragments that are formed by explosion and are projected from volcanic vents. The important point is that pyroclastic and epiclastic refer to different processes of fragmentation, but not necessarily to different processes of deposition (Fisher, 1966). Processes of fragmentation are commonly difficult or impossible to discern when dealing with ancient terranes.

"Agglomerate", as used in this study, follows the definition of Williams and McBirney (1979): "a poorly sorted or stratified deposit composed chiefly of monolithologic bombs of intermediate or basaltic composition; the matrix consists mainly of scoriaceous fragments." Agglomerates result from rapid accumulation within or close to eruptive vents.

Bedding thickness of rocks displaying primary layering is defined, in general terms, according to a metric scale (e.g., centimetre-scale); in some, more specific cases the classification used in this study is adapted from Ingram (_in_ Krumbein and Sloss, 1963):

Thinly laminated	<0.3 cm

Thickly laminated	0.3-1 cm
Very thinly bedded	1-3 cm
Thinly bedded	3-10 cm
Medium bedded	10-30 cm
Thickly bedded	30-100 cm
Very thickly bedded	1-3 m
Extremely thickly bedded	>3 m

Some rocks (e.g., rusty-weathering schists of Member B, Whitney Creek formation) have been assigned descriptive rather than genetic names where, in the course of field mapping, the progenitor was uncertain. In addition, descriptive names are, for most rocks of the present study area, more appropriate for classifying rocks on the basis of thin section study. The major descriptive names used for metamorphic rocks in the present study area are:

Schist: a fine- to coarse-grained rock characterized by a strong planar fabric, expressed by abundant (>15%) plates of micas, chlorite, etc.

Semi-schist: a fine- to coarse-grained rock having a weaker planar fabric than a schist, expressed by <15% mica, chlorite, etc. plates.

Fels: a massive metamorphic rock lacking schistosity

Rock name modifiers include essential and varietal minerals present in the rock; these are listed in increasing order of abundance.

Granitic rocks are classified according to Streckeisen (1976).

Grade size (mm)	Epiclastic fragments	Pyroclastic fragments	
	Boulders (and "blocks")	Coarse	Blocks and bombs
256			
	Cobble	Fine	
64			
	Pebble	Lapilli	
2			
	Sand	Coarse	Ash
1/16			
	Silt	Fine	
1/256			
	Clay		

Table A1. Terminology used to define grain size of epiclastic and pyroclastic fragments (after Fisher, 1961).

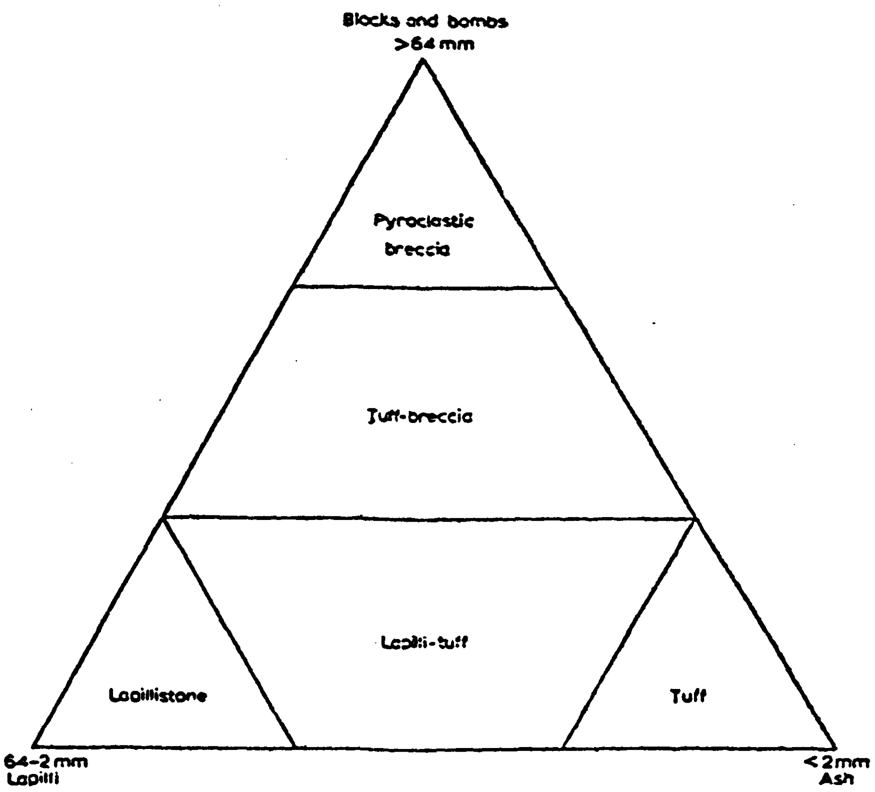

Figure A1. Mixture and end-member terms used for rocks composed of pyroclastic fragments (after Fisher, 1966).

Appendix B

UTM Reference Grid

Localities throughout this report have been referenced to the Universal Transverse Mercator grid, zone 18. Figure B1 illustrates the approximate grid layout in the map-area, relative to lithologic units.

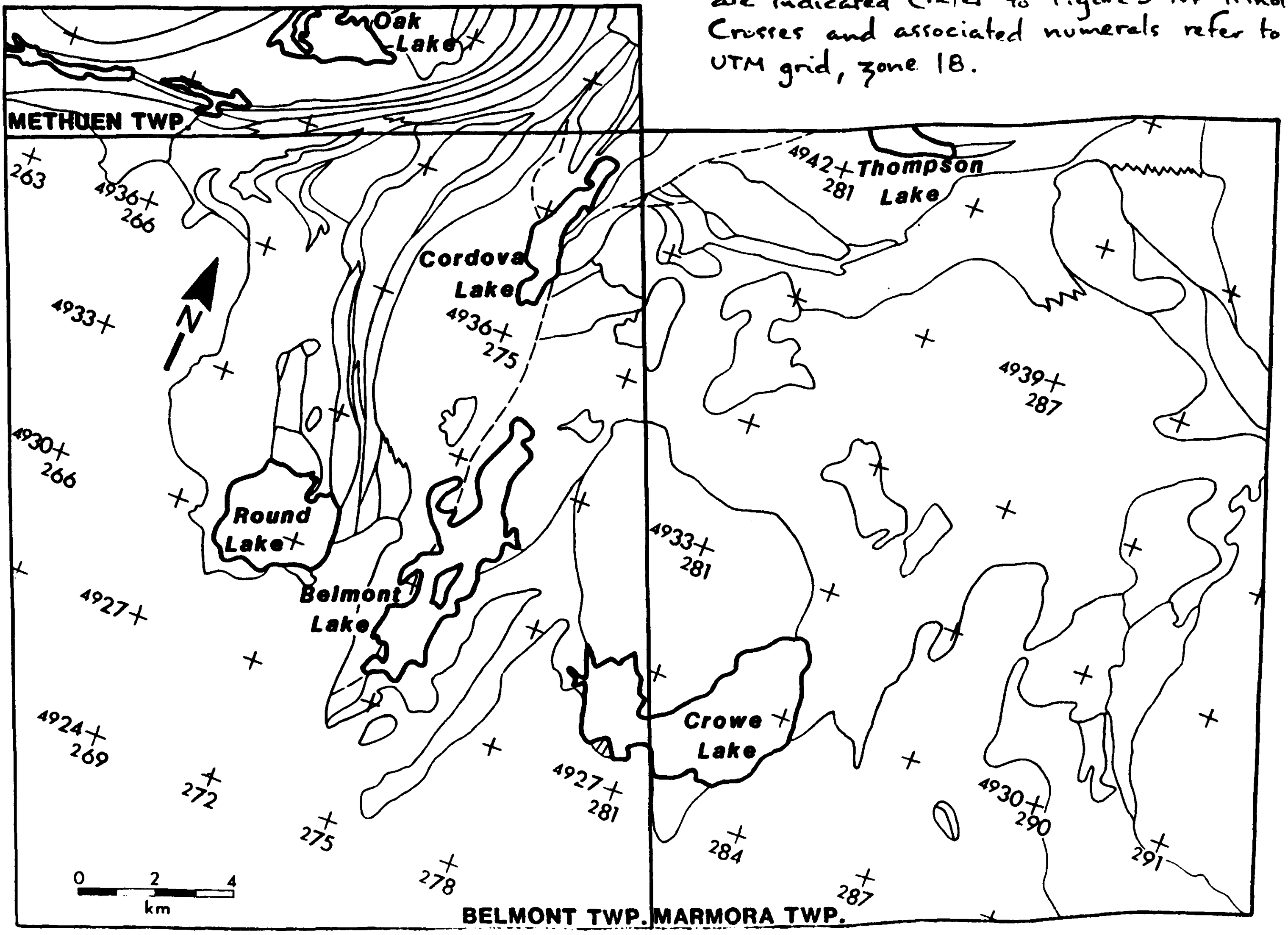

Figure B1. Generalized UTM reference grid for map-area. Lithologic boundaries are indicated (refer to Figure 3 for lithology). Crosses and associated numerals refer to UTM grid, zone 18.

Appendix C

Analytical Results

Table C1 is a compilation of analytical results determined by X-ray Assay Laboratories Ltd., and the University of Ottawa. Although Ga, Mo, Sn, and Gd were determined by X-ray Assay Laboratories Ltd., they were all below detection limit for every sample, and are thus not included in Table C1.

Although Table C1 includes results obtained from two different labs, most manipulations of data have been made using the University of Ottawa's results. The reasons for this include the desire to maintain uniformity of data, greater general confidence in the results, and greater access to the writer of computer-assisted manipulation techniques at the University of Ottawa.

Table C1

Chemical Composition of Rocks of the Belmont Lake Metavolcanic Complex (modified from Bartlett, 1983).

- See Appendix B, Bartlett (1983) for sample description and location.
- Analysts: UO - University of Ottawa

  XRA - X-Ray Assay Laboratories Ltd.,
  Don Mills, Ontario.
- Major elements (SiO_2 to Total) are expressed in weight %.
- Trace elements (Ba to Th) are expressed in ppm
- C.I.P.W. normative minerals are expressed in % cation equivalents; determined using chemical analysis recalculated to 100%.
- Footnotes:
  1. FeO, S, CO_2, H_2O+, and H_2O-, determined by Geoscience Laboratories, Ontario Geological Survey (GLOGS), Toronto. FeO recalculated to include Fe_2O_3 in excess of (TiO_2 + 1.5) (cf., Irvine and Baragar, 1971). S also determined at University of Ottawa, and listed in UO column.
  2. Fe_2O_3 calculated by subtracting FeO from FeO* and multiplying by 1.11; if value is greater than (TiO_2 + 1.5), excess is converted to FeO (see above).
  3. Total in XRA column calculated using Fe_2O_3[2] and FeO[1] (see above), and S, CO_2, H_2O+, and H_2O-, as determined by GLOGS.
  4. S.G. = Specific Gravity (g/cc), determined by GLOGS.
- "-" indicates below detection limit.
- Fe_2O_3* = total iron expressed as Fe_2O_3 (UO data only).
- FeO* = total iron expressed as FeO (XRA data only).

Table C1:

Sample No.	012B1		020B1		025B1		034B3		067B2		074B1		109B1		135B1	
Analyst	UO	XRA '	UO	XRA '	UO	XRA '	UO	XRA '	UO	XRA '	UO	XRA '	UO	XRA '	UO	XRA
SiO_2	47.10	45.9	45.77	44.1	46.82	45.7	53.62	52.5	46.52	44.9	49.22	46.9	51.37	49.7	48.88	46.8
Al_2O_3	14.98	14.8	17.39	17.0	14.63	14.6	15.36	15.2	21.00	20.7	15.41	15.0	17.70	17.2	16.39	15.9
$Fe_2O_3{}^*$	13.88		13.13		14.72		10.42		8.72		13.47		10.94		12.13	
Fe_2O_3		3.32		3.18		3.14		2.68		2.44		3.04		2.77		2.90
FeO^*		12.3		11.70		13.20		9.20		7.52		11.70		9.60		10.60
FeO^1		9.43		9.02		10.65		7.23		5.47		9.01		7.24		8.06
MgO	7.22	7.49	6.68	6.80	6.36	6.48	1.14	0.85	5.19	5.32	6.99	7.05	4.89	5.03	7.37	7.71
CaO	9.11	9.54	10.47	10.8	11.32	11.9	13.67	14.4	11.33	11.4	10.23	10.4	9.44	9.51	10.73	10.7
Na_2O	2.73	2.74	2.06	2.07	0.78	1.45	0.0	0.16	3.30	3.19	2.34	2.57	3.13	2.95	2.08	2.31
K_2O	0.10	0.10	0.16	0.15	0.11	0.11	0.09	0.08	0.11	0.11	0.16	0.16	0.62	0.64	0.22	0.22
TiO_2	1.69	1.82	1.58	1.68	1.51	1.64	1.11	1.18	0.59	0.94	1.46	1.54	1.21	1.27	1.33	1.40
P_2O_5	0.03	0.18	0.0	0.13	0.0	0.13	0.34	0.49	0.0	0.07	0.0	0.13	0.13	0.24	0.0	0.11
MnO	0.19	0.19	0.20	0.20	0.19	0.19	0.15	0.14	0.14	0.13	0.20	0.19	0.17	0.16	0.19	0.18
S^1	0.08	0.10	0.03	0.05	0.09	0.18	0.04	0.11	0.00	0.01	0.08	0.14	.01	0.01	0.01	0.09
$CO_2{}^1$		0.17		0.44		0.25		1.36		0.82		0.10		0.08		0.01
H_2O+^1		1.72		1.63		0.33		0.31		1.33		0.63		0.33		0.26
H_2O^{-1}		0.64		0.57		0.84		0.34		0.91		0.42		0.47		0.48
LOI		2.70		2.70		1.62		2.77		3.47		1.16		1.00		1.23
Total^3	97.22	98.14	97.59	97.82	96.63	97.59	96.03	97.03	97.28	97.74	99.66	97.28	99.72	97.60	99.43	97.13
S.G.^{4}		3.04		3.05		3.13		3.11		2.94		3.07		2.97		3.06
Ba	29	250	69		22		68		81		38		139		75	
Cr	279	280	265	270	267	270	0	0	102	70	171	160	106	100	321	320
Zr	129	50	134	60	129	40	196	190	108	40	136	70	139	100	122	50
Sr	95	90	178	210	110	140	454	540	202	220	126	140	404	480	139	200
Rb	7	10	12	0	10	0	10	10	11	0	12	0	15	20	11	0
Y	35	30	31	20	33	30	47	50	22	20	35	30	22	20	25	20
Zn	91	43	71	42	96	28	35	30	48	34	83	27	83	22	73	17
Ni	63	35	45	20	69	44	18	-	56	20	42	17	47	11	79	24
Li		12		11		9		7		9		8		12		15

Be		-		-		-		-		-		-		-		-
Sc		56		51		50		18		34		48		31		46
V		430		360		410		22		240		350		340		300
Co		23		22		19		5		19		13		9		12
Cu		94		35		79		22		11		34		91		76
La	4.94	6		7	3.44	5		24		3	6.02	7	13.21	19	3.80	4
Ce	13.4	13		19	9.68	14		59		-	15.5	18	36.9	44	9.6	11
Nd		13		17		10		37		9		15		32		12
Sm	3.10	4.4		4.5	2.15	4.2		8.2		2.6	3.51	4.3	2.81	6.0	2.24	3.5
Eu	1.32	1.7		2.3	1.18	1.8		2.2		1.0	1.21	2.0	1.45	2.3	1.11	1.7
Dy		7		5		7		9		4		8		5		5
To	0.85				0.81						0.79		0.71		0.13	
Yb	3.60	5		5	3.68	5		7		3	3.06	4	2.50	4	2.49	4
Hf	2.4				2.2						2.4		2.3		2.3	
Pb		4		-		-		-		-		4		-		-
U		0.2		0.2		0.2		1.0		0.1		0.3		0.6		0.1
Th	0.0	-		1.0	0.0	-		3.0		0.5	0.0	1.0	1.57	2.0	0.0	-
Q	0.00		0.00		6.04		25.03		0.00		1.22		2.12		0.92	
C	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
OR	0.62		0.99		0.70		0.59		0.67		0.97		3.74		1.34	
AB	24.07		19.41		7.58		0.00		27.23		21.60		28.66		19.15	
AN	29.79		39.60		39.05		46.22		43.37		31.96		33.07		35.64	
NE	0.00		0.00		0.00		0.00		1.94		0.00		0.00		0.00	
DI	9.29		7.82		10.35		6.28		8.13		10.51		6.95		10.44	
HE	4.74		4.11		7.02		14.99		3.43		5.68		4.12		4.74	
EN	13.09		11.91		13.82		0.35		0.00		14.59		10.29		15.65	
FS	6.68		6.27		9.38		0.85		0.00		7.88		6.11		7.11	
FO	2.41		2.65		0.00		0.00		8.00		0.00		0.00		0.00	
FA	1.23		1.40		0.00		0.00		3.38		0.00		0.00		0.00	
WO	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
MT	3.51		3.38		3.40		3.03		2.57		3.18		2.89		3.04	
IL	2.48		2.31		2.28		1.72		1.28		2.09		1.72		1.90	
CR	0.05		0.05		0.05		0.00		0.02		0.03		0.02		0.05	
HM	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
AP	0.07		0.00		0.00		0.79		0.00		0.00		0.28		0.00	
PO	0.29		0.11		0.34		0.15		0.00		0.29		0.04		0.04	

Table C1:

Sample No.	142B1		146B1		153B1		158B1		159B1		165B1		169B1		174B1	
Analyst	UO	XRA	UO	XRA	UO	XRA	UO	XRA	UO	XRA	UO	XRA	UO	XRA	UO	XRA
SiO_2	51.33	48.9	48.00	45.9	49.34	48.8	48.64	46.3	70.99	70.2	54.01	53.4	48.78	46.6	51.18	50.7
Al_2O_3	14.35	13.8	27.34	21.9	17.70	18.1	15.25	14.7	9.19	9.32	13.17	13.5	13.87	13.5	17.86	17.8
$Fe_2O_3{}^*$	15.25		8.69		12.67		12.89		2.02		15.53		17.50		9.10	
Fe_2O_3		4.02		2.10		2.72		3.05		0.42		3.90		3.33		2.05
FeO^*		13.30		7.56		11.40		11.20		1.76		14.10		15.60		8.09
FeO^1		9.76		5.67		9.36		8.47		1.38		10.90		12.60		6.24
MgO	4.98	4.94	5.08	5.25	2.87	3.43	6.97	7.12	0.84	0.73	1.95	2.19	5.60	5.69	5.85	6.33
CaO	9.40	9.40	10.17	10.00	8.71	8.84	12.28	12.00	6.64	7.01	5.91	6.16	6.15	6.30	7.98	7.94
Na_2O	2.65	2.53	3.35	3.27	2.70	2.84	2.17	2.26	3.27	3.36	3.45	3.81	3.91	3.81	0.60	0.90
K_2O	0.31	0.34	0.71	0.70	1.15	1.12	0.18	0.17	0.75	0.74	0.57	0.55	0.14	0.14	2.33	2.39
TiO_2	2.40	2.52	0.84	0.89	1.14	1.22	1.48	1.55	0.18	0.21	2.25	2.40	3.70	3.91	0.79	0.86
P_2O_5	0.20	0.32	0.00	0.10	0.06	0.19	0.00	0.15	0.00	0.05	0.99	0.94	0.50	0.51	0.07	0.18
MnO	0.21	0.20	0.14	0.13	0.24	0.24	0.23	0.22	0.05	0.04	0.25	0.24	0.39	0.39	0.20	0.20
S^1	0.00	0.01	0.00	0.01	0.00	0.01	0.02	0.08	0.04	0.05	0.00	0.01	0.03	0.17	0.00	0.01
$CO_2{}^1$		0.08		0.19		0.07		0.11		5.21		0.21		0.32		0.18
H_2O+^1		0.53		0.95		0.19		0.21		0.06		0.03		1.10		1.07
H_2O^{-1}		0.39		0.47		0.60		0.51		0.47		0.49		0.56		0.68
LOI		0.80		1.85		1.16		1.16		5.31		0.31		1.00		2.00
Total^3	101.18	97.74	99.45	97.67	96.70	97.73	100.21	96.90	94.07	101.01	98.18	98.73	100.66	98.93	96.06	97.53
S.G.^{4}		3.06		2.93		2.97		3.08		2.67		2.97		3.04		2.98
Ba	110	50	224	250	168	50	38	250	243	-	47	150	0	150	323	200
Cr	95	70	129	130	11	0	300	290	1	0	0	0	63	30	80	60
Zr	194	170	112	50	190	110	133	50	137	110	314	260	195	180	110	40
Sr	219	240	461	530	309	320	173	190	188	200	247	260	261	310	198	240
Rb	11	0	21	40	31	20	12	0	29	30	19	0	9	0	32	10
Y	57	40	16	20	45	50	30	20	24	30	81	70	55	50	23	20
Zn	110	22	73	26	96	57	76	10	37	47	177	59	110	19	57	10
Ni	44	5	57	17	17	-	61	17	17	-	17	2	33	11	47	3
Li		14		89		27		13		10		15		14		43

Be		-		-		-		-		-		-		-		-
Sc		46		21		30		50		6		40		52		23
V		370		190		210		380		-		85		510		240
Co		7		8		12		7		3		5		28		4
Cu		70		7		3		41		8		1		140		14
La	15.05	18		4		14	3.23	10		12		24	5.93	6	7.15	7
Ce	35.5	50		11		34		8.8	16		32		66	16.00	17	15
Nd		37		5		24		9		18		53		22		12
Sm	7.17	9.2		2.3		5.7	1.93	4.2		4.2		14.0	5.44	6.8	3.17	3.2
Eu	2.06	3.2		1.0		2.3	1.22	1.8		1.0		4.6	2.01	3.1		1.5
Dy		11		4		7		5		6		16		10		4
Tb	1.27						0.72						1.22			
Yb	5.63	7		2		6	3.04	4		5		10	5.66	7		3
Hf	4.8						2.1						4.7			
Pb		-		-		-		4		4		4		-		-
U		0.6		0.2		0.5		0.3		0.9		1.4		0.9		0.4
Th		2.0		-		2.0		-		2.0		3.0		1.0		1.0
Q	6.17		0.00		2.77		0.00		39.52		13.91		2.19		9.24	
C	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.01	
DR	1.89		4.22		7.27		1.09		4.83		3.62		0.86		14.69	
AB	24.51		28.52		25.89		19.92		31.93		33.27		36.27		5.74	
AN	27.14		44.04		35.02		32.05		8.90		20.16		20.55		41.73	
NE	0.00		1.02		0.00		0.00		0.00		0.00		0.00		0.00	
DI	9.08		3.70		3.63		16.03		5.05		1.16		3.89		0.00	
HE	6.56		1.63		4.95		8.17		0.00		2.34		2.19		17.22	
EN	9.62		0.00		6.65		10.96		0.00		5.20		14.03		7.48	
FS	6.94		0.00		9.05		5.58		0.00		10.54		7.89		0.00	
FO	0.00		9.18		0.00		0.52		0.00		0.00		0.00		0.00	
FA	0.00		4.03		0.00		0.27		0.00		0.00		0.00		0.00	
WO	0.00		0.00		0.00		0.00		8.25		0.00		0.00		0.00	
MT	4.20		2.46		2.95		3.19		0.29		4.21		5.62		2.55	
IL	3.44		1.18		1.70		2.11		0.27		3.37		5.33		1.17	
CR	0.00		0.02		0.00		0.05		0.00		0.00		0.01		0.01	
HM	0.00		0.00		0.00		0.00		1.08		0.00		0.00		0.00	
AP	0.43		0.00		0.13		0.00		0.00		2.23		1.08		0.16	
PO	0.00		0.00		0.00		0.07		0.15		0.00		0.11		0.00	

Table C1:

Sample No.	179B1		195B1		202B1		207B1		212B1		215B1		216B1		222B1	
Analyst	UO	XRA	UO	XRA	UO	XRA	UO	XRA	UO	XRA	UO	XRA	UO	XRA	UO	XRA
SiO_2	48.58	47.2	76.54	53.4	74.98	7.12	48.86	47.4	50.56	48.3	49.35	46.8	48.56	47.2	76.34	72.0
Al_2O_3	15.96	15.7	13.76	13.8	14.95	14.7	14.69	14.5	15.98	15.6	14.59	13.2	13.54	14.3	14.65	14.3
Fe_2O_3*	12.18		1.76		1.65		12.74		12.67		14.81		17.93		1.93	
Fe_2O_3		2.01		0.71		0.84		3.22		2.68		3.44		3.64		1.32
FeO*		10.80		1.53		1.33		11.50		11.20		16.10		13.20		1.51
FeO^1		8.99		0.89		0.57		8.35		9.98		13.00		10.07		0.32
MgO	6.83	7.12	0.62	0.42	0.51	0.24	6.37	6.68	6.48	6.66	5.83	4.57	4.50	5.99	0.45	0.11
CaO	10.87	10.80	0.39	0.46	0.67	0.66	11.16	11.30	9.98	9.94	9.52	8.34	8.28	9.72	0.77	0.81
Na_2O	2.18	2.43	6.81	6.02	3.07	3.19	2.51	2.34	3.28	3.21	2.91	3.30	3.18	3.03	6.13	5.83
K_2O	0.26	0.28	0.79	0.79	5.22	5.03	0.14	0.14	0.20	0.21	0.27	0.64	0.56	0.26	0.29	2.24
TiO_2	1.29	1.37	0.23	0.26	0.23	0.24	1.60	1.72	1.10	1.18	2.03	3.57	3.30	2.14	0.29	0.31
P_2O_5	0.00	0.13	0.01	0.04	0.01	0.04	0.20	0.33	0.00	0.10	0.07	0.53	0.42	0.19	0.05	0.05
MnO	0.19	0.19	0.04	0.04	0.03	0.02	0.20	0.19	0.21	0.20	0.17	0.26	0.26	0.16	0.03	0.02
S^1	0.02	0.21	0.02	0.07	0.00	0.00	0.03	0.02	0.00	0.01	0.00	0.16	0.01	0.09	0.00	0.01
${CO_2}^1$		0.09		0.61		0.12		1.16		0.19		0.62		0.71		0.50
H_2O+^1		0.61		0.00		0.00		0.64		0.48		0.36		0.44		0.00
H_2O^{-1}		0.44		0.77		0.44		0.34		0.46		0.39		0.70		0.44
LOI		0.93		0.93		0.70		1.93		1.54		0.93		1.85		1.31
$Total^3$	98.47	97.57	101.04	98.28	101.42	97.29	98.60	99.33	100.55	98.20	98.48	101.18	100.70	98.64	103.06	98.26
$S.G.^4$		3.04		2.66		2.63		3.04		3.03		3.10		3.06		2.66
Ba	66	100	258	50	428	300	0	150	62	250	20	-	0	65	723	700
Cr	287	300	0	20	0	0	220	220	126	110	78	20	55	60	0	0
Zr	126	60	149	160	212	180	135	50	123	50	155	170	189	110	159	130
Sr	164	220	31	20	85	90	200	230	123	160	159	160	142	160	109	120
Rb	9	20	23	30	153	140	11	20	9	0	12	40	18	0	39	30
Y	32	20	27	30	30	50	34	30	31	20	42	60	55	40	17	30
Zn	73	11	17	18	20	23	86	19	94	22	87	35	97	21	4	3
Ni	57	36	20	-	16	-	49	18	42	6	27	11	43	8	14	-
Li		16		8		9		12		10		19		10		6

Be	-		-	-		-	-		-	-		-
Sc	43		7	4		41	41		48	47		3
V	310		24	-		340	320		510	410		-
Co	22		4	3		9	8		17	19		-
Cu	99		6	1		78	18		70	25		3
La	5	23.23	25	180	5.05	9	6	12.30	15	9	19.64	21
Ce	10	51.9	61	370	14.1	21	14	29.5	38	27	40.2	42
Nd	9		29	160		20	14		32	16		21
Sm	3.5	5.08	5.9	19.0	2.74	5.2	3.3	5.27	9.3	5.0	3.77	3.9
Eu	1.6	0.86	1.2	2.4	1.54	2.6	1.3	2.58	3.3	1.7	0.67	1.0
Dy	5		7	7		7	5		11	8		4
Tb		0.99			0.74			1.36			0.58	
Yb	3	4.60	5	3	3.04	4	4	5.61	8	6	3.21	4
Hf		5.6			2.3			4.1			4.8	
Pb	-		-	-		-	-		-	4		-
U	0.2		2.2	7.4		0.3	0.4		0.5	0.7		2.9
Th	0.5	6.17	5.0	32.0	1.81	0.5	1.0	2.91	1.0	1.0	8.02	8.0

Q	0.83	29.28	32.32	1.45	0.00	2.28	2.50	26.63
C	0.00	1.09	3.32	0.00	0.00	0.00	0.00	0.85
DR	1.60	4.59	30.82	0.86	1.20	1.66	3.45	13.10
AB	20.30	60.07	27.52	23.44	29.60	25.29	29.76	53.22
AN	34.24	1.84	3.25	29.55	28.60	27.92	21.92	3.38
NE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DI	11.59	0.00	0.00	14.07	10.67	10.08	7.87	0.00
HE	5.79	0.00	0.00	7.28	6.49	6.49	6.57	0.00
EN	13.77	1.68	1.41	11.26	8.98	1.69	9.24	1.20
FS	6.88	0.00	0.00	5.83	5.46	7.53	7.71	0.00
FO	0.00	0.00	0.00	0.00	2.82	0.00	0.00	0.00
FA	0.00	0.00	0.00	0.00	1.71	0.00	0.00	0.00
WO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MT	3.03	0.00	0.00	3.37	2.75	3.89	5.23	0.00
IL	1.86	0.05	0.07	2.32	1.55	3.01	4.79	0.25
CR	0.05	0.00	0.00	0.04	0.02	.01	0.01	0.00
HM	0.00	1.19	1.15	0.00	0.00	0.00	0.00	1.21
AP	0.00	0.02	0.02	0.44	0.00	0.15	0.92	0.10
PO	0.07	0.07	0.00	0.11	0.00	0.00	0.04	0.00
RU	0.00	0.13	0.13	0.00	0.00	0.00	0.00	0.07

Table C1:

Sample No.	229B1		237B2		240B1		255B2		256B1		008M		022M1		044M2	
Analyst	UO	XRA	UO	XRA	UO	XRA	UO	XRA	UO	XRA	UO	XRA	UO	XRA	UO	XRA
SiO_2	76.52	74.2	47.74	45.5	47.69	45.7	49.76	47.8	50.34	48.3	69.53	67.3	49.02	47.4	61.04	58.8
Al_2O_3	12.54	12.5	15.63	15.2	17.28	17.0	14.86	14.6	14.16	13.8	15.36	15.3	15.07	14.9	18.91	18.9
Fe_2O_3*	2.65		15.53		11.78		14.96		15.10		3.94		14.63		4.05	
Fe_2O_3		0.59		3.95		0.00		3.97		4.03		0.70		3.37		1.75
FeO*		2.31		13.80		10.50		13.40		13.30		3.47		13.00		3.44
FeO^1		1.78		10.72		11.30		10.23		9.85		2.84		9.96		1.86
MgO	0.80	0.60	4.92	4.97	7.23	7.73	4.72	4.87	4.99	.08	1.04	1.00	5.13	5.28	1.36	1.53
CaO	1.55	1.67	9.54	9.61	8.18	8.13	9.08	9.19	9.49	9.55	1.18	1.17	9.39	9.56	2.20	2.14
Na_2O	5.32	4.91	3.51	3.52	2.57	2.60	2.21	2.37	2.14	2.18	5.98	5.46	3.15	2.93	4.65	4.42
K_2O	0.48	0.47	0.22	0.24	0.20	0.21	0.45	0.45	0.46	0.48	2.22	2.14	0.54	0.60	5.37	5.27
TiO_2	0.26	0.30	2.37	2.45	1.57	1.65	2.34	2.47	2.41	2.53	0.56	0.60	2.12	2.23	0.75	0.77
P_2O_5	0.03	0.05	0.18	0.30	0.07	0.17	0.19	0.30	0.18	0.29	0.09	0.10	0.19	0.31	0.19	0.21
MnO	0.06	0.06	0.24	0.23	0.13	0.13	0.23	0.22	0.22	0.21	0.14	0.14	0.19	0.18	0.06	0.07
S^1	0.02	0.09	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.03	0.16	0.00	0.01	0.01	0.04
$CO_2{}^1$		0.59		0.07		0.42		0.11		0.08		0.37		0.07		0.28
H_2O+^1		0.32		1.49		2.97		1.47		1.07		0.51		0.91		0.32
H_2O^{-1}		0.45		0.51		0.55		0.55		0.49		0.39		0.50		0.52
LOI		1.47		2.16		4.08		2.47		2.31		1.31		1.31		1.39
Total[3]	101.04	98.57	99.99	98.76	96.80	98.56	98.89	98.61	99.60	97.95	100.22	98.27	99.52	98.21	99.09	96.88
S.G.[4]		2.67		3.05		2.96		3.05		3.09		2.70		3.06		2.69
Ba	258	300	38	-	44	200	65	150	68	100	828	700	45	100	2520	2100
Cr	0	0	99	90	120	110	62	40	97	70	0	0	106	70	0	0
Zr	149	100	173	160	147	130	173	140	191	190	139	100	181	150	485	740
Sr	31	90	326	350	190	230	263	330	192	230	171	190	230	270	987	930
Rb	23	0	14	0	13	0	19	30	16	10	57	30	14	10	110	110
Y	27	10	41	40	36	40	43	40	58	50	44	40	53	50	44	30
Zn	17	21	103	70	96	68	96	68	106	40	116	110	117	30	68	71
Ni	20	-	34	15	67	40	27	11	32	10	19	-	28	4	21	-
Li		12		12		35		80		11		22		13		28

Be		-		-		-		25		-		-		-		-
Sc		8		41		34		38		48		10		43		11
V		-		390		280		400		440		-		370		46
Co		6		24		26		24		14		4		10		5
Cu		8		3		6		44		46		4		4		6
La		13	9.60	12	9.04	10	12.77	13	15.50	17	22.76	23		17		95
Ce		33	26.9	30	23.2	25	28.4	31	39.6	46	54.8	55		44		190
Nd		24		28		24		27		34		36		36		110
Sm		4.2	4.55	6.7	4.38	5.8	6.08	6.8	6.32	9.0	7.98	7.6		8.3		16.0
Eu		1.4	1.96	2.7	1.75	2.3	2.02	2.8	2.27	3.3	1.74	2.3		2.8		4.7
Dy		3		7		7		8		11		7		9		8
Tb			1.00		0.93		1.09		1.40		1.05					
Yb		3	4.06	5	3.54	4	4.02	6	5.49	7	4.77	5		6		4
Hf			3.6		3.3		3.9		4.9		4.1					
Pb		4		-		-		-		-		-		-		-
U		0.9		0.5		0.3		0.5		0.7		1.8		0.7		3.4
Th		4.0	2.10	1.0	1.99	0.5	1.94	1.0	2.96	1.0	4.74	4.0		2.0		12.0
Q	36.61		0.00		0.69		6.95		7.36		20.41		0.30		6.72	
C	0.58		0.00		0.00		0.00		0.00		1.29		0.00		2.08	
DR	2.85		1.34		1.24		2.81		2.86		13.07		3.31		31.92	
AB	48.02		32.54		24.19		20.96		20.18		53.42		29.32		41.96	
AN	7.54		27.11		36.72		30.96		29.07		5.24		26.33		9.72	
NE	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
DI	0.00		9.29		3.06		7.02		8.99		0.00		9.70		0.00	
HE	0.00		7.16		1.21		5.24		6.33		0.00		6.85		0.00	
EN	2.22		4.79		19.39		10.36		9.97		2.80		9.83		3.77	
FS	0.00		3.69		7.66		7.66		7.02		0.51		6.95		0.00	
FO	0.00		3.44		0.00		0.00		0.00		0.00		0.00		0.00	
FA	0.00		2.65		0.00		0.00		0.00		0.00		0.00		0.00	
WO	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
MT	1.37		4.18		3.36		4.24		4.29		2.14		3.92		2.28	
IL	0.36		3.41		2.29		3.44		3.53		0.78		3.06		1.05	
CR	0.00		0.02		0.02		0.01		0.02		0.00		0.02		0.00	
HM	0.32		0.00		0.00		0.00		0.00		0.00		0.00		0.05	
AP	0.06		0.39		0.15		0.42		0.40		0.19		0.41		0.40	
PO	0.07		0.00		0.00		0.04		0.00		0.10		0.00		0.04	

Table C1:

Sample No.	481B1	482B1	483B1	484B1	486B1	487B1	488B1	489B1	49CB1	491B1	492B1	494B1	495B1	315E1	
Analyst	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO
SiO_2	69.84	69.97	59.85	73.07	66.17	49.36	47.97	66.31	79.16	76.06	47.05	52.26	79.29	47.11	
Al_2O_3	14.06	14.51	14.74	12.32	13.66	14.82	14.30	12.61	11.74	12.15	17.05	14.34	11.39	11.08	
Fe_2O_3*	4.22	4.49	8.41	2.36	9.54	14.01	15.82	7.18	1.88	2.47	14.09	14.57	1.75	12.95	
MgO	1.05	1.00	1.90	0.91	1.09	6.48	6.48	1.73	0.55	0.69	7.43	5.06	0.56	5.66	
CaO	3.08	2.10	4.52	3.52	2.74	7.61	9.97	9.35	1.30	1.94	10.54	8.65	1.45	9.29	
Na_2O	3.28	5.73	4.46	0.18	6.76	3.74	2.16	2.29	5.90	6.13	1.90	2.90	4.20	1.24	
K_2O	2.75	2.52	2.37	3.85	0.81	1.00	0.20	1.71	0.85	0.96	0.90	0.04	1.36	0.26	
TiO_2	0.73	0.82	1.65	0.39	1.28	2.09	1.88	1.16	0.19	0.26	0.96	1.95	0.24	1.86	
P_2O_5	0.10	0.19	0.66	0.01	0.12	0.18	0.02	0.36	0.0	0.04	0.02	0.19	0.02	0.06	
MnO	0.12	0.07	0.15	0.09	0.06	0.22	0.19	0.13	0.04	0.05	0.19	0.22	0.05	0.18	
S	0.00	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.02	0.04	0.00	0.04	0.01	0.02	
Total	99.37	101.53	98.87	96.85	102.38	99.68	99.08	98.94	101.69	100.90	100.24	100.33	100.40	89.8	
Ba	478	456	560	433	181	196	13	223	212	214	161	0	253	0	
Cr	0	0	0	0	87	208	190	0	4	9	71	75	0	144	
Zr	212	221	195	215	380	177	145	185	163	163	111	169	168	146	
Sr	281	261	418	151	136	321	127	184	43	44	330	219	68	70	
Rb	73	59	49	73	34	30	12	42	24	20	20	5	28	10	
Y	52	51	39	57	41	48	38	54	36	52	15	47	61	26	
Zn	44	60	94	17	231	113	51	47	5	400	76	106	2	53	
Ni	23	26	24	17	38	47	60	32	17	21	52	37	19	51	
La		29.44		28.81			4.84	28.36	27.97		4.36				
Ce				62.6			12.6	59.8	58.9		10.6				
Sm		12.00		8.3			2.27	10.20	9.15		1.60				
Eu				1.92			1.16	1.96	0.96		0.82				
Tb				1.39			0.71	1.31	1.14		0.37				
Yb				6.23			3.55	5.79	5.37		1.42				
HF				7.2			2.7	5.9	6.0		0.5				
Th				5.37			2.31	6.47	4.92		1.41				
Q	30.59	20.06	12.99	43.30	14.01	0.00	1.37	32.02	35.00	30.40	0.00	7.11	42.95	11.71	

C	0.37	0.00	0.00	1.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00
OR	16.72	14.72	14.44	24.54	7.74	6.05	1.24	10.63	4.96	5.63	5.43	0.25	8.15	1.99
AB	30.27	50.80	41.26	1.74	59.99	34.34	20.32	21.60	52.29	54.61	17.41	26.91	38.20	12.98
AN	15.04	6.35	13.60	18.75	4.49	21.17	30.11	20.04	3.00	2.78	36.08	26.88	7.16	27.57
NE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DI	0.00	1.92	2.57	0.00	2.26	8.55	10.19	2.64	2.69	3.78	8.34	7.49	0.00	13.17
HE	0.00	0.25	1.48	0.00	4.28	4.44	7.08	1.65	0.00	0.00	5.40	5.59	0.00	7.16
EN	2.98	1.77	4.12	2.71	1.85	5.87	13.65	3.70	0.15	0.00	6.23	10.69	1.57	11.63
FS	0.39	0.23	2.36	0.00	3.50	3.05	9.49	2.31	0.00	0.00	4.03	7.98	0.00	6.33
FO	0.00	0.00	0.00	0.00	0.00	6.11	0.00	0.00	0.00	0.00	7.91	0.00	0.00	0.00
PA	0.00	0.00	0.00	0.00	0.00	3.17	0.00	0.00	0.00	0.00	5.12	0.00	0.00	0.00
WO	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.00	0.00
MT	2.40	2.40	3.39	0.26	2.87	3.84	3.70	2.92	0.01	0.85	2.63	3.73	0.00	4.10
IL	1.05	1.13	2.37	0.59	1.76	2.98	2.74	1.70	0.26	0.36	1.37	2.81	0.08	3.02
CR	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.01	0.01	0.00	0.03
HM	0.00	0.00	0.00	1.25	0.00	0.00	0.00	0.00	1.15	0.85	0.00	0.00	1.23	0.00
AP	0.22	0.39	1.42	0.02	0.25	0.39	0.04	0.79	0.00	0.05	0.04	0.41	0.04	0.15
PO	0.00	0.00	0.00	0.11	0.00	0.00	0.04	0.00	0.07	0.14	0.00	0.14	0.04	0.05
RU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00

Table C1:

Sample No.	053M1		259B1	260B1	261B1	398B1	469B3	473B1	474B1	475B2	476B1	478B1	479B1	480B1
Analyst	UO	XRA	UO	XRA	UO	XRA	UO	XRA	UO	XRA	UO	XRA	UO	XRA
SiO_2	57.11	58.3	73.21	48.85	76.11	69.13	51.09	49.66	49.54	48.30	48.64	56.58	55.70	56.21
Al_2O_3	15.20	16.0	13.26	14.08	12.46	12.76	13.99	15.26	13.83	14.32	13.89	13.93	13.59	13.19
Fe_2O_3*	8.67		3.77	14.60	2.81	2.89	13.60	13.42	16.31	13.95	14.01	9.02	9.33	8.19
Fe_2O_3		2.68												
FeO*		8.02												
FeO^1		5.94												
MgO	1.95	2.21	1.29	5.16	1.35	0.43	5.41	4.69	4.64	7.11	6.92	2.37	1.68	1.60
CaO	5.03	5.28	1.39	8.37	0.48	2.36	8.85	9.01	8.17	10.58	11.09	3.80	5.56	5.60
Na_2O	3.62	4.47	4.59	2.61	5.46	0.85	3.71	4.54	3.71	2.96	2.40	3.19	3.72	4.17
K_2O	1.24	1.22	2.03	0.85	1.14	9.18	0.34	0.65	0.28	0.15	0.15	2.44	1.95	0.85
TiO_2	1.07	1.18	0.55	1.99	0.33	0.28	1.97	1.84	2.75	1.63	1.69	1.68	1.61	1.53
P_2O_5	0.15	0.21	0.10	0.35	0.05	0.00	0.07	0.16	0.24	0.00	0.00	0.67	0.59	0.67
MnO	0.15	0.15	0.05	0.25	0.05	0.03	0.23	0.21	0.22	0.21	0.21	0.15	0.15	0.19
S^1	0.00	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00
CO_2^1		0.08												
H_2O+^1		0.31												
H_2O^{-1}		0.38												
LOI		0.54												
$Total^3$	94.30	98.42	100.37	97.22	100.32	98.02	99.43	99.55	99.77	99.31	99.12	93.97	99.00	92.30
$S.G.^4$		2.83												
Ba	210	250	450	97	326	576	68	175	27	11	37	34	289	87
Cr	17	0	0	64	0	1	106	89	63	321	257	9	5	9
Zr	194	130	148	149	154	222	161	170	189	132	133	253	247	247
Sr	325	350	118	260	70	56	222	266	213	113	99	254	228	257
Rb	38	30	47	24	26	61	16	21	13	10	7	60	50	19
Y	37	60	28	39	24	19	45	45	52	33	25	48	54	47
Zn	83	69	169	124	8	0	92	74	73	73	85	130	120	102
Ni	18	2	16	46	19	23	40	43	51	57	58	32	20	19
Li		14												

Be		-												
Sc		21												
V		150												
Co		11												
Cu		1												
La	15.45	18				29.93	7.39	10.79			5.61	26.80		
Ce	39.7	41				53.6	20.6	23.0			16.5	55.1		
Nd		2												
Sm	4.33	5.7				5.79	2.98	3.59			1.98	7.45		
Eu	1.55	1.9				0.96	1.55	1.53			1.19	2.05		
Dy		7												
Tb	0.91					0.65	0.94	0.97			0.67	1.27		
Yb	3.86	5				1.94	4.12	4.16			3.05	4.70		
Hf	3.6					8.0	3.5	3.7			2.4	5.6		
Pb		-												
U		1.4												
Th	4.19	3.0				3.77	3.00	3.00			2.22	6.18		
Q	15.74		31.74	3.33	34.39	24.25	1.26	0.00	1.62	0.00	0.45	17.11	13.60	16.81
C	0.00		1.35	0.00	1.63	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.00	0.00
DR	7.96		12.10	5.36	6.75	56.85	2.07	3.93	1.72	0.91	0.92	15.80	12.62	5.58
AB	35.28		41.52	25.00	49.08	7.99	34.34	38.14	34.68	27.35	22.36	31.36	36.54	41.54
AN	23.41		6.29	25.82	2.06	4.04	21.16	19.77	21.10	26.09	27.69	15.84	16.00	16.38
NE	0.00		0.00	0.00	0.00	0.00	0.00	2.11	0.00	0.00	0.00	0.00	0.00	0.00
DI	1.05		0.00	7.40	0.00	2.49	11.67	11.55	8.68	14.43	15.17	0.00	4.08	4.45
HE	1.05		0.00	5.44	0.00	0.00	7.25	8.33	6.90	7.92	8.35	0.00	3.89	3.21
EN	5.32		3.59	11.50	3.73	0.00	9.59	0.00	4.00	6.30	12.24	7.16	3.03	2.67
FS	5.32		0.21	8.46	0.00	0.00	5.94	0.00	7.16	3.46	6.74	4.10	2.89	1.93
FO	0.00		0.00	0.00	0.00	0.00	0.00	5.59	0.00	5.01	0.00	0.00	0.00	0.00
FA	0.00		0.00	0.00	0.00	0.00	0.00	4.04	0.00	2.75	0.00	0.00	0.00	0.00
WO	0.00		0.00	0.00	0.00	2.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MT	2.92		2.16	3.89	1.43	1.89	3.74	3.57	4.63	3.37	3.46	3.64	3.56	3.51
IL	1.62		0.77	2.96	0.46	0.41	2.83	2.62	3.99	2.38	2.44	2.56	2.45	2.37
CR	0.00		0.00	0.01	0.00	0.00	0.02	0.02	0.01	0.05	0.04	0.00	0.00	0.00
HM	0.00		0.00	0.32	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AP	0.34		0.21	0.78	0.11	0.00	0.15	0.34	0.52	0.00	0.00	1.54	1.35	1.56
PO	0.00		0.07	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00

Table C1:

Sample No.	350B1	357B1	406B1	427B1	439B1	457B1	485B1								
Analyst	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO	UO
SiO_2	70.37	74.89	46.14	73.30	54.15	60.99	73.06								
Al_2O_3	16.58	11.88	5.47	15.38	16.59	18.48	15.49								
Fe_2O_3*	1.36	2.76	8.54	1.27	5.76	4.36	1.23								
MgO	0.46	0.43	12.41	0.70	1.95	1.20	0.43								
CaO*	0.36	0.65	13.50	1.70	5.36	2.62	0.84								
Na_2O	5.46	3.96	0.00	6.67	4.72	6.24	5.73								
K_2O	4.94	4.54	0.14	1.72	0.52	6.96	2.38								
TiO_2	0.16	0.16	0.38	0.18	0.80	1.01	0.03								
P_2O_5	0.04	0.00	0.0	0.01	0.03	0.25	0.06								
MnO	0.04	0.01	0.15	0.03	0.09	0.08	0.01								
S[1]	0.02	0.00	0.0	0.02	0.00	0.01	0.02								
Total	100.05	99.43	87.08	101.10	90.078	102.56	99.40								
Ba	1521	301	97	576	200	1392	795								
Cr	0	0	1867	7	3	0	0								
Zr	173	386	116	138	151	335	80								
Sr	497	9	74	284	382	1078	132								
Rb	146	88	13	57	13	99	56								
Y	19	168	1	10	21	38	1								
Zn	27	37	83	11	65	68	53								
Ni	16	27	143	23	24	19	11								

Table 1: Table of Lithologic Units[a]

PHANEROZOIC

- CENOZOIC[a]
  - QUATERNARY
    - RECENT
      - Stream lake and swamp deposits
    - PLEISTOCENE
      - Glacial, glaciofluvial, and glaciolacustrine deposits

UNCONFORMITY

- PALEOZOIC
  - ORDOVICIAN
    - SIMCOE GROUP
      - Grey, chalky-weathering limestone. An interlayered sequence of limestone, sandy limestone, dolomitic limestone and shale at the base of the Simcoe Group may also be long to this group.
    - BASAL GROUP
      - Shadow Lake Formation
        - Red conglomerate, siltstone, shale.

UNCONFORMITY

PRECAMBRIAN[b]

- MIDDLE PROTEROZOIC
  - INTRUSIVE ROCKS
    - FELSIC INTRUSIVE ROCKS
      - Massive biotite granite; porphyritic

granite; foliated granite; pegmatite, granite, aplite dikes; microgranite, porphyritic microgranite, syenite, quartz syenite, felsite; massive medium- to coarse-grained amphibole-perthite granite; fine-grained leucogranite; massive, medium-to coarse-grained syenite to quartz syenite; massive medium-grained muscovite leucogranite; fine-grained and/or porphyritic leucodiorite, trondhjemite, syenite, felsite.

INTERMEDIATE TO ULTRAMAFIC INTRUSIVE ROCKS

Diorite, plagioclase-phyric diorite, quartz diorite

INTRUSIVE CONTACT

Medium- to coarse-grained gabbro; fine-grained gabbro; plagioclase-phyric gabbro; coarse-grained oikocrystic gabbro; leucogabbro; anorthosite; trondhjemite, diorite (small intrusions spatially related to the Cordova Gabbro body); syenite, granite, granophyre intrusions (spatially related to the Cordova Gabbro body); biotite lamprophyre; pyroxenite

INTRUSIVE CONTACT

GRENVILLE SUPERGROUP[c]

CROWE RIVER FORMATION

Mafic and intermediate volcanic flows and pyroclastics, skarn, calcitic marble, felsic tuff, volcanic conglomerate.

BELMONT LAKE FORMATION

Conglomerate, sandstone, mudstone, dolomitic marble, felsic pyroclastics

MARMORA FORMATION

Calcitic and dolomitic marble, interlaminated carbonate and siliceous clastic sediments, mudstone, conglomerate

VANSICKLE FORMATION

Sandstone, mudstone, mafic volcanic flows, calcitic marble, interlayered calcitic marble and siliceous clastic sediments, dolomitic marble, felsic tuff, chert.

CORDOVA LAKE FORMATION

Mafic, intermediate and felsic volcanic flows and tuff; volcanic wacke; oxide and silicate facies iron formation; chert; mudstone.

WHITNEY CREEK FORMATION

Mafic and intermediate volcanic flows and pyroclastics, felsic volcaniclastics, mudstone, calcitic and dolomitic marble, felsic tuff, chert.

LITTLE WHITNEY LAKE FORMATION

Calcitic and dolomitic marble, interlayered carbonate and siliceous clastic sediments.

OAK LAKE FORMATION

Felsic, intermediate and mafic volcanic flows and pyroclastics, volcanic conglomerate, chert, sulphide facies iron formation.

Table 2: Mineral assemblages of mafic and intermediate volcanic rocks of Belmont Township. Minerals in parentheses may be present in some rocks. Minerals present in trace amounts not included. From Bartlett (1983).

Zone	Mineral assemblage
Actinolite	ab-ac-ep-mt
	pc-ac-ep-mt-ch (ti)
	pc-ac-ep-mt-bi
	ab-ep-mt-ch-hb (bi, cz)
	pc-hb-mt
	pc-hb-ep-ch
Chlorite-hornblende	ab-qz-hb-ch-mt-ep (ac)
	ab-qc-hb-bi-mt-ep
	ab-qz-hb-bi-ch-mt-ep
	ab or og-hb-bi-mt-ep-qz
	og-hb-ch-ep-mt (cc, ti, qz, bi, ap)
	pc-hb-ep-mt (cc)
	pc-hb-ep (mt, ti, qz, gt, cz)
	pc-ac-ch-ox
Hornblende	pc-hb-qz-ch^1-mt-ep-ap
	pc-hb-ch^1-bi-ap-hm
	pc-hb-ep-qz (ti)
	pc-hb-ep-qz-bi-mt (ti, ap)
	pc-hb-ep-qz-mt (ti, ap)
	pc-hb-ap-ox
	pc-qz-bi-mt-ep-ti-ap (cc, gt, mu)
	og-qz-hb-bi-mt-ap (ti, ep, cc)

1) Chlorite present in hornblende zone due to locally high CO_2 activity.

Note: Abbreviations

ab: albite
ac: actinolite
ap: apatite
bi: biotite
cc: calcite
ch: chlorite
cz: clinozoisite
gt: garnet
hm: hematite
hb: hornblende
mt: magnetite
mu: muscovite
og: oligoclase
ox: Fe/Ti oxide
pc: plagioclase of unknown composition
qz: quartz
ti: titanite

Table 3 Mineral distribution and textural preservation in metamorphic zones of Belmont Township. Not all minerals occur in a given rock type. Quartz, apatite, magnetite, hematite, graphite, and pyrite may occur as accessories. Dashed line indicates that the mineral or texture/structure concerned is rare. From Bartlett (1983).

Metamorphic facies	Greenschist facies	Greenschist/Amphibolite Transition	Amphibolite facies
Mineral zoning	Actinolite	Chlorite-hornblende	Hornblende
Plagioclase	Albite	Albite-sodic oligoclase	Calcic oligoclase
Epidote			
Clinozoisite			
Hornblende			
Actinolite			
Biotite			
Chlorite			
Retrograde chlorite			
Chlorite			
Muscovite			
Biotite			
Almandine			
Cummingtonite			
Kyanite			
Sodic plagioclae			
K-feldspar			
Tremolite			
Dolomite			
Quartz			
Primary volcanic flow textures			
Pillows/hyaloclastites			
Phenocrysts/amygdules			
Fragment outlines			
Algal structures			

Table 4 Correlation of metamorphic and deformational events in the map-area (modified from Bartlett, 1983).

Deformation	Metamorphism	Planar Fabric	
		S_0	Original sedimentary and volcanic fabric.
D_1	M_1	S_1	Major isoclinal folding, resulting in homoclinal arrangement of strata. Recrystallization and development of planar fabric: chlorite and mica plates, amphibole porphyroblasts, and inclusion trails incorporated in later porphyroblasts. Metamorphism outlasted deformation to produce main regional zonation: growth of chlorite, garnet, cummingtonite and kyanite porphyroblasts. Major faulting (?). Regional emplacement of gabbro, diorite, granite, and syenite plutons. Contact metamorphism.
D_2			Map-scale open to close folding in western part of Belmont Township; outcrop-scale folding local in east. Continuation of M_1 metamorphic event. Rotation of late-M_1 porphyroblasts. Local crenulation of cleavage in M_1 minerals.
	M_2	S_2	Recrystallization and development of localized planar fabric: mica plates and elongate calcite grains.
D_3			NW-SE regional compression (continuation of D_2 event (?)). S_2 fabric deformed around major plutons.
	M_3		Overprinting of S_1 (and S_2 ?) by muscovite porphyroblasts.
D_4			Local faulting and brecciation.

Table 5: Summary of the Stratigraphy and Evolution of Cycle I (modified from Bartlett, 1983).

Formation	Member	Thickness (metres)^1	Dominant rock type(s)	Minor rock type(s)	Facies analysis and depositional environment	Environmental indicators
Little Whitney Lake		0-1000	Calcitic and dolomitic marble	Siliceous clastic rocks	A quiescent interval following volcanism; shallow water deposition in restricted basin (caldera?); minor component of carbonate (and sulphide) from fumarolic deposition.	Algal structures; massive pyrite interlayered with carbonate.
Oak Lake	C (felsic volcanics) north part	1500->2000	Heterogeneous-felsic flows, tuff, lapilli tuff, tuff breccia volcanic conglomerate		Near-vent deposition in area of major syncline west of Little Whitney Lake - evidence: abundant felsic flows with lateral extent of 2 km, and coarse and massive to thickly bedded nature of most fragmental deposits; volcanic conglomerates mainly deposited on south flank of volcano; heterolithic nature and abundance of these deposits indicates active erosion, suggestive of subaerial or shallow water provenance and (?) deposition; forms part of major composite cone.	Thick bedding; heterolithic volcanic conglomerate.
	C south part	1500->2000	Felsic tuff, ash flow tuff	Felsic lapilli tuff, intermediate tuff, chert, sulphide facies iron formation, siliciclastics	Proximal to distal facies deposition indicated by fining of bedding and grain size of airfall pyroclastics to south; moderately to strongly welded ash flow tuffs, commonly tens of metres thick, indicate subaerial deposition; chert and sulphide facies iron formation probably deposited by fumarolic activity.	Thin to very thin bedding; graded bedding; moderate to strong welding in ash flow tuff.
	B intermediate	0-400	Intermediate tuff, lapilli tuff, tuff		Near-vent deposition indicated by presence of intermediate flows, and coarse nature of pyroclastics; amygdules in flows, and presence of	Amygdules; coarse grain size; medium to thickly bedded pyroclastics.

Table 5 (cont'd)

volcanics, north part		breccia, flows		pyroclastics indicates subaerial or shallow water deposition; away from near-vent area bedding and grain size are finer, and reworked deposits more abundant; occur mainly as small, lenticular units.	
B south part	0-100	Intermediate tuff	Intermediate lapilli tuff	Relatively distal, subaqueous deposition indicated by thin bedding and fine grain size; occur as small lenses throughout.	Thin bedding, fine grain size.
A mafic volcanics, north part	0-300	Mafic flows	Mafic tuff	Near-vent deposition suggested by proximity to felsic flows; in part deposited in shallow water environment; local mafic airfall tuff represents last phase of mafic volcanism before deposition of Little Whitney Lake formation; mainly confined to nose and limbs of syncline.	Pillows, hyaloclastites, amygdules, thin to very thin bedding in tuff.
A south part	0-20	Mafic flows		Amygdules indicate shallow water or subaerial deposition; may represent isolated flank eruptions, as associated gabbro swarm is probably subvolcanic to a poorly exposed mafic sequence.	Amygdules

1. Measured thickness without allowance for tectonic thickening or thinning.

Table 6: Summary of the Stratigraphy and Evolution of Cycle II (modified from Bartlett, 1983).

Formation	Member	Thickness (metres)[1]	Dominant rock type(s)	Minor rock type(s)	Facies analysis and depositional environment	Environmental indicators
Whitney Creek	D	150-700	Felsic volcaniclastics, mudstone	Chert	Felsic volcaniclastics thickest in north, suggesting proximal facies; bedding and grain size fine to south, indicating more distal facies; a major facies transition occurs east of north side of Round Lake: the volcaniclastics pinch out in a southward thickening pile of mudstone, representing distal facies deposition in deepening marine basin; chert is more abundant to south and as thin layers in uppermost part of member, possibly indicating deposition in deeper water; graphite content increases to south, suggesting environment was more euxinic; thin pyritic unit at top of most of member may have formed partly from fumarolic activity after and in the late stages of deposition of volcaniclastics.	Very thin to medium bedding, graded bedding, chert, graphite.
	C	0-150	Marble		Deposited during hiatus in late stage of mafic volcanic activity; dolomitic marble, bearing algal structures, is most common in north part of member, indicating shallow water deposition; member thickens gradually to south; calcitic component increases to south through zone of interbedded calcitic and dolomitic marble to dolomite-poor, non-stromatolitic part of unit - this may indicate deepening marine basin to south.	Algal structures; relative abundance of calcite vs. dolomite.

Table 6 (cont'd)

B	0-100	Silicate facies iron formation	Chert, mudstone	Deposited by exhalative activity during hiatus in volcanism; distribution of silicate, oxide and sulphide minerals indicates vertically and laterally fluctuating chemical conditions.	
A	250-800	Mafic flows, mafic agglomerates, tuff, intermediate tuff, lapilli tuff	Intermediate flows, felsic tuff, chert	Interstratified flows and pyroclastics in the north form east flank of composite volcano, the apex of which has been eroded away; smaller, subaerial volcanoes probable 2-3 km north of Round Lake where agglomerates are abundant; area between north and south parts of member may represent restricted subaqueous basin where pillows and hyaloclastites formed, and where chemical precipitation of Member B occurred; lavas and pyroclastics lying between Members C and D may represent a brief return to mafic volcanism.	Agglomerates, pillows, hyaloclastites, amygdules.

1. Measured thickness without allowance for tectonic thickening or thinning.

Table 7: Summary of the Stratigraphy and Evolution of Cycle III (modified from Bartlett, 1983).

Formation	Member	Thickness (metres)[1]	Dominant rock type(s)	Minor rock type(s)	Facies analysis and depositional environment	Environmental indicators
Belmont Lake		0-700	Conglomerate	Sandstone, mudstone, marble, felsic tuff	Polymictic conglomerate; most volcanic and chert clasts strongly resemble rocks of the Cordova Lake formation, the proposed provenance; marble clasts are in part derived from the lower part of the Marmora formation and in part from immediately underlying marble units within the formation; the Belmont Lake formation is time-equivalent to part of the Marmora formation, the distinction being a facies change; cobble- and locally boulder-size clasts, poor sorting and low to moderate sphericity suggest relatively proximal facies relative to source area(s); fluvial transport of detritus evidenced by filled scour channels cut into earlier conglomerates; alluvial and laharic processes may also have contributed to the transport and deposition of rocks of this formation; mudcracks in fine clastic sediments attest to periodic subaerial exposure; fluctuating energy conditions allowed deposition of dolostone with algal mats and columnar stromatolites; some dolostones caked and reworked by wave and (or) current action to form minor conglomerate; felsic ash flow tuff near top of formation may signify the return to a predominantly volcanic regime; welding in this rock indicates subaerial or shallow subaqueous deposition; it is tentatively assigned to Cycle III volcanism, however it may, alternatively, be associated with a volcano outside the map-area, or not presently exposed; two thin clastic units	Coarse clast size, poor sorting, scour channels, mudcracks, algal structures, welding in ash flow tuff.

Table 7 (cont'd)

					in the uppermost part of the Belmont Lake formation are interstratified with rocks of the Crowe River formation; these units contain siltstones, sandstones and conglomerates with felsic volcanic, calcitic marble and cherty mudstone clasts, and are virtually identical to rocks underlying the lowermost mafic volcanics of the Crowe River formation; no mafic volcanic detritus appears to be present in the conglomerates of these units - this may reflect tectonic placement of the units, or deposition by special (eg. non-erosional) processes.	
Marmora		0-2000[2]	Calcitic and dolomitic marble, interlaminated carbonate and siliceous clastic sediments	Mudstone, conglomerate	Divisible into two regimes: one, predominantly dolomitic, occupies the lower part of the formation; the abundance of algal structures, mainly mats, indicates that deposition took place in very shallow water; one or more erosional unconformities yielded material deposited in the Belmont Lake formation; upper part of Marmora formation, including most of the unit in Marmora Township, is predominantly non-stromatolitic calcitic marble, with or without interlaminations of siliceous clastic material, suggesting a deeper water environment of deposition.	Domal and laminar algal structures, relative abundance of calcite vs. dolomite.
Vansickle	D	0-1000[2]	Intermediate volcanics	Mudstone	Probably mostly reworked intermediate volcanics; relatively distal facies.	Thin bedding, fine grain size.
	C	0-300[2]	Mafic flows	Mafic schist of uncertain derivation	Subaqueous deposition; similar and probably related to Member A of Cordova Lake formation.	Hyaloclastites

Table 7 (cont'd)

	B	4 distinct units^2 0-300 0-150 0-500 0-650	Sandstone, mudstone	Felsic tuff, volcanic conglomerate	Subaqueous deposition; involved reworking of felsic and intermediate volcanics; relatively distal facies.	Thin bedding; fine grain size.
	A	2 units^2: 0-1200 0-400	Calcitic marble	Dolomitic marble, calcareous wacke	Subaqueous deposition; predominating non-stromatolitic calcitic component vs. minor dolomitic component may indicate shallow to moderate water depth; calcareous wacke represents facies change from carbonate to siliceous clastic deposition.	Thin bedding.
Cordova Lake	B	0-200	Felsic and intermediate flows and tuff	Volcanic wacke	Near-vent deposition indicated by felsic and intermediate flows with lateral extent of 2 km, and by locally intense alteration; pillows and thin bedding of tuffs indicate subaqueous deposition; restricted to Belmont Lake area; major source of detritus for deposition of Belmont Lake formation.	Pillows, thin bedding, alteration.
	A	100-3500	Mafic flows	Intermediate and felsic tuff, oxide and silicate facies iron formation, chert, mudstone	Abrupt attenuation of member to north probably due to tectonic thinning; intercalations of intermediate and felsic tuff with mafic lavas suggestive of composite volcano; relationship to Member B suggests proximal facies in Belmont Lake area; abundance of small gabbro and diorite bodies, and presence of intermediate flows may indicate a vent area in the Lost Lake area; numerous dikes in upper half of member may indicate that fissure eruptions were important; small lenses of chemical sediments indicate periodic, probably local, cessations in volcanism, and deposition in restricted basin; most, if not	Pillows, hyaloclastites.

Table 7 (cont'd)

all of member deposited subaqueously, as evidenced by the ubiquitous hyaloclastites.

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1. Measured thickness without allowance for tectonic thickening or thinning.
2. Thickness of Marmora and Vansickle formations based on exposure in Belmont Township only; refer to Figure 3 and Lithologic Descriptions section for tentative extrapolation of these formations outside of Belmont Township.

Table 8: Summary of the Stratigraphy and Evolution of Cycle IV (modified from Bartlett, 1983).

Formation	Member	Thickness (metres)[1]	Dominant rock type(s)	Minor rock type(s)	Facies analysis and depositional environment	Environmental indicators
Crowe River	B	70	Skarn	Calcitic marble	Deposited during quiescent interval at or near end of volcanism; subsequently converted to skarn by intrusion of gabbro body.	
	A	0-4500	Mafic and intermediate flows and pyroclastics	Felsic tuff, volcanic conglomerate	Upper part: continuation of growth of maturing shield volcano. Middle part: agglomerates indicate central facies, agglutinates indicate subaerial deposition; thin laminations and normal grading in felsic tuff suggest local subaqueous deposition; degree of reworking of felsic volcanic conglomerate suggests subaerial source; consistent with growth of maturing shield volcano. Lower part: flows and agglomerates deposited with conformity on and interstratified with shallow water or subaerial, clastic rocks of the Belmont Lake formation; relatively large amygdules indicate shallow water or subaerial deposition; agglutinates reflect subaerial eruption and deposition; shield-building stage.	Middle part: amygdules, iron oxides; thin, graded bedding in felsic tuff. Lower part: amygdules

1. Measured thickness without allowance for tectonic thickening or thinning.

Table 9: Major Mineral Deposits: Producers, Past Producers and Occurrences - Marmora, Belmont & Southern Methuen Townships

NAME	LOCALITY	DEPOSIT TYPE	EXPLORATION, MINING ACTIVITY, AND PROPERTY DESCRIPTION
1. ARMBRO LTD.[1]	Lots 4, 5 Concessions V, VI Marmora Twp.	Ordovician Limestone	25.5 million tons of limestone was removed to uncover the iron deposit of the Marmoraton Mine, thus exposing the township's thickest section (maximum 40 m) of limestone. The limestone from the waste pile is being crushed and trucked out for use as aggregate.
2. BELMONT GRANITE[8]	W1/2 Lot 31 Concession X Belmont Twp.	Uniform medium-grained granite	Dimension stone quarry, intermittently active
3. CORDOVA GOLD MINES[129]	E 1/2 Lots 20, 21 Concession I Belmont Twp.	Quartz-Ankerite Veins in Schistose Metagabbro (Au, Ag)	Circa 1890: Discovered by H.T. Strickland 1891-1892: Three shafts: No.1 to 40.2 m; No.2 to 10.4 m; No.3 to 9.6 m. Work by South African General Exploration and Mining Company of London, England. 1898-1902: No.1 shaft continued to 125 m, No.2 to 56 m; No.3 to 99 m. An additional 5 shallow shafts were sunk, generally 24-30 m deep. Drifting totalled 1.317 m. A ten-stamp mill was in operation. Work by Cordova Exploration Company Limited. Circa 1912: No.3 shaft deepened to 148 m. Thirty-stamp mill in operation. 1935-1939: No.3 shaft continued to 320 m. Drifting and crosscutting totalled 3213 m and 833 m respectively. Underground diamond drilling from more than 13 holes totalled 2087.9 m. 125-ton mill erected. Work by the Consolidated Mining and Smelting Company of Canada Ltd. 1965: Diamond drilling and sampling of Tailings Dump by Orvana Mines Limited. Circa 1980: Remaining reserves reported to average 0.12 ounce of Au per ton, with 46000 tons proven, 50000 tons Probable, and 100,000 tons possible ore outlined. An estimated 10,000 to 15,000 tons of broken ore contained in a large pile on surface, and a similar quantity of tailings from past milling operations. 1984: The deposit is currently being developed by Lasir Gold Incorporated and Minetek.
4. 3M CANADA INC.[3]	W 1/2 Lot 6 Concession VI Belmont Twp.	Mafic Metavolcanics	Large quarry and plant producing roofing granules. Exploratory drilling in 1964 (14 DDH) and 1978 (2 DDH).
PAST PRODUCERS			
5. BELMONT	N.W. 1/4 Lot 19	Contact - Meta-	1899 - 1901: Two open pits

IRON MINE[1]	Concession I Belmont Twp.	somatic pyrite-magnetite body in marble at metagabbro contact	1905-1906: 1911-1914: Circa 1970:	Six diamond drill holes and magnetometer survey Shaft sunk to 80 m Sampling, mill tests. Work by Canada Costa Rica Mines Limited.
6. BLAIRTON IRON MINE[1]	NW 1/4 Lot 7 Concession I Belmont Twp.	Skarn at contact of gabbro with calcite marble; magnetite, pyroxene, epidote, garnet.	1820-1963: 1908-1910: 1951: 1957-1958: 1959: 1960:	Three open pits 13 diamond drill holes, total drilled 1161m. Work by Trent River Mines Ltd. 2 diamond drill holes, work by W.S. Moore Co. Diamond drill holes, total drilled 1511m. 7 diamond drill holes. Total 688 m by Canal Iron Co. 1 diamond dril hole to 55.5 m by W.S. Moore Co.
7. BONTER, W.F. AND COMPANY[1]	Lots 16, 17 Concession XI Marmora Twp.	Calcitic marble	Circa 1963 to circa 1971:	Six quarries in operation. Marble used as blocks for pulp and paper industry, poultry grit, feed dust, terrazzo chips and crushed stone.
8. CANADA CONSOLIDATED[1] MINE	Lot 5 Concession IX Marmora Twp.	Au-As bearing quartz carbonate veins in sheared (?) syenite	1882: 1885:	Six shafts sunk (from 12.2 m to 39.5 m); mill erected; assays. 440 tons of crude and refined as shipped to U.S.A.
9. COOK MINE[1,2,4]	Lots 7-9, Concession IX; Lots 10-12, Concession X; No.1 shaft on Lot 9, Concession IX; No.4 shaft on Lot 10, Concession IX, Marmora Twp.	Au-bearing arsenopyrite-pyrite-chalcopyrite quartz-carbonate veins in diorite	1901-1904:	Two shafts, No.1 and 4, sunk to 54 m and 36.5 m respectively, with several levels; 16.5 m and 13.5 m drifting, pitting, trenching, and drilling; 389 ounces Au milled, average grade was 0.26 ounce per ton Au.
10. CROWE RIVER MARBLE QUARRIES[1]	Lot 9, Concession IV, Marmora Twp.	Calcitic Marble	Pre 1938-Pre 1963:	Quarried by Bonter Marble and Calcium Company. The white to gray, fine- to medium-grained calcitic marble was used for industrial purposes. The quarry is 45 m long, 23 m wide and 9 m deep; an additional depth of 17m had been proven by drilling. The strike is westerly and dip vertical, mafic dikes have intruded the marble.
11. DEAN AND WILLIAMS MINE[1,2]	SE 1/4 Lot 7, Concession IX, Marmora Twp.	Au-bearing arsenopyrite-pyrite-chalcopyrite-quartz-carbonate veins in diorite and granite	1870:	Pitting and a shaft sunk to 49 m; ten-stamp mill errected; 500 ounces Au milled from 1000 tons of ore. Records indicate that the quartz carbonate veins or "Lenses" strike N25°W and dip 45°E.

12. DELORO MINE[1,2,4,5]	Lot 9, Concession VIII Marmora Twp.	Au-As-bearing quartz veins in diorite and/or gabbro	Prior to 1871:	Worked by unrecorded operators.
			1871-1896:	At least three shafts were sunk: Gatling (No.1) shaft, inclined 55°, was sunk to 47 m with 150 m of drifting on levels at 21 m and 38 m, Tuttle (No.2) shaft (inclined) was sunk to 21 m. Developers included: 1872-1880, Gatling Gold and Silver Mining Co.; 1880-1884, Canada Consolidated Gold Mining Co. (who erected original mill); 1892-1894, The Hastings Mining and Reduction Company.
			1896-1903:	Gatling shaft continued to 105 m and new levels established at 71 m and 101 m; a Winze was sunk from the 101 m level to an approximate depth of 152m. Tuttle shaft deepened to 39 m. Timber shaft deepened to 30 m. Shafts were interconnected by drifts and winzes. Total drifting was approximately 485 m and crosscutting 237 m. Eight other shafts were sunk, for a total depth of 157m; 66 m of drifting was done from these shafts. Some diamond drilling Twenty-stamp mill and works for arsenic recovery constructed. Work by Canadian Gold Fields Ltd. Some gold was produced prior to 1884.
			1897-1902:	10,360 ounces of Au were milled from 39,143 tons of ore.
			1899-1903:	2,112 tons of arsenic were produced.
				The mine was closed in 1903 - in 1907 the property was bought by the Deloro Mining and Reduction Co. Ltd. and the Mill converted into a refinery for treating cobalt-nickel-arsenic ores from Cobalt, Ont. Recently, the Ontario Ministry of the Environment has been assessing Potential Environmental hazards due to tons of arsenic by-products stored in unspecified locales in the mine workings.
				In general, the deposits are hosted by metagabbro and/or metadiorite that is cut by quartz veins 30 m to 300 m long, 0.5 m to 1.5 m wide, dipping 20-55°W, and containing up to 10% arsenopyrite. The Gatling shaft lies in carbonatized metagabbro that hosts a quartz vein dipping 40°W. The host rock at the air shaft is a metadiorite or metagabbro, cut by granitic dikes. The vein material consists of quartz with rusty-weathering calcite, mainly in a very fine-grained, pale green mica schist/phyllite; arsenopyrite, pyrite, chalcopyrite and a gray, acicular sulphosalt(?) are associated.
13. GATLING FIVE ACRES MINE[1,2]	Lot 9, Concession VIII Marmora Twp.	Au-bearing arsenopyrite quartz veins in felsic and mafic intrusive rocks (continuations of the air and gatling veins	1899-1903:	Shaft, inclined 60°NW, was sunk to greater than 61 m; levels at 23 m, 31 m, and 58 m; drifting (150 m) and crosscutting (6 m) were done on the continuation of the Air Vein. Shaft was sunk to 17 m on the continuation of the Gatling Vein. Ten-stamp mill installed by the Atlas Arsenic Co. Ltd.
			1900,	2,553 ounces of gold were milled from 6,114 tons of ore.

		of the Deloro Mine)	1902-1903:	
14. GLADSTONE MINE[2]	W 1/2 Lot 17, Concession XI, Marmora Twp.	Au-bearing quartz veins in felsic intrusive rocks (continuation of the veins at the Gatling Five Acres Mine)	Pre 1878:	Some pitting.
			1878:	Approximately 970 ounces of gold were reportedly recovered from both the Sovereign Mine and the Gladstone Property.
15. HASTVILLE QUARRY[1]	SE 1/4 Lot 17, Concession X, Marmora Twp.	Calcitic marble	1961-1963:	Quarried by Hastings Marble Products Ltd. Records indicate that the marble lies in close proximity to the Deloro Pluton. The quarry, which in 1963, measured 24 m by 7.5 m by 3.5 m, consists of Gray-Green, layered, siliceous (?), fine-grained calcitic marble striking N15°E and dipping vertically. The rock is sheared and mylonitized, and contains tremolite, serpentine and some sulphides.
16. LEDYARD GOLD MINE[1,2]	E 1/2, Lot 19, Concession I Belmont Twp.	Quartz-ankerite veins in metagabbro (Au, Ag)	1893-1896:	30 m shaft with 8 m of drifting and 26 m of crosscutting. Mill capacity of 20 tons per day. Work by Ledyard Gold Mines Company Ltd. 1893-1894, 55 tons of ore milled, yielding 13 ounces gold; recovered grade, 0.24 ounces Au per ton.
17. MALONE MINE[1,2]	SE 1/4, Lot 6, Concession VIII Marmora Twp.	Au-bearing arsenopyrite-quartz vein in felsic intrusive rocks	1894:	Shaft sunk to 18m; 100 tons of ore treated, yielding 0.60 ounces Au per ton. Work by Crescent Gold Mining Co.
18. MARMORATON MINE[1]	Lots 4, 5, Concession V, VI, Marmora Twp.	Contact metasomatic iron in altered carbonate rocks (skarn)	1950-51:	Anomaly delineated by ODM-GSC Aeromagnetic Survey flown in 1949; ground follow-up included: magnetometer, gravity surveys, and diamond drilling (40 holes, 11,300 m).
			1952-55:	Stripping of more than 20 million tons of overburden including limestone, construction of recovery plant on mine site; construction of dock at Picton.
			1950-55:	Work done by Bethlehem Mining Corp.
			1955-1978:	Mining performed by subsidiary company: Marmoraton Mines Ltd.
			1955-1978:	Recovery of 30 million tons of magnetite ore; pelletization done at mine site, and concentrates shipped by rail to Picton, where they were loaded onto ore carriers and transported across Lake Ontario, to Lackawanna, New York. The composition of the intrusive body associated with the deposit is variable, ranging from a biotite-hornbldende metadiorite to leucodiorite to syenite-quartz syenite. It intruded marble that

				strikes slightly west of north and dips steeply southwesterly. The resultant contact zone is composed of pods and lenses of hornblende-magnetite skarn (high grade ore) separated by garnet-pyroxene skarn (low grade ore). The magnetite ore deposit was 740 m long and had a maximum true thickness of about 120 m; it dipped steeply to the southwest. Veinlets of pyrrhotite, chalcopyrite and pyrite, and veinlets of epidote, serpentine and carbonate, some with pyrite and marcasite, cut the magnetite ore. The open pit exceeds 800 m in length, 400 m in width and is 220 m deep.
19. PEARCE MINE[1,2]	E 1/2, Lot 8 Concession VIII Marmora Twp.	Au-Ag-bearing arsenopyrite-quartz veins in felsic intrusive rocks	Circa 1893:	Shaft sunk to 27 m with a level at 12.5 m on which 8 m of drifting was done by the Hastings Mining and Reduction Co.
			Circa 1901:	Shaft deepened to 50 m; levels established at 16 m and 45 m on which about 72 m of drifting was done by Atlas Gold and Arsenic Mining Co.
			1904-1905:	Shaft deepened to 52 m and 12 m of drifting was done by the Cleveland Mining Co. of Ontario.
			1893, 1908:	302 ounces of gold and 60 ounces of silver were milled from 239 tons of ore.
			Pre-1935:	Centaur Mining Co. Ltd. sunk a 21 m shaft and did 25 m of drifting and crosscutting.
			1935:	A one ton sample assayed 0.785 ounces Au per ton, 0.05 Ag per ton and 2.17% As.
20. SOVEREIGN MINE[1,2]	Lots 16, 17 Concession XI Marmora Twp.	Au-bearing arsenopyrite-quartz vein in felsic intrusive rocks and calcareous metasediments	1866-1878:	Work done by unrecorded operators.
			Circa 1878:	Pitting and shallow shaft sinking by D.E.K. Stewart under lease.
			1878:	970 ounces of gold was reportedly recovered from both the Sovereign Mine and Gladstone Property.
			1890-1892:	Shafts were sunk, one to 20 m; ten-stamp mill erected (Crescent Gold Mining Co. of Marmora Ltd.).
			1891-1892:	Approximately 328 ounces of gold were recovered from 1,700 tons of ore.
			1900:	42 ounces of gold were recovered from 262 tons of ore.
			Circa 1903:	Reworking of old pits and openings by the Sovereign Gold Mining and Development Corp. of Ontario Ltd.
				The gold deposit consists of a quartz vein of varying thickness that strikes northerly and dips westerly at 70°; it cuts both granite and impure carbonate metasediments that have been, in part, metasomatized. The workings now consist of a co-linear succession about 150 m long of trenches with two shafts; these excavations follow the quartz vein. A 7 m square shaft marks the northerly working. The vein at this shaft is 60 cm thick, and cuts silicified

				skarn, containing 10-15% arsenopyrite. The trenches to the south expose skarn, sheared(?) granite, and the quartz vein. The sheared(?) granite contains many xenoliths of interlayered carbonate and siliceous metasedimentary rock.
21. STOKLOSAR IV[1]	SE 1/4 Lot 6, Concession VIII, Marmora Twp.	Calcitic marble	1965-1974:	Quarrying by Stoklosar Marble Quarries Ltd.
OCCURRENCES				
22. ACKERMAN[1,2]	NE 1/4 Lot 6 Concession VIII Marmora Twp.	Au-bearing arsenopyrite-quartz vein in felsic and intermediate intrusive rocks	Pre 1938:	Drilling, 6 holes by Consolidated Mining and Smelting Co. Canada Ltd.
			Circa 1938:	Shaft sunk to 82 m (Ackerman Gold Mines Ltd.)
			1942:	Diamond drilling (6 holes)
				Surface sampling of one vein yielded 0.32 ounes Au per ton over a length of 46 m and a width of 1.7 m.
			Circa 1951:	Diamond drilling (987 m)
			1960:	Diamond drilling, 1 hole, 58 m (Roach Marmora claims)
				Gold mineralization appears to be similar to those in and around the Deloro Mine camp.
23. BELMONT CALCITE (WHITNEY PROPERTY)[1]	Lots 31, 32 Concession VI Belmont Twp.	Pure calcite and dolomite marbles	1975:	Geological Survey
			1962-1963:	Drilling by Northumberland Mines Ltd., 5 holes total depth drilled 264 m.
			1976:	Drilling by Canadian White Pigment Corp., 2 holes total depth: 225 m.
			1980:	Drilling by Preussag Canada Ltd., 9 holes, total depth: 853.6 m.
24. BELOPORINE CREEK[1]	Lot 16 Concession X Belmont Twp.	Paleozoic limestone	1954:	Drilling, 1 hole, 32 m
			1977-78:	Drilling by C.R. Young, 3 holes, total depth 133 m.
			1980:	Drilling, 3 holes, total depth 126 m. Work by C.R. Young for Harnden and King Construction Ltd.
25. BENINGER[1]	SE 1/4 Lot 30, Concession I Marmora Twp.	Zn-Cu-Ag sulphide disseminated in volcanogenic metasediments	1970:	Diamond drilling, 1 hole, 62 m; assays: Zn-0.39% over 1.5 m of core. Rocks hosting the Zn mineralization here are similar to the "Deer Lake Rusty Schists" (Young-Cumming I and II, nos. 56 and 55, this Table), they are rusty weathering pyrite-pyrrhotite bearing schists derived from mudstones and exhalites.
26. BONTER, R.E.[1]	W 1/2 Lot 27 Concession V Marmora Twp.	Disseminated and fracture-filling Cu-Ni sulphide	1925:	Test pitting and trenching (1 pit, 4 trenches); average samples across a width of 18 m in the longest trench contained 1.34% Cu and 0.42% Ni; an average sample across 18 m taken from the trench

		mineralization in ultramafic intrusive rocks		immediately north contained 2.39% Cu and 0.48% Ni.
			1944:	Diamond drilling (6 holes, 585 m), and core assays richest sections averaged 0.26% Cu and 0.45% Ni over 5.2 m, 0.54% Cu and 0.35% Ni over 12 m, 2.15% Cu and 0.55% Ni over 3 m, 0.66% Cu and 0.61% Ni over 8.5 m, 0.28% Cu and 1.11% Ni over 9.5 m. Work by Consolidated Mining and Smelting Company of Canada Limited.
			1950:	Surface sampling and assays: the best mineralization in the most northerly trench assayed 0.35% Cu and 0.22% Ni; a chip sample from the walls of the test pit assayed 1.86% Cu and 0.47% Ni; some (<1%) Cr in each sample.
			1953:	Diamond drilling (7 holes, 1,100 m) by Ontario Nickel Mines Ltd.; 3 holes cut 68 m of mineralization, but assays were lower than 1% Cu and Ni.
			Cu-Ni mineralization occurs as disseminations and fractue fillings of chalcopyrite and pyrrhotite in a metapyroxenite body intruding siliceous clastic metasediments. Pyroxenes within the variably mineralized, coarse-grained metapyroxenite are well preserved, but locally other minerals in the rock have been altered to powdery hematite, reducing the rock's cohesion. Of the four easterly-trending trenches, the most southerly exposes relatively non-mineralized metapyroxenite that is fairly uniform, same for several narrow (<1 m thick) northerly trending, strongly schistose shear zones, which now consist of micas, chlorite, and clay minerals. Four metres north, AP exposes rusty weathering host rocks with up to 15% disseminated pyrrhotite (+ pyrite?). Eight metres north again, is a trench with a similar occurrence of sulphides and host rock. The next trench, five metres north, bears considerable sulphides as disseminations and fracture fillings. Rusty weathering sulphidic metapyroxenite is exposed in the most northerly trench (8 m from the previous trench).	
27. CAMPBELL-BLOMFIELD[1,2]	E 1/2 Lot 6, Concession VIII Marmora Twp.	Au-bearing arsenopyrite-quartz vein in felsic intrusive rocks	1901:	Two shafts sunk to 3.7 m and 18.3 m. Records indicate that the mineralization occurred in a two metre southeasterly-trending quartz vein that dipped 30°SW, and contained arsenopyrite and gold.
28. CROWE RIVER IRON	S.W. 1/4 Lot 15 Concession I Belmont Twp.	Hematite and martite in metagabbro and altered mafic metavolcanics (Fe, V, Ti)		
29. CROWE RIVER	Lot 13 Concession I	Fine- to medium-grained	Surface sampling	

TRAP ROCK[6]	Belmont Twp.	metagabbro		
30. DAUST, A.P.[1,2]	NW 1/4 Lot 6, Concession IX Marmora Twp.	Pyrite-pyrrhotite-chalcopyrite-arsenopyrite bearing diorite (Asp)	1966:	Diamond drilling, 3 holes, total drilled: 110 m
31. DEMARS OCCURRENCE[2]	Lot 24, Concession V Marmora Twp.	Metasediments and felsic intrusions containing auriferous arsenical ores	1891-1893:	Test pitting; some free gold
32. DOMINION GULF[1]	Lot 5 Concession II Belmont Twp.	Magnetic anomaly in area of Paleozoic outcrop	Ground magnetic survey	
33. DOSTANKO I[7,10]	NE 1/4 Lot 2 Concession IX Marmora Twp.	Contact metasomatic arsenopyrite in altered carbonate rocks	Circa 1930:	Test pitting
34. DOSTANKO II[7,10]	SE 1/4 Lot 2 Concession IX Marmora Twp.	Contact metasomatic arsenopyrite, magnetite, pyrite, chalcopyrite in altered carbonate rocks	Circa 1935:	Test pitting, assays: Cu-340 ppm
35. DOSTANKO III[7,10]	SE 1/4 Lot 2 Concession IX Marmora Twp.	Contact metasomatic arsenopyrite, Cu and Co in altered carbonate rocks	Circa 1935:	Test pitting, assays: Cu-440 ppm, Co-104 ppm
36. DOSTANKO IV[7,10]	SE 1/4 Lot 2 Concession IX Marmora Twp.	Contact metasomatic arsenopyrite, chalcopyrite, pyrite, Au in altered carbonate rocks	Circa 1970:	Test pitting; assays: Au-0.01, 0.02 ounces/ton

37. DOSTANKO V[7,10]	SE 1/4 Lot 2 Concession IX Marmora Twp.	Contact metasomatic arsenopyrite & Cu in altered carbonate rocks	Circa 1935:	Test pitting; assays: Cu-280 ppm
38. GAWLEY No. 1[1,2]	E 1/2 Lot 18 Concession IX Marmora Twp.	Au-As bearing quartz-carbonate vein in calcareous metasediments; pyrite & chalcopyrite associated	1901:	Shaft sunk to 31 m by Atlas Arsenic Co. Ltd., one level 56 m long. Calcareous metasediments enclose a 3 m wide. Quartz vein containing approximately 0.34 oz Au/ton and 14% As.
39. GAWLEY No.2[1,2]	Lot 9, Concession X Marmora Twp.	Au-As-bearing quartz veins in felsic intrusive rocks	Pre-1902:	Trenching, assays: average 0.37 oz Au/ton, 15% As.
40. GILLEN OCCURRENCE[1,2]	NE 1/4 Lot 6, Concession VIII Marmora Twp.	Au-bearing quartz vein in felsic intrusive rocks	1870-71:	5-stamp mill operated; 100 ton sample averaged 0.30 oz Au/ton. Quartz vein in a felsic intrusion is about 1 m wide.
41. HARRINGTON, J.[1]	Lot 6, Concession IX Marmora Twp.		1982:	Geophysics, magnetometer survey
42. HAWKEYE[1,2]	E 1/2 Lot 10 Concession VIII Marmora Twp.	Au-bearing arsenopyrite-quartz veins in mafic and felsic intrusive rocks	1870-71: The deposit is immediately north of the Deloro Mine and the Gatling Five Acres Mine and consists of arsenopyrite-quartz veins that cut granite and quartz syenite to the east, and carbonate-impregnated metagabbro(?) to the west.	Two shafts sunk (14 m and 9.2 m) and some ore removed.
43. HORSE LAKE (TRAP) PROPERY	Lot 5 Concession X Methuen Twp.	Massive diorite cut by granitic dikes	Drilling	
44. MALONEY [1,6,10]	SE 1/4 Lot 18, Concession I Marmora Twp.	Contact metasomatic Fe and Fe-Ti oxides in gabbroic rocks	Pre 1923: Pre 1959: 1959: The deposit lies only slightly to the western side of the contact between the Cordova Pluton and carbonate metasediments. Skarn zones were intersected by drill holes.	Two test pits and stripping Four trenches Diamond drilling (2 holes, 200 m) by C.R. Young, ground magnetic survey (Young-McQuigge Prospect).

			The trenches trend northerly, are 30 m apart, and occupy the eastern most part of the property. The eastern most trench cuts 11 m of contact metasomatic, magnetite-rich rock, and exposes a contact with carbonate metasediments. The trenched rock consists of massive magnetite; pyrrhotite is present in local abundance. Only rubble was located at the western trench. Immediately to the south of these trenches, foliated metagabbro and leucogabbro crop out. About 60 m southwest of the trenches, a small pit, no longer exposing rock, is surrounded by a mafic-rich metagabbro with local disseminated magnetite and pyrrhotite. Further southwest, about 150 m, is a pit exposing rusty-weathering magnetite-rich rocks with layers and disseminations of pyrite. An unaltered, medium- to coarse-grained metagabbro crops out nearby. A sample of magnetite-pyrite-rich rock from this pit returned anomalous assays of Cr (1180 ppm), Cu (310 ppm) and Ni (360 ppm). Values of more than 17% Ti have been reported (C.R. Young, Havelock).
45. MATTAGAMI LAKE MINES[1]	W 1/2 Lot 6 Concession IX Marmora Twp.	Au-As bearing quartz veins in mafic to felsic intrusive rocks	1976: Electromagnetic survey, grab sample assayed 2.4 oz Au/ton 1979: Detailed electromagnetic survey.
46. METHUEN LEAD[1]	Lot 1 Concession I Methuen Twp.	Galena-carbonate vein in marble	Pit
47. MOIRA RIVER[1]	Lot 14, Concession X Marmora Twp.	Calcitic marble; (Brucite bearing in part)	Pre 1938: Sampling; assays 1938-1980: Sporadic quarrying 1981: Quarrying At least three small quarries in white, calcitic marble that occupies a narrow zone between the Deloro Pluton and the large felsic intrusive body to the northwest. Within the marble are local concentrations of brucite, tremolite, and serpentine.
48. NEILL, BOB OCCURRENCE[2]	W 1/2 Lot 14 Concession X Marmora Twp.	Au-bearing quartz vein between granite and country rock	Circa 1867: Vein discovered, surface samples assayed upwards of 0.25 oz Au/ton. 1870-1871: Test pit, sample assayed 0.117 oz Au/ton.
49. PERSHING[1]	Lot 2, Concession V Belmont Twp.	Magnetite-bearing skarn associated with gabbro, mafic volcanics, carbonate rocks	Drilling, assays
50. ROUND	Lot 23	Pure Dolomitic	1976-1980: Diamond drilling, 3 holes, total drilled: 122 m. Work by C.R.

LAKE DOLOMITE[6]	Concession VI Belmont Twp.	marble		Young and Harnden and King Construction.
51. ROUND LAKE SULPHIDE[6]	Lot 20 Concession VII Belmont Twp.	Three stratiform pyrite-pyrrhotite zones in chert, mudstone and wacke (Fe, Cu, Zn)	Trenching Drilling Assays	
52. STOCKLOSAR[1]	NW 1/4 Lot 13 Concession X Marmora Twp.	Calcitic marble	1983:	Stripping, blasting and drilling by Stocklosar Marble Quarries Ltd.
53. SUDBURY CONTACT[1]	SW 1/4 Lot 9 Concession IX Marmora Twp.	Au-bearing quartz veins in felsic intrusive rocks	1973:	Diamond drilling (11 holes, 408 m) by Sudbury Contact Mines Ltd.; Assays: 0.34 oz. Au/ton over 1 m of core. Shaft #1 of Cook Mine is blieved to be within 100 m of this deposit.
54. VANSICKLE MARBLE[1]	Lot 5 Concession I Methuen Twp.	Pure calcitic and dolomitic marbles	Drilling	
55. YOUNG-CUMMING PROPERTY No. 1[1,6]	Lot 27 Concession II; S 1/2 Lot 27 Concession I Marmora Twp.	Disseminated sulphides in graphitic schists (Fe, Cu, Zn, Ag, Au)	1957: 1967: 1976-1978:	Geological, ground magnetic, electromagnetic, geochemical surveys by Texas Gulf Sulphur Co.; also diamond drilling. Detailed geological mapping by Syngenore Explorations Ltd. Diamond drilling (3 holes, 130 m) by C.R. Young.
56. YOUNG CUMMING PROPERTY No. II[1,6]	Lots 27, 28 Concession I Belmont Twp.	Disseminated sulphides in graphitic schists (Fe, Cu, Zn, Ag, Au)	1964: 1967: 1968: 1969: 1969:	Diamond drilling (1 hole, 112 m) by Keevil Mining Group Geological mapping by Syngenore Explorations Ltd. Diamond drilling (4 holes, 855.5 m) by Syngenore Explor. Ltd. Diamond drilling (3 holes, 290 m) by the Coniagas Mines Ltd. Diamond drilling (1 hole, 243 m) by Metalridge Mines Ltd. The geological context of the deposit appears to remain constant from east to west: rusty-weathering schists derived from pyrite-pyrrhotite-bearing mudstones and exhalites containing significant amounts of chalcopyrite and sphalerite. Total sulphide contents are typically 10-25%, three metre core smples ranging from 0.06-0.16% Cu, 0.3-1.7% Zn, and 0.15-0.33 oz/Ag ton.
57. YOUNG-PHILLIPS[6]	Lot 14, Concession VI,	Magnetite and hematite in schist	Diamond drilling, 3 holes, 120 m.	

	Belmont Twp.	and chert (ironstone?) (Beneath paleozoic limestone)	
58. YOUNG-PURDY[6]	N.E. 1/4 Lot 20 Concession IV Belmont Twp.	Magnetite, chert and ironstone in mafic metavolcanics and associated metasediments	Trenching, drilling, assays

1. Information from: Assessment Files Research Office, Ontario Geological Survey, Toronto.
2. Information from: Gorden, J.B., Lovell, H.L., de Grijs, Jan, and Davie, R.F. 1979. Gold Deposits of Ontario, Part 2; Ontario Geological Survey, Mineral Deposits Circular 18, 253p.
3. Information from personal communication with R.M. Reid, Plant Engineer, 3m Canada Inc., Havelock, Ont. (1980).
4. Ontario Bureau of Mines, Report II, 1902.
5. Report of the Royal Commision on the Mineral Resources of Ontario, Warwick and Sons, Toronto, 1890, 566p.
6. Information from personal files of C.R. Young, Havelock, Ont.
7. Informtion from N. Dostanko, Deloro, Ont.
8. Information from operators (Belmont Granite).
9. Information from Carter, T.R., 1980: Metallic Mineral Deposits of the Grenville Province, Southeastern Ontario, p.169-174 in Summary of Field Work, 1980, Ontario Geological Survey Misc., Paper 96, 201p.
10. Assays provided by Geoscience Laboratories, Ontario Geological Survey, Toronto.

Table 10: Assay Data Belmont Township

	DEPOSIT TYPE	ANOMALOUS MINERALS, METALS[1]	LOCALITY[2]	ASSAY VALUES[3], REMARKS
a)	Stratiform sulphides in volcanogenic metasediments (host rocks are rusty-weathering, pyritic metamorphosed mudstones with or without garnet, cummingtonite, and magnetite)	py; Cu, Zn, Cr, Ni, V	Cycle III E. of Lost Lake 27444/493798	Cu = 166; Zn = 980
		gar, cumm, mag, py, Zn, Ag	Cycle III E. of Cordova Lake 27740/494009	Zn = 240
		gar, cumm; Cu, Zn	Cycle III E. of Cordova Lake 27732/494012	Cu = 118; Zn = 1000
		py; Cu, Zn	Cycle III E. of Cordova Lake 27732/494016	Cu = 260; Zn = 170
		py; Cu, Zn, As, Au, Cr, Ni, Hg, V, Pd, Pt	Cycle III E. of Cordova Lake 27739/493968	Cu = 156; Zn = 550
		cumm, mag; Cu, Zn, V	Cycle III E. of Cordova Lake 27688/493916	Cu = 198; Zn = 0.39%
		py; Cu, Zn, Cd, As, Au, Ag, Hg, Ni, Sb, V, B, F, Pt, Pd	Cycle II W. of Whitney Creek 27148/493677	Cu = 1150; Zn = 1.24%
		cumm, mag, py; Zn, Ba, V	Cycle III S of Lost Lake 27360/493605	Zn = 215
		py; Cu, Zn, Cd, Hg, Ni, V	Cycle II E. of Little Whitney Lake 27260/493918	Cu = 190; Zn = 0.8%
		py; Cu, Pb, Zn, Cd, Hg, Ag, Pd	Cycle II N. of Lost Lake 27428/494038	Cu = 540; Pb = 215; Zn = 300%; Hg = 2600
		cumm, py; Cu, Pb, Zn	Cycle II W of Whitney Creek, 271590/4935750	Cu = 198; Pb = 136; Zn = 320
b)	Quartz Veins	Au	Cycle III N of Munn Bay 27478/493302	Au = 0.007 oz/t; 0.3 m vein in mafic metavolcanics

py; Cu, Zn, Co	Cycle IV E of Crowe River Bay 27773/493230	Cu = 1220, Zn = 170; Co = 151; 1.5 m qz-py-iron carbonate vein in pyritic metasiltstone.
py; Au, V	Shaft no.5, Cordova Gold Mines 27902/493492	Au = .065 oz/t; qz - ferrodolomite-(pyrite) vein in altered gabbro
py; Ag	Cycle III N of Belmont Lake 27566/493526	Ag = 0.10, 0.12 oz/t; 3 m quartz vein and quartz - iron carbonate-py-biotite-k-feldspar-bearing altered rock, in chlorite schist. Vein reported to have yielded Au values.

Footnotes:

1) Anomalies based on field notes and visual inspection of assay data. In most cases elements reported are at least 3-4 times "background" of the sample suite submitted for assay (60 samples).
2) Numbers are UTM coordinates, Zone 18 (easting/northing).
3) Values are reported where 10-20 times "background", in parts per million unless otherwise specified.

Table 11: Minor Metal/Mineral Occurrences (Marmora Township)

Associated Deposit Type	Mineral/ Elements^1	Location^2	Past Exploration/Assay Values^3
Au-As and/or Ag bearing quartz veins in mafic, intermediate and felsic intrusive rocks	asp	Lot 17, Con IX	
	Ag	28148/493245	- Ag: 0.16 oz/ton
	Ag	28134/494174	- Ag: 0.18 oz/ton
	Ag	29044/493844	- Ag: 1.24 oz/ton
	Ag, Pb	29051/493840	- Ag: 0.38 oz/ton; Pb = 210 ppm
	Ag	27959/493386	- Ag: 0.10 oz/ton
	Ag	28087/493351	- Ag: 0.22 oz/ton
(mafic extrusive rock)	Au, py	28412/494398	- Au: 0.02 oz/ton; trenching
Contact metasomatic Fe oxides and sulphides in altered carbonate and gabbroic rocks	Fe	Lot 12, Con.III	
	Fe	Lot 17, Con.II	- 2 tests pits; assays by unknown party; Fe = 34.8%
	py, cp, Co	28263/493394	- 2 trenches; Cu = 2100 ppm Co=210 ppm
	mag, hem, Au	28087/493451	- pit; Au = 0.01 oz/ton
Intermediate intrusive rocks	Zn	28480/493939	- Zn = 170 ppm
	py, Cu, Zn, Cr	28428/494184	- Cu = 210 ppm; Zn = 230 ppm Cr = 218 ppm
Contact metasomatic arsenopyrite and/or magnetite and/or pyrite-chalcopyrite in altered carbonate rocks	mag, asp, py, Cu, Ni, Sb, Co, Zn	29463/492806	- 1981: test pitting; mag-asp-rich skarn Cu = 470 ppm, Sb = 410 ppm Ni = 200 ppm, Co = 136 ppm grab sample of pit: Cu = 1280 ppm, Ni = 142 ppm, Zn = 118 ppm, Co = 103 ppm
	mag, Zn, Au, Ag	29514/499848	- pit; Zn = 460 ppm, Au = 0.02 oz/ton, Ag = 0.54 oz/ton
	Au, trem.	29639/492713	- pit; Au = 0.01 oz/ton
	Au, po, py	29233/492992	- Au = 0.03 oz/ton
Strataform Zn-Cu-Ag	Cu, Zn	28071/494164	- Cu = 128 ppm, Zn = 250 ppm

sulphides in volcanogenic metasediments			
sub-type rusty weathering volcanic wackes	V V, Zn, Cr, Cu	28031/493439 29434/492790	- V = 120 ppm - V = 250 ppm, Zn = 175 ppm Cr = 165 ppm, Cu = 58 ppm
Magnetite ironstone	mag	28248/494342	associated magnetic anomaly
Fluorite-barite veins in felsic intrusive rocks	fl, ba, py	29484/492982	Ba = 800 ppm; Cr = 172 ppm
	fl, ba, mar	29315/493058	Ba = 2570 ppm
Calcitic marble	mb	Lot 18, Con II	pre 1938 sampling assays

Footnotes:.

1) Mineral/Element Symbols:.
Ag - silver
Asp - arsenopyrite
Au - gold
Ba - barium
ba - barite
Co - cobalt
cp - chalcopyrite
Cr - chromium
Cu - copper
Fe - iron
fl - fluorite
hem - hematite
mag - magnetite
mar - marcasite
mb - marble
Ni - nickel
Pb - lead
py - pyrite
Sb - antimony
trem - tremolite
V - vanadium
Zn - zinc

2) UTM co-ordinates given where exact location is known (UTM Zone 18)

3) Unless otherwise specified; all assays supplied by Geoscience Laboratories, Ontario Geological Survey, Toronto.

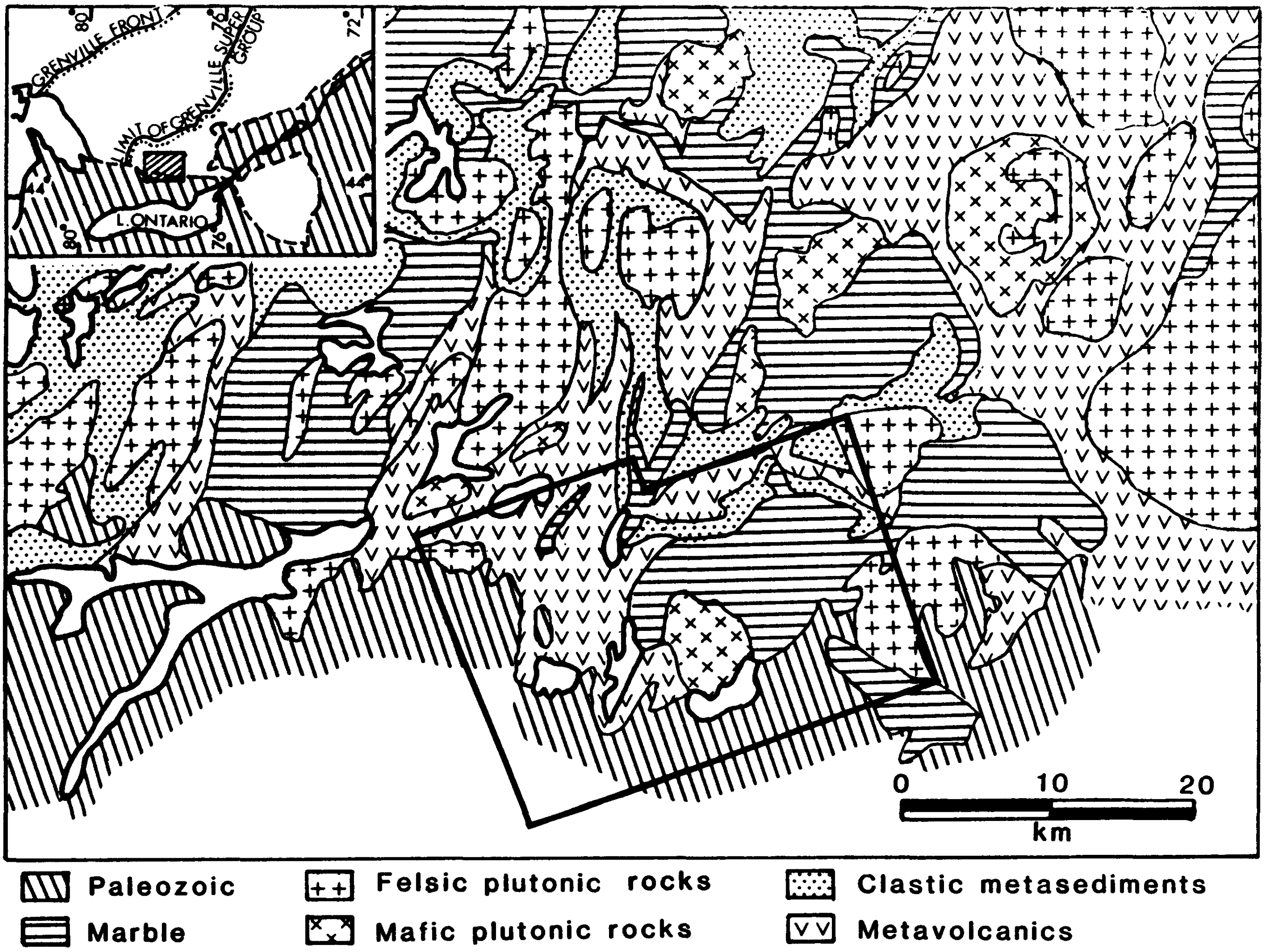


Figure 2: General geology of part of eastern Ontario, showing location of study area. Modified from Freeman (1978).

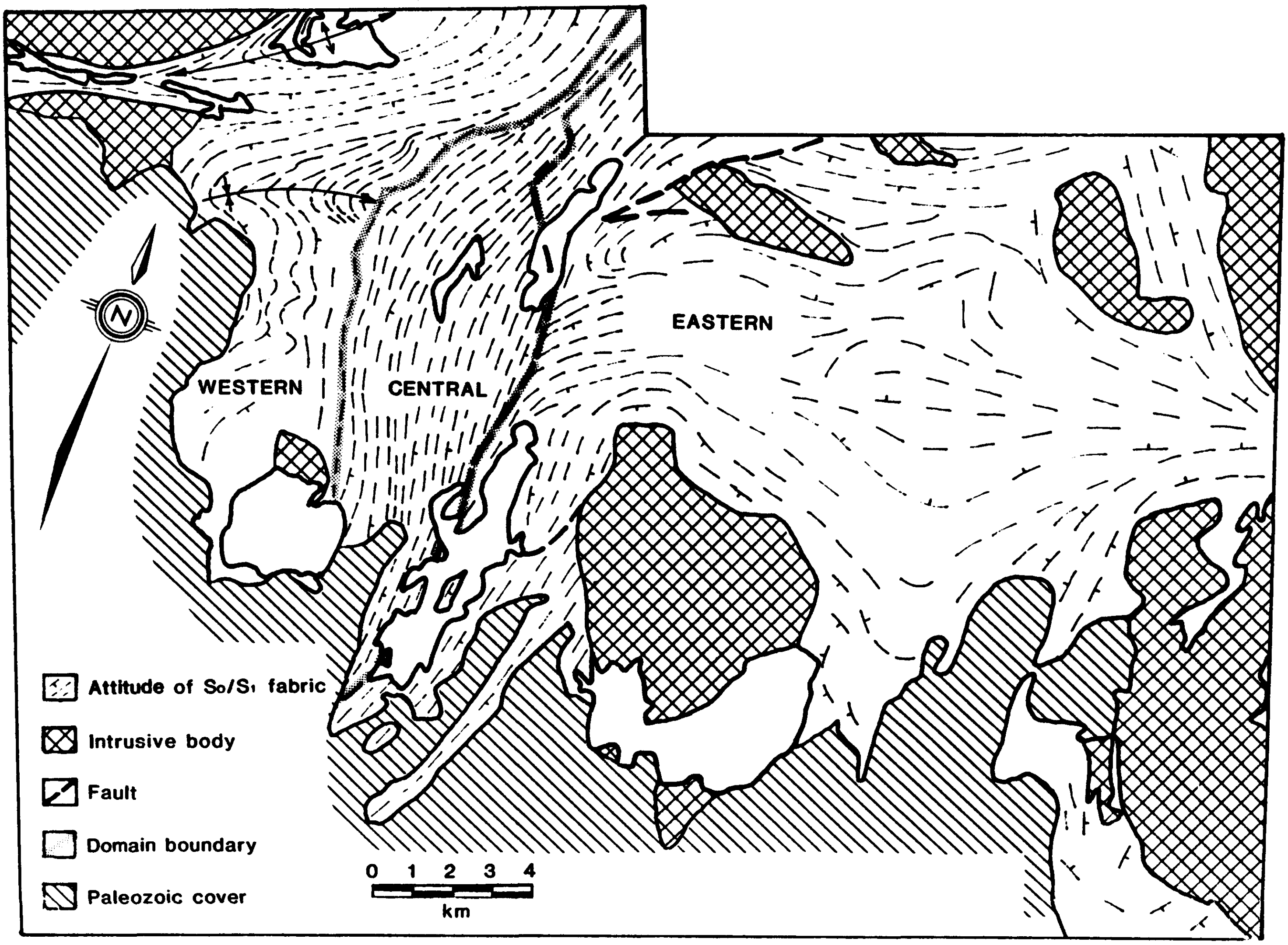


Figure 3: Map-area divided into structural domains. Note deflection of planar fabric around plutons.

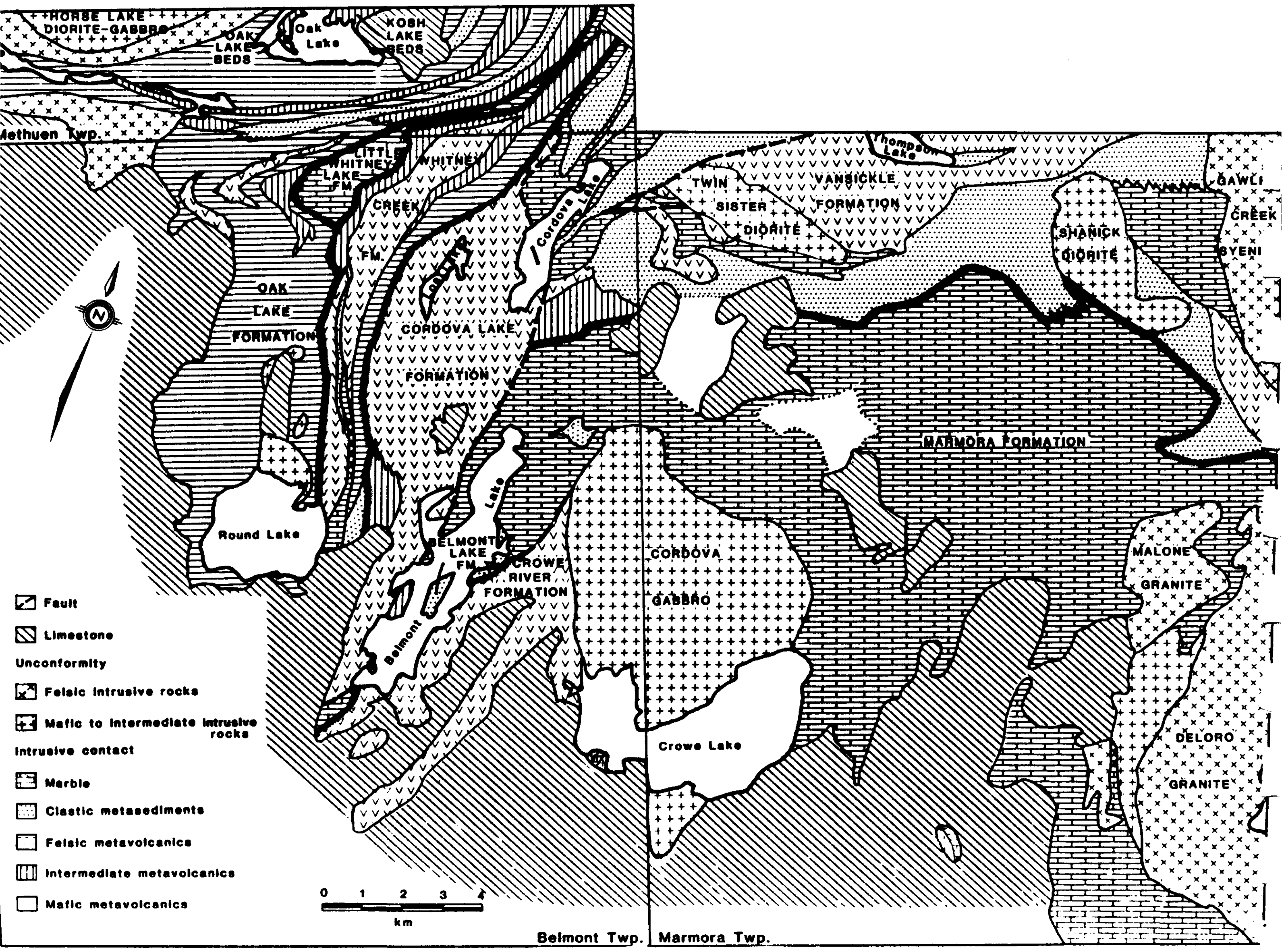


Figure 4: Generalized geological map of the study area, showing the distribution of formations (separated by thick lines), lithology and major plutonic bodies. Formations are separated by thick grey lines; faults separate the Cordova Lake from the Vansickle and Marmora Formations, and the Marmora Formation from the north part of the Crowe Lake formation.

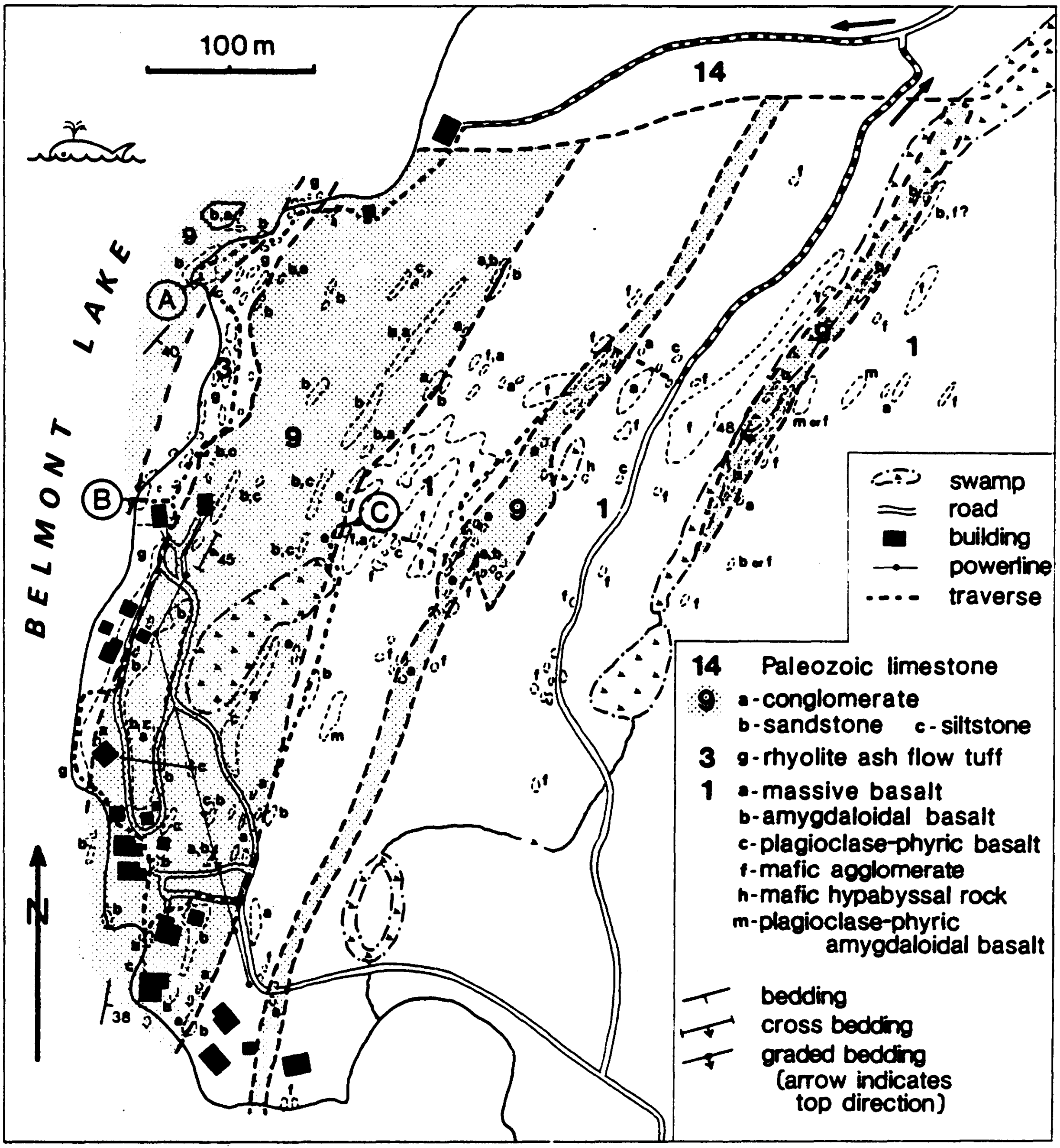


Figure 5: Detailed geology at Belmont Lake/Crowe River formation contact, showing the interstratified nature. Letters refer to localities mentioned in text.

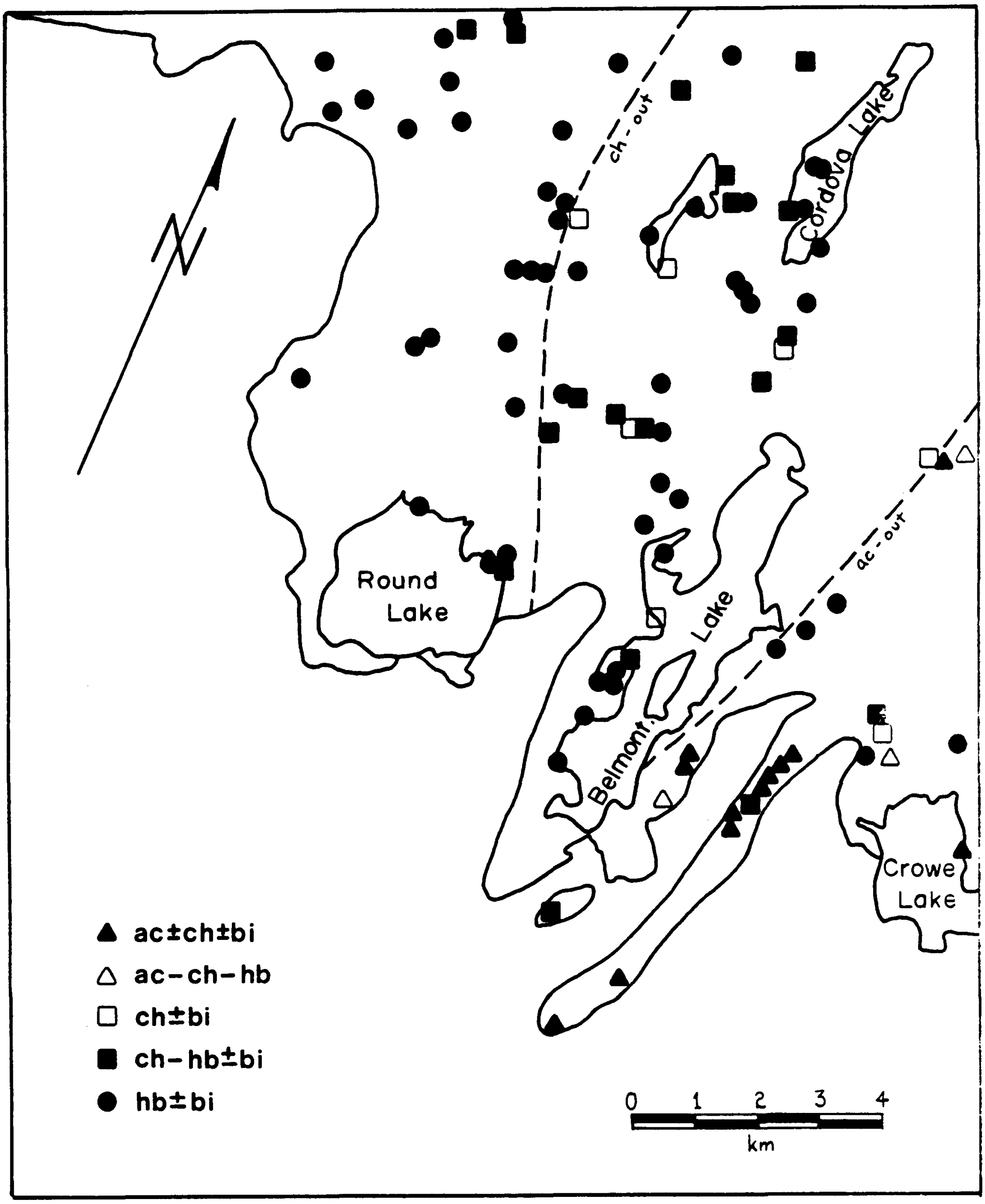


Figure 6: Distribution of metamorphic zones and isograds based on stable mineral assemblages in mafic and intermediate volcanic rocks of Belmont Township. Refer to Fig. 3 for geological units, and to Table 1 for abbreviations. From Bartlett (1983).

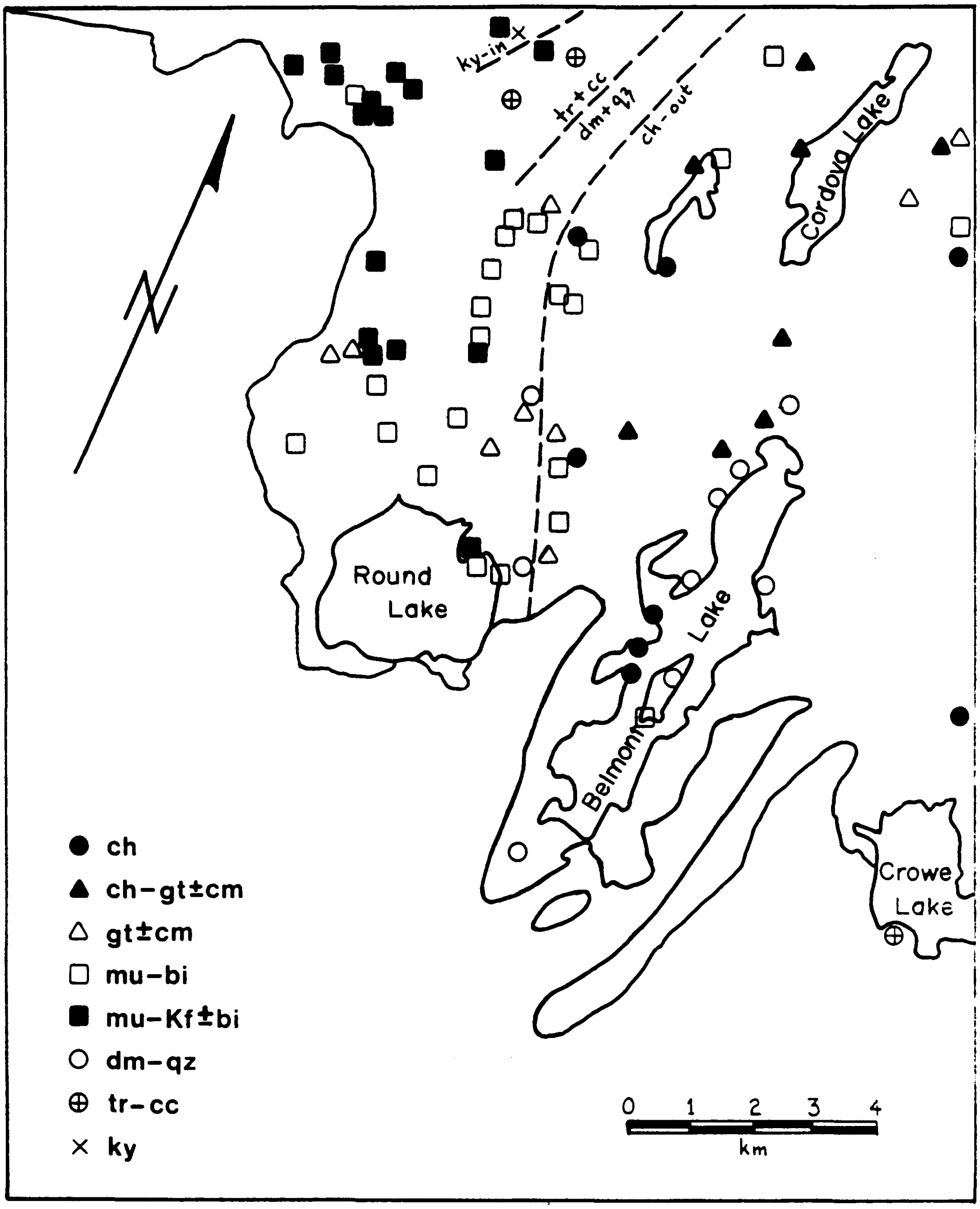


Figure 7: Distribution of isograds and selected stable mineral assemblages in quartzofeldspathic, pelitic and siliceous carbonate rocks in Belmont Township. Refer to Fig. 3 for geological units. Abbreviations: cm = cummingtonite, dm = dolomite, Kf = K-feldspar, ky = kyanite, tr = tremolite; see also Table 1. From Bartlett (1983).

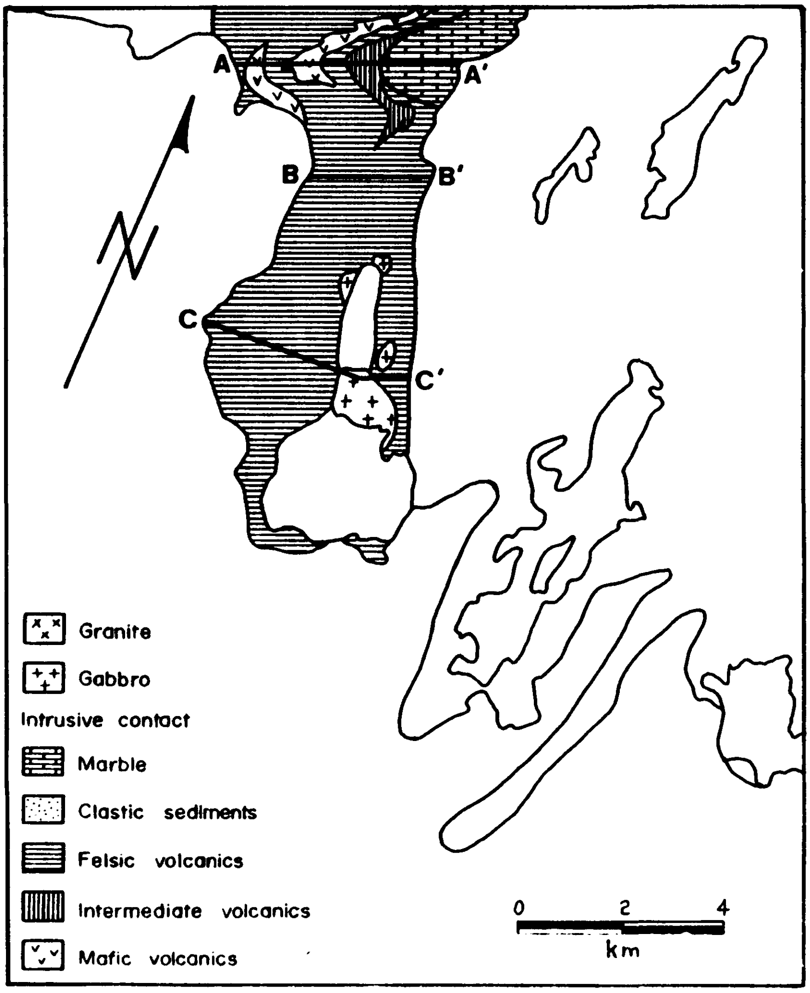


Figure 8: Distribution and general geology of Cycle I. Stratigraphic sections are illustrated in Fig. 8. Refer to Fig. 3 for formation boundaries. From Bartlett (1983).

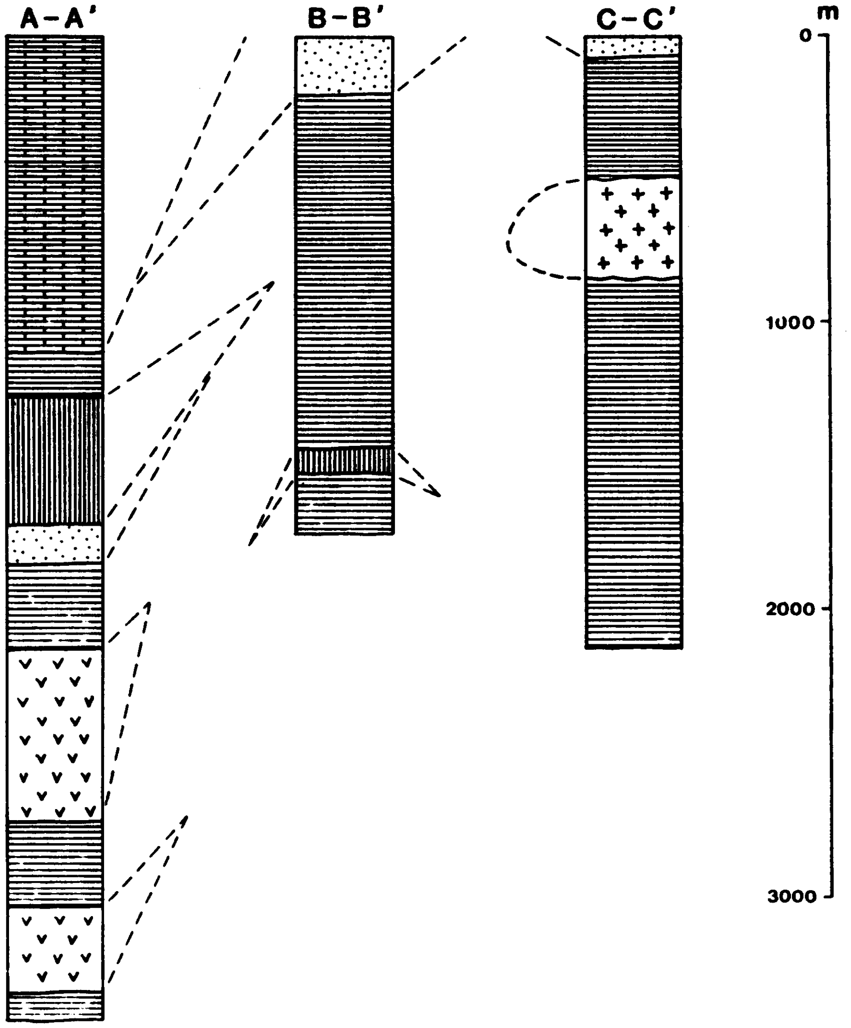


Figure 9: Stratigraphic sections of Cycle I, illustrating facies relationships. Sections are located in Fig. 7. Legend as in Fig. 7. Section A-A' probably thickened tectonically. From Bartlett (1983).

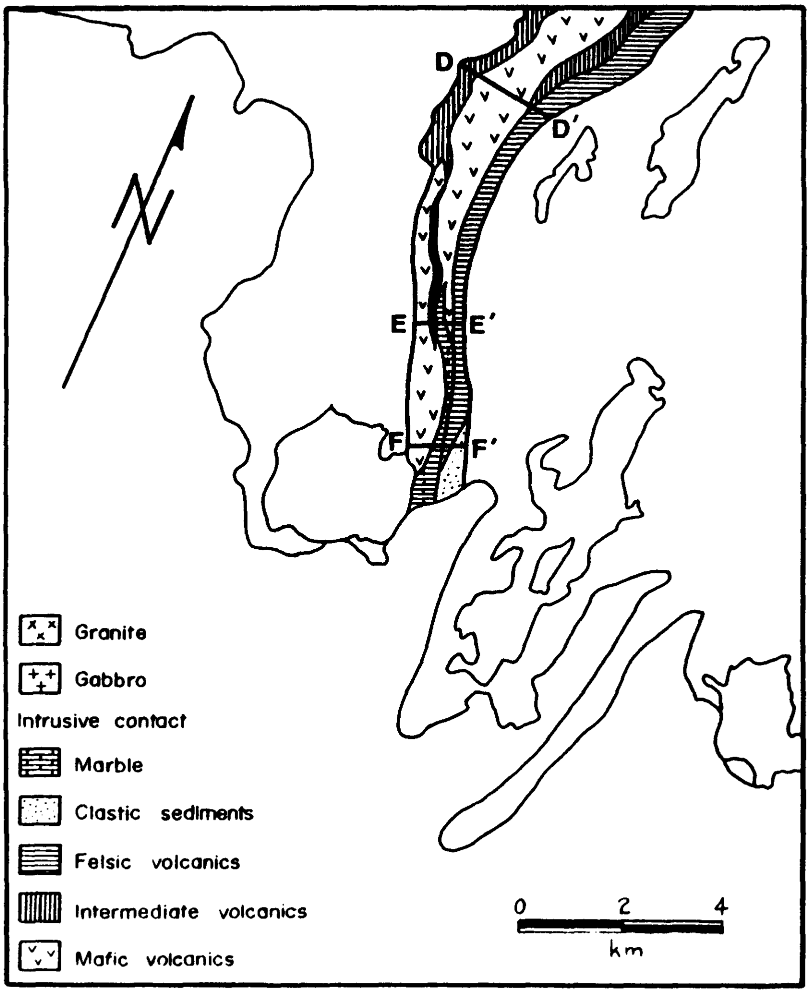


Figure 10: Distribution and general geology of Cycle II. Black unit is silicate facies iron formation. Stratigraphic sections are illustrated in Fig. 10. From Bartlett (1983).

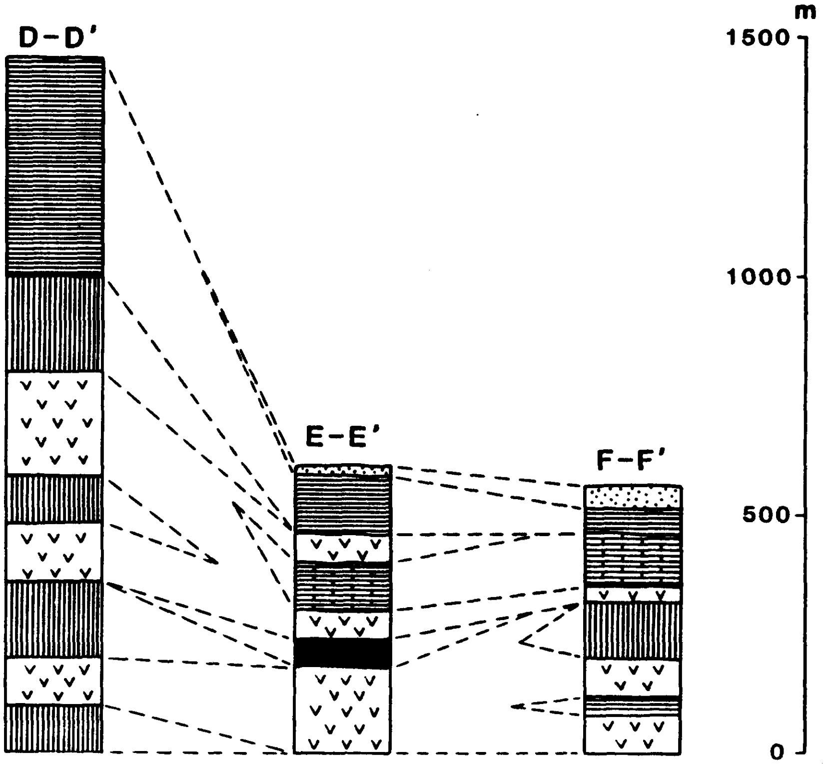


Figure 11: Stratigraphic sections of Cycle II, illustrating facies relationships. Sections are located in Fig. 9. Legend as in Fig. 9. Black unit is silicate facies iron formation. From Bartlett (1983).

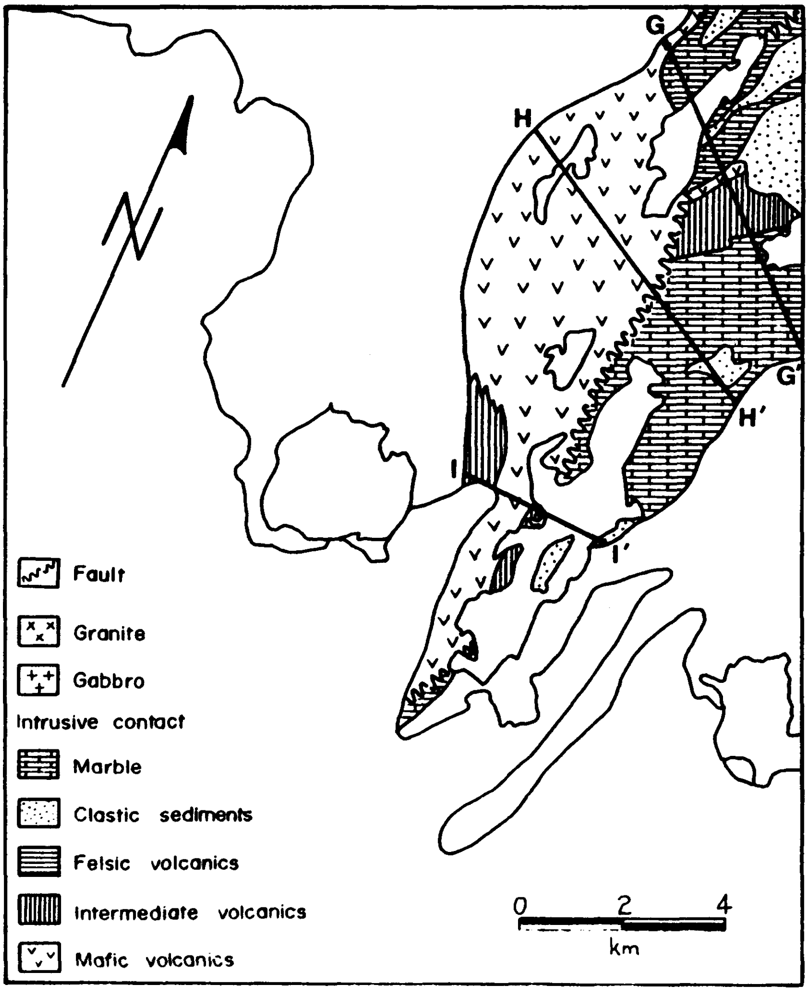


Figure 12: Distribution and general geology of Cycle III. Stratigraphic sections are illustrated in Fig. 12. Refer to Fig. 3 for formation boundaries. From Bartlett (1983).

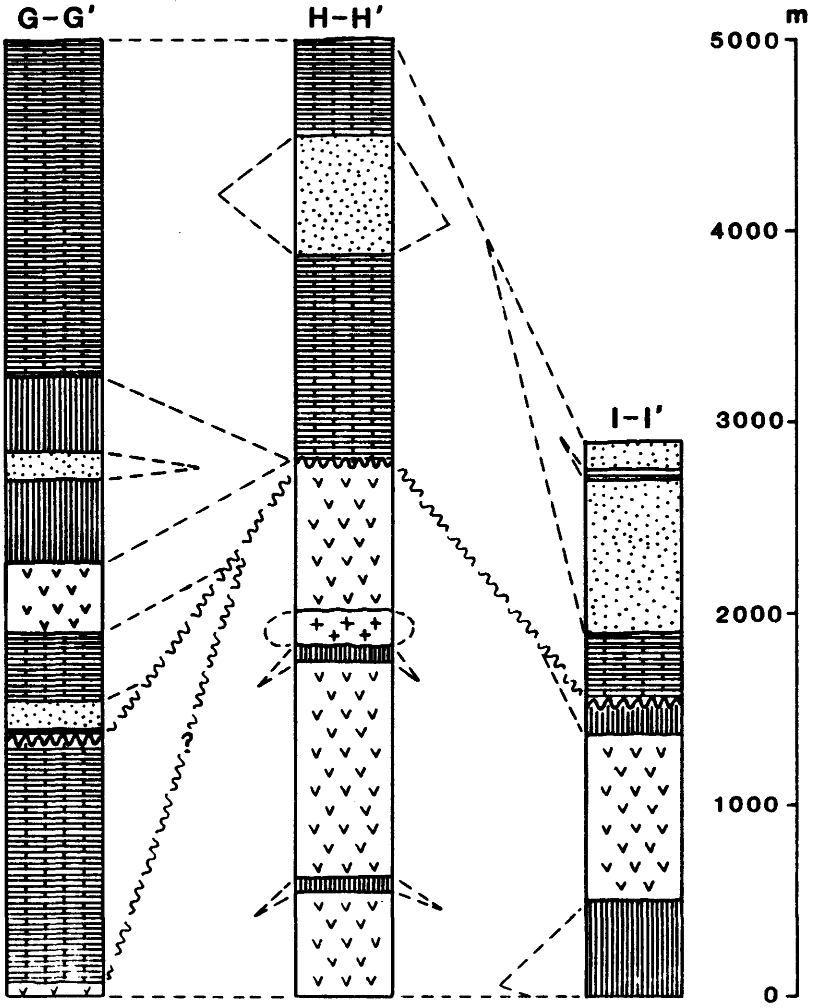


Figure 13: Stratigraphic sections of Cycle III, illustrating facies relationships. Sections are located in Fig. 11. Legend as in Fig. 11. From Bartlett (1983).

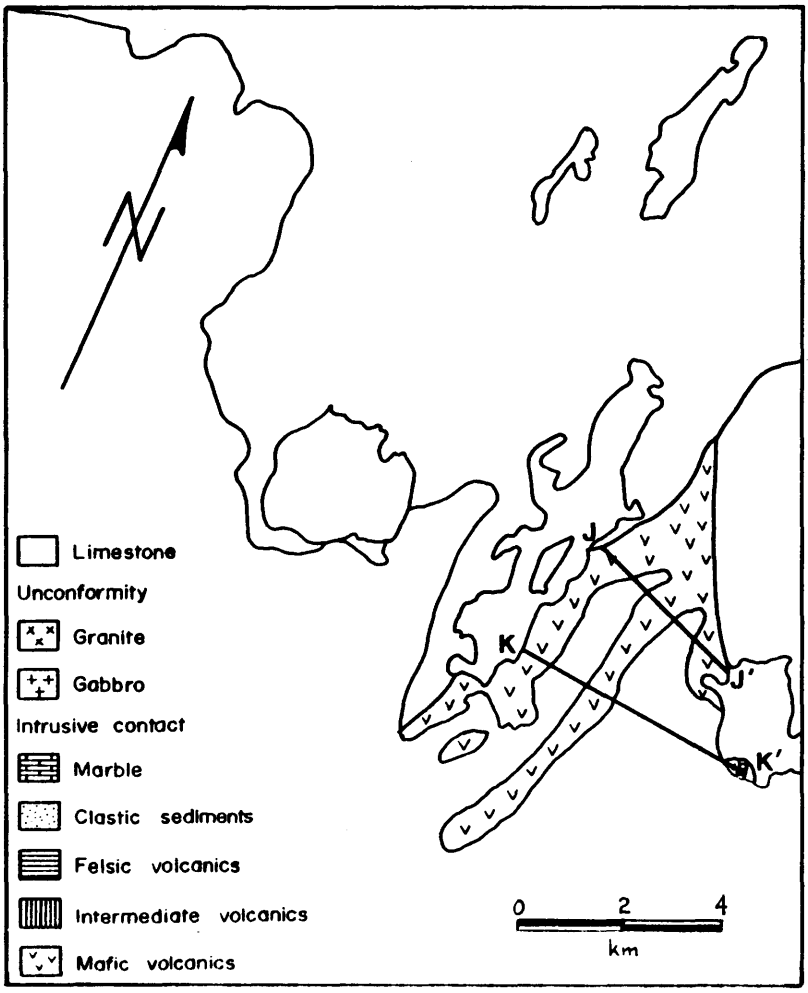


Figure 14: Distribution and general geology of Cycle IV. Stratigraphic sections are illustrated in Fig. 14. Modified from Bartlett (1983).

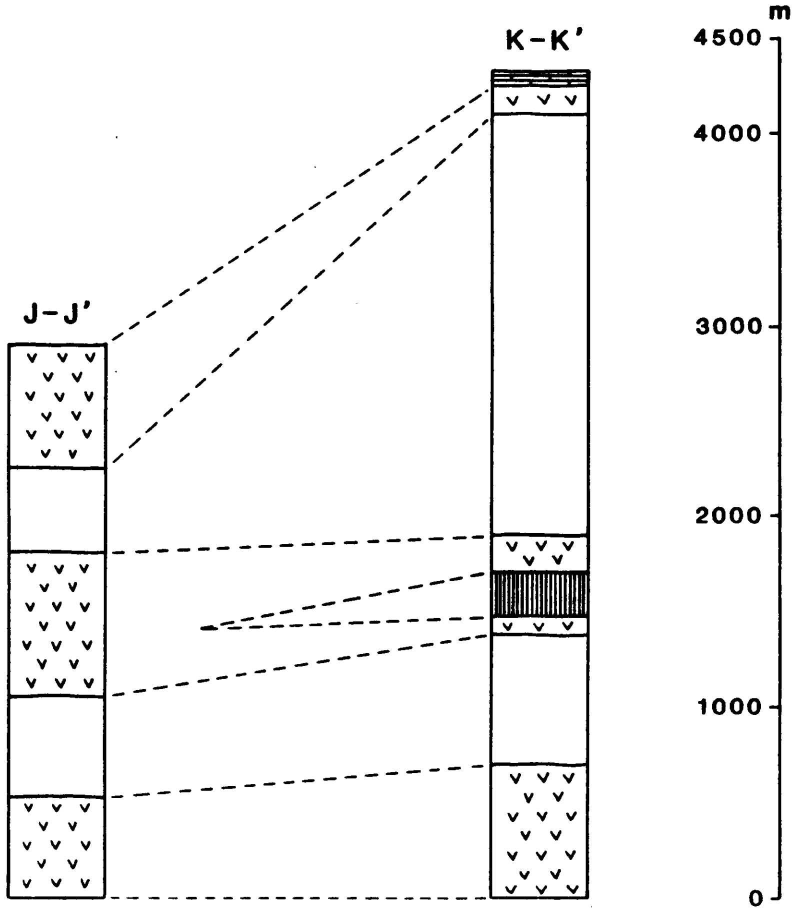


Figure 15: Stratigraphic sections of Cycle IV, illustrating facies relationships. Sections are located in Fig. 13. From Bartlett (1983).

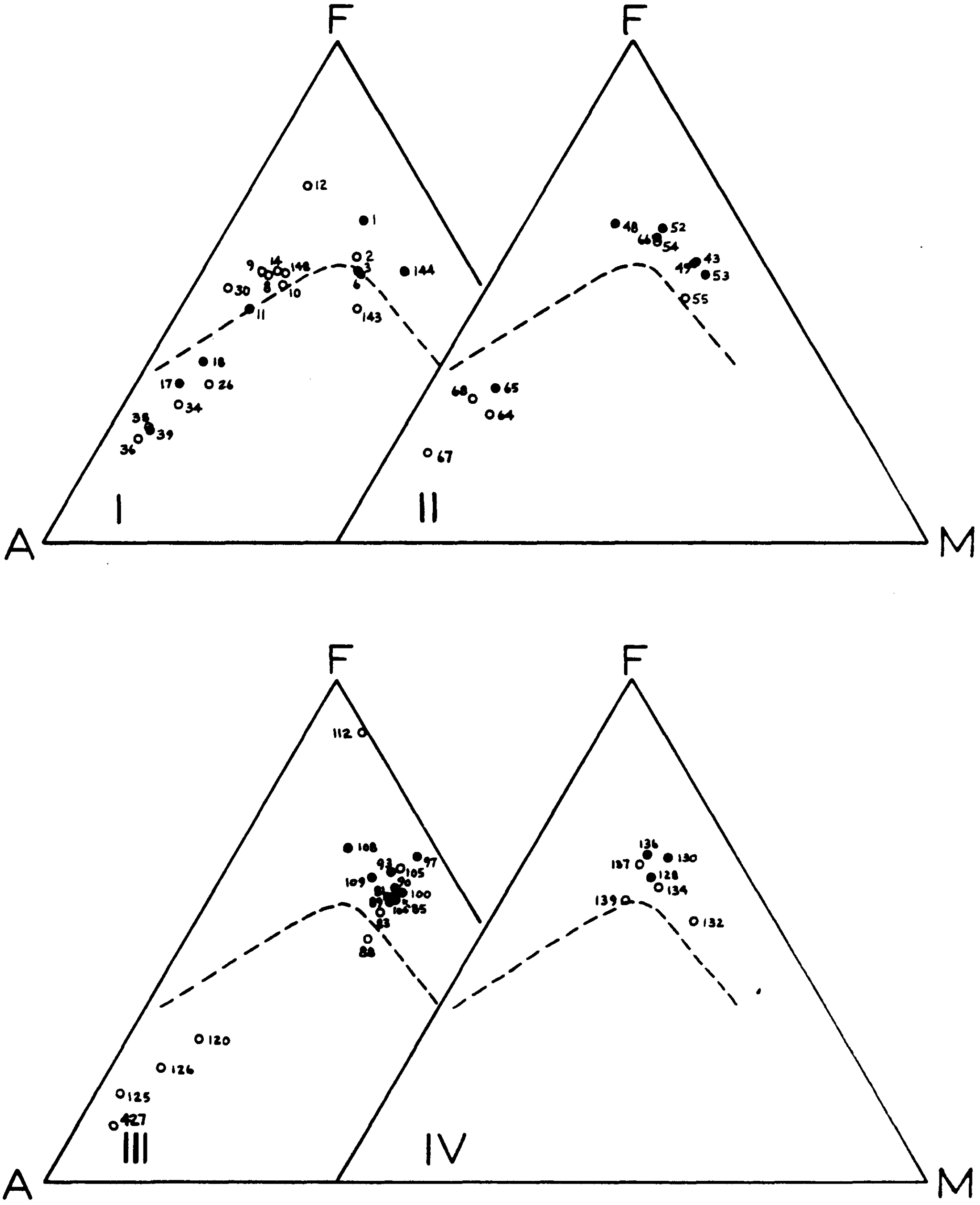


Figure 16: AFM diagrams for Cycles I-IV of the Belmont Lake Metavolcanic Complex. The dashed line dividing the tholeiitic field (above) from the calc-alkaline field is from Irvine and Baragar (1971). A = $Na_2O + K_2O$; F = $FeO + 0.8998\ Fe_2O_3$; M = MgO, all in weight percent. Open circles represent altered rocks, closed symbols unaltered rocks. Abbreviated sample numbers correspond to Table C_1. Modified from Bartlett (1983).

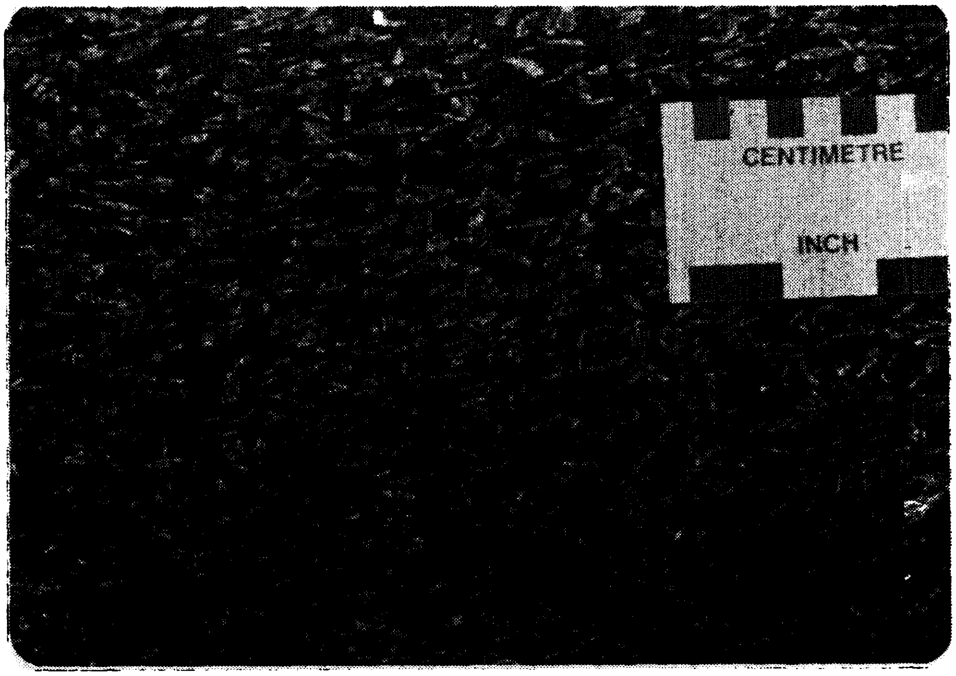


Photo 1. Plagioclase-phyric, quartz amygdaloidal basalt, Oak Lake formation, Belmont Township.

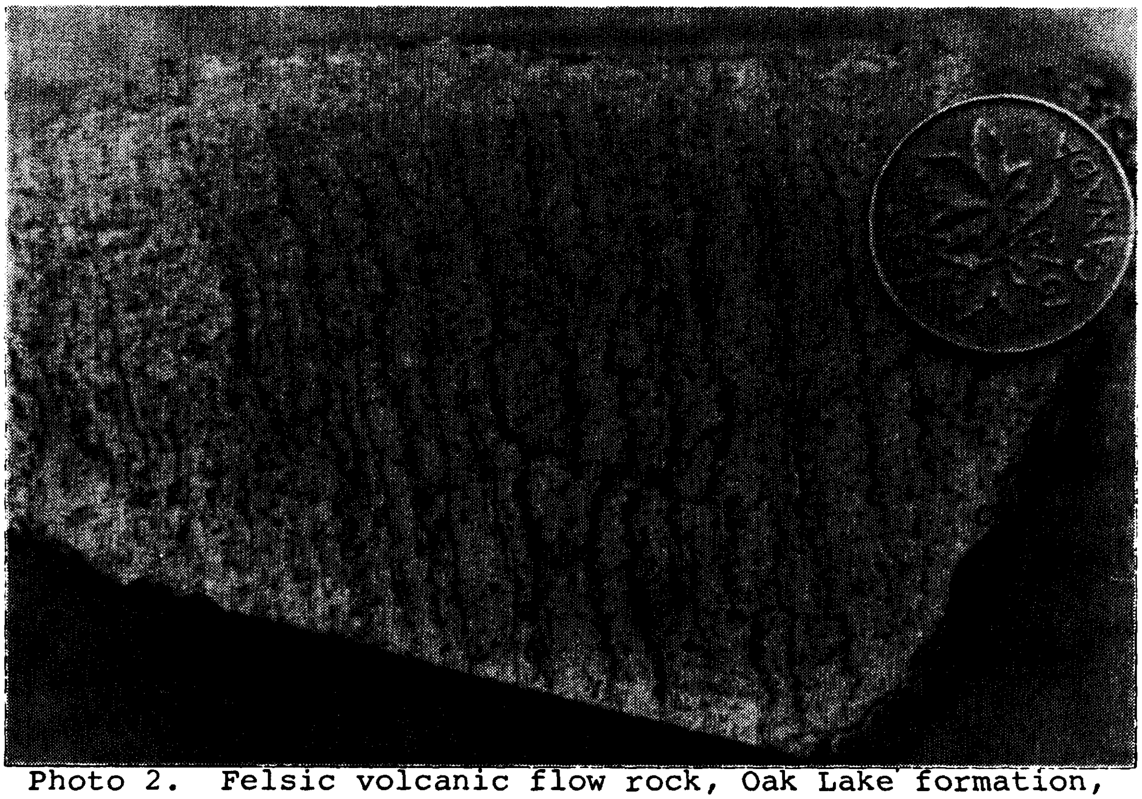


Photo 2. Felsic volcanic flow rock, Oak Lake formation, Belmont Township.

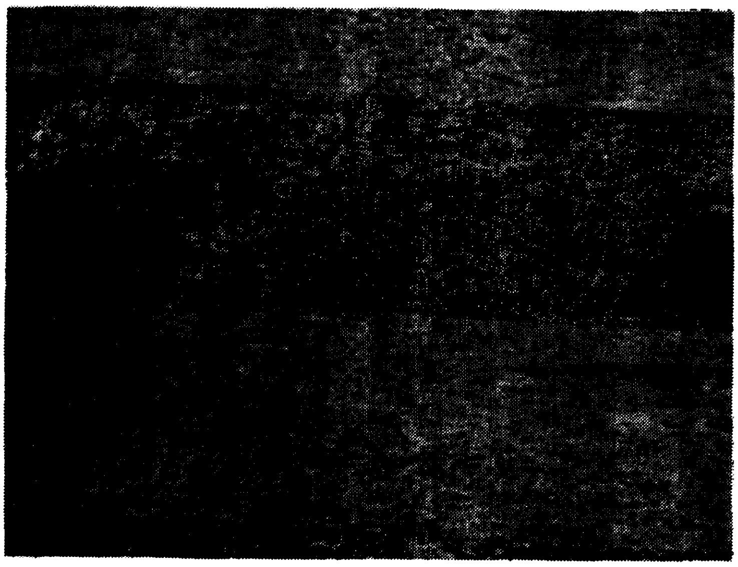


Photo 3. Felsic ash flow tuff, Oak Lake formation, Belmont Township.

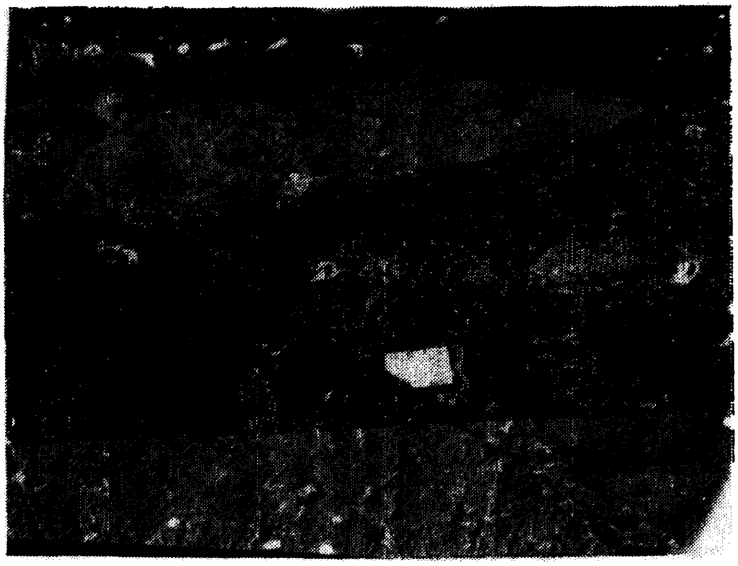


Photo 4. Isolated pillow breccia, Cordova Lake Formation, Cordova Lake.

Photo 5. Broken pillow breccia, Cordova Lake Formation, Cordova Lake.

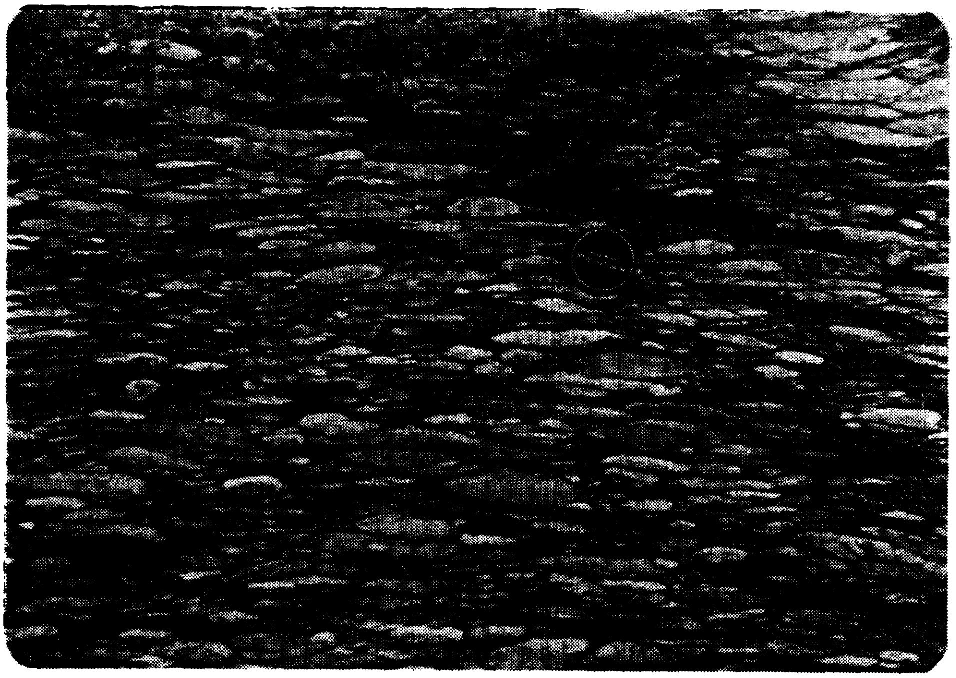


Photo 6. Volcanic conglomerate, Vansickle formation, southeastern Metuen Township.

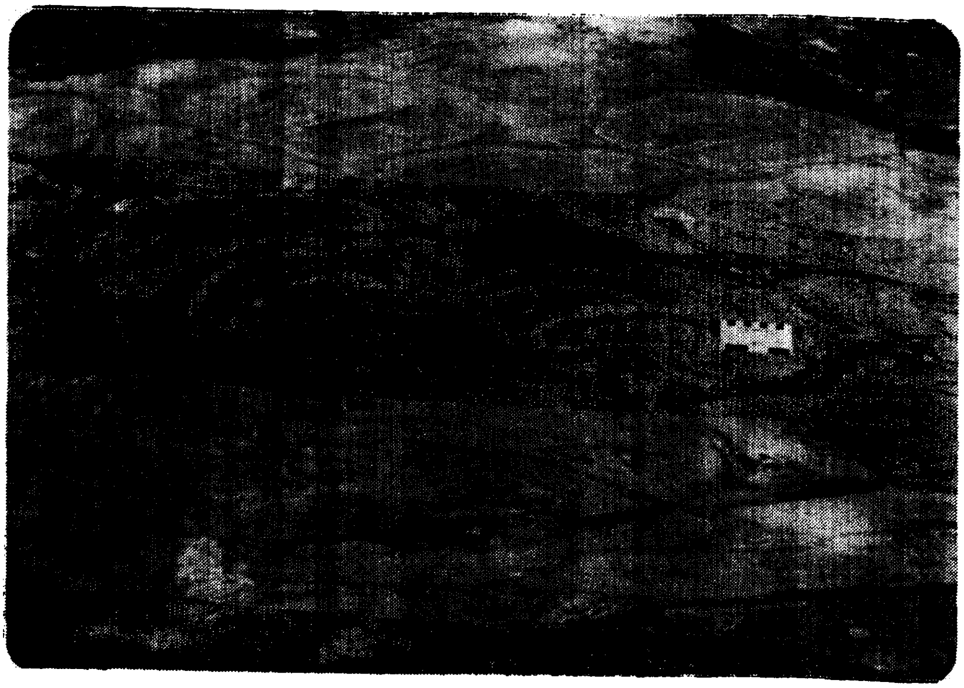


Photo 7. Pillowed mafic flow, Vansickle formation, east-central Marmora Township.

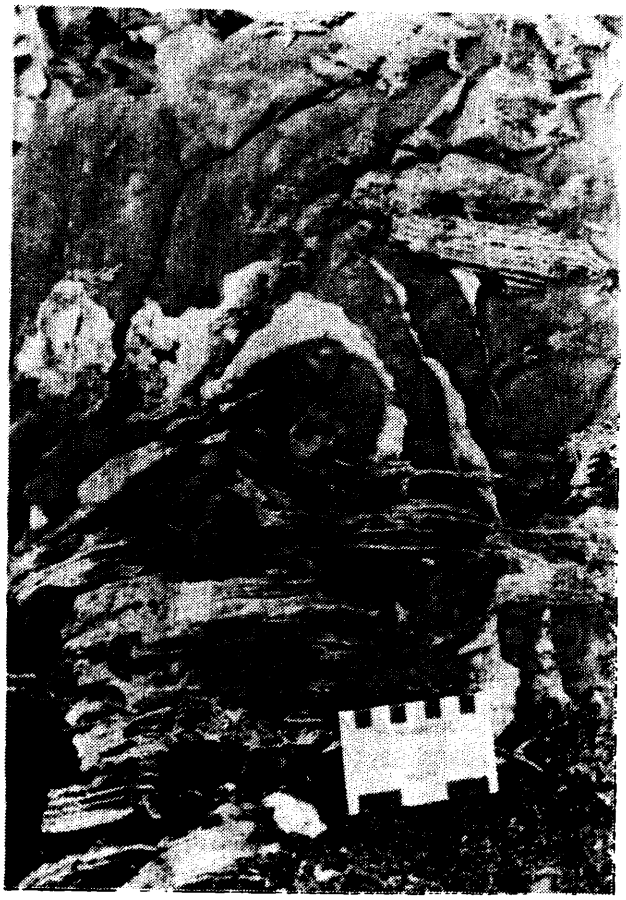


Photo 8. Fossilized algal mats, Marmora formation, Belmont Lake.

Photo 9. Thinly laminated siliceous, calcitic carbonate metasedimentary rocks, Marmora formation, Belmont Township.

Photo 10. Interlayered fine-grained grey-weathering calcitic marble and thinner, dark grey-weathering dolomitic marble, Marmora formation, central Marmora Township.

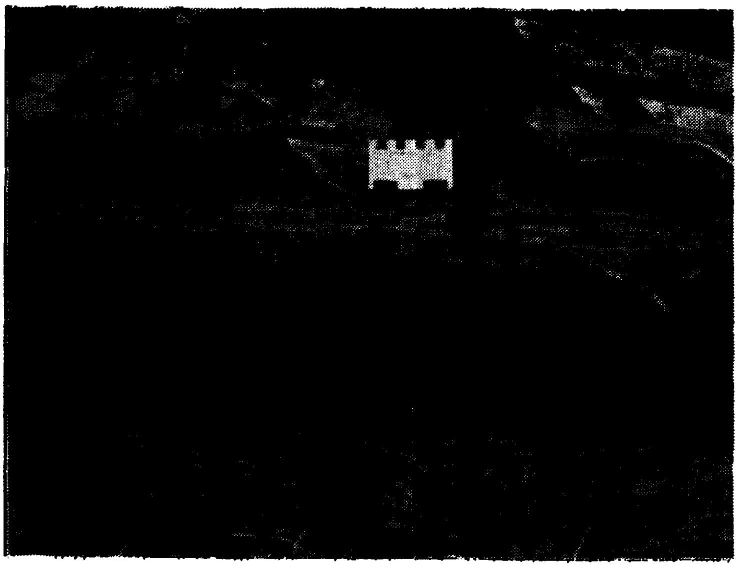


Photo 11. Isoclinal slump folding in interbedded feldspathic arenite and siltstone, near top of Belmont Lake formation, Belmont Lake.

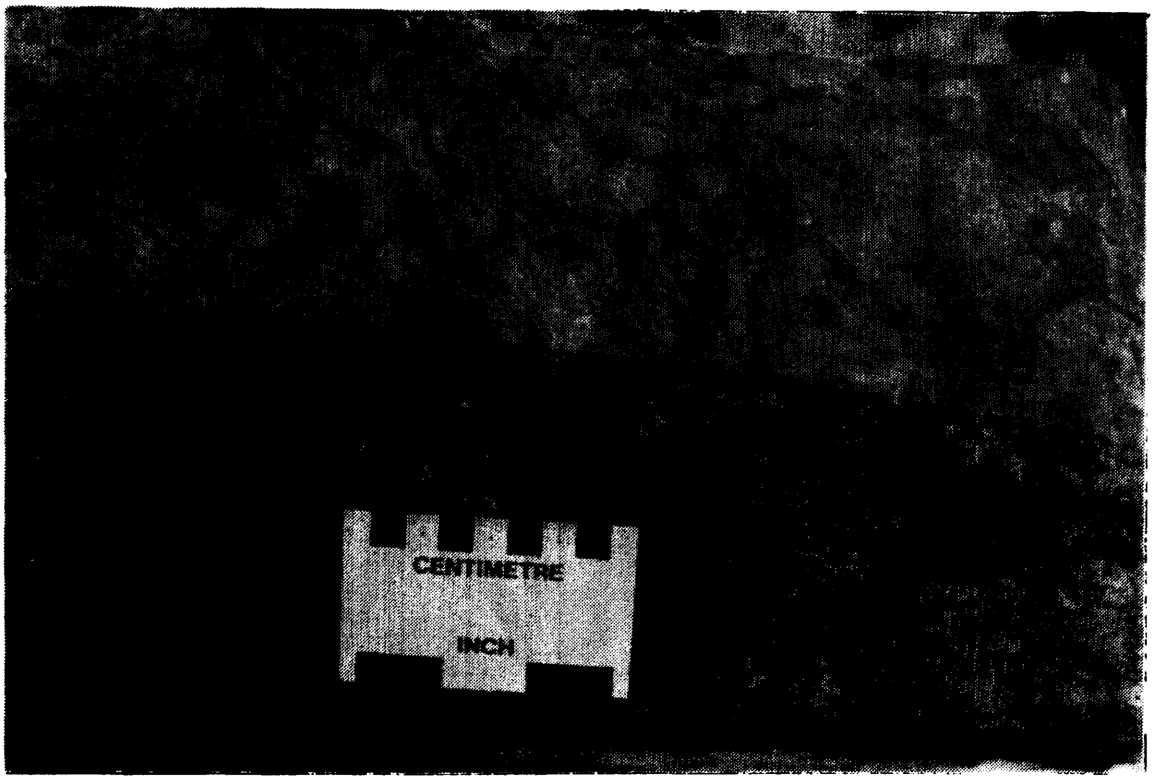


Photo 12. Mafic agglomerate, near base of Crowe River Formation, central Belmont Lake area.

Photo 13. Mafic to intermediate, heterolithic lapilli-tuff with primary layering deformed around an epidotized pod.

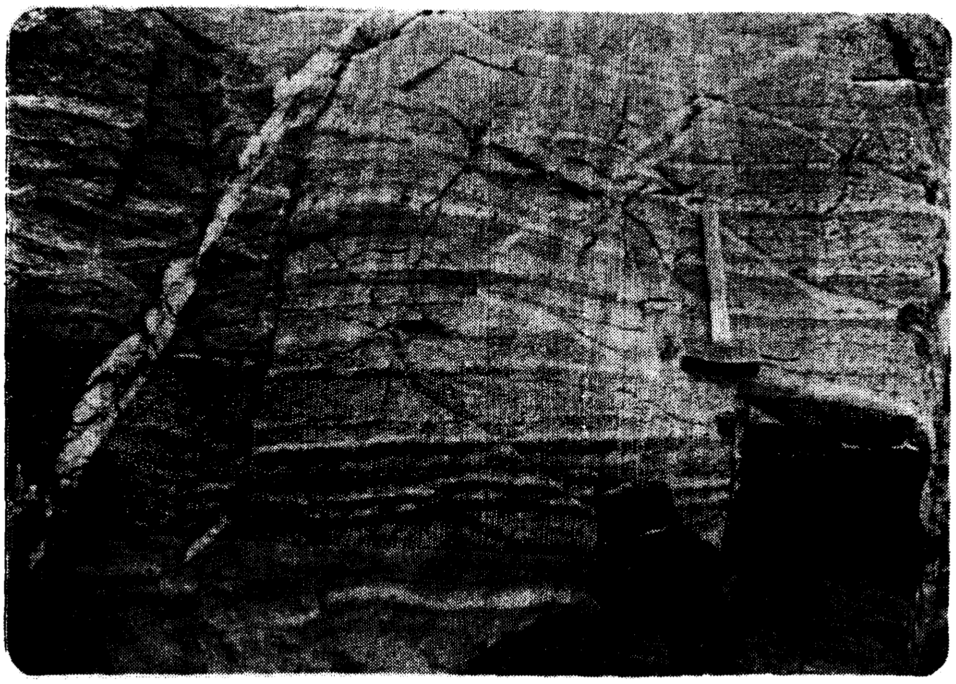


Photo 14. Compositional layering in gabbro near north boundary of the Cordova Gabbro on the Belmont-Marmora town line.

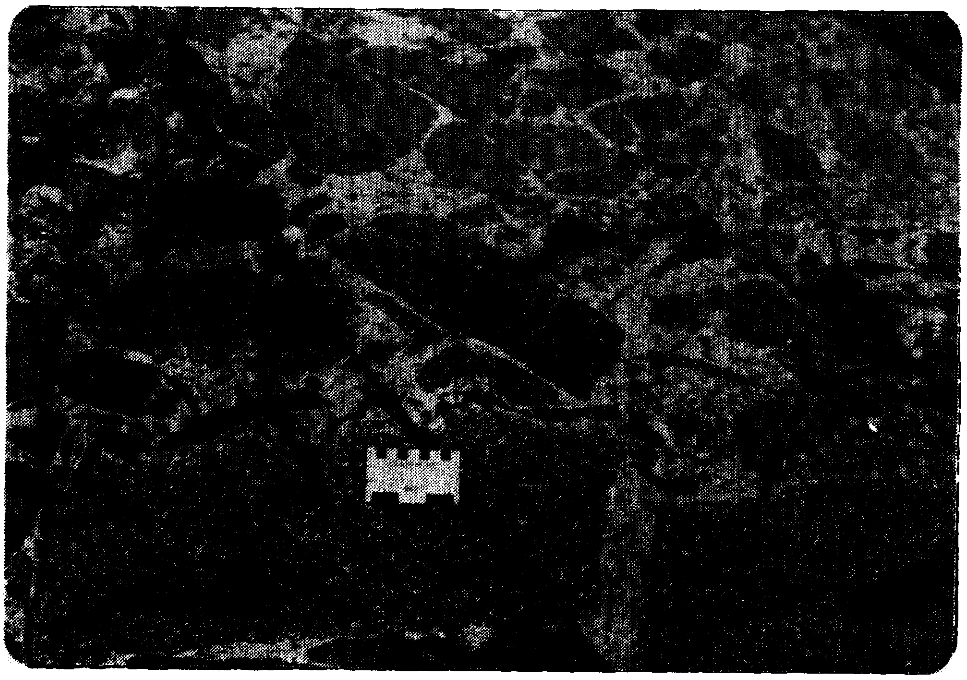


Photo 15. Coarse intrusive breccia, western margin of the Cordova Gabbro, Belmont Township.

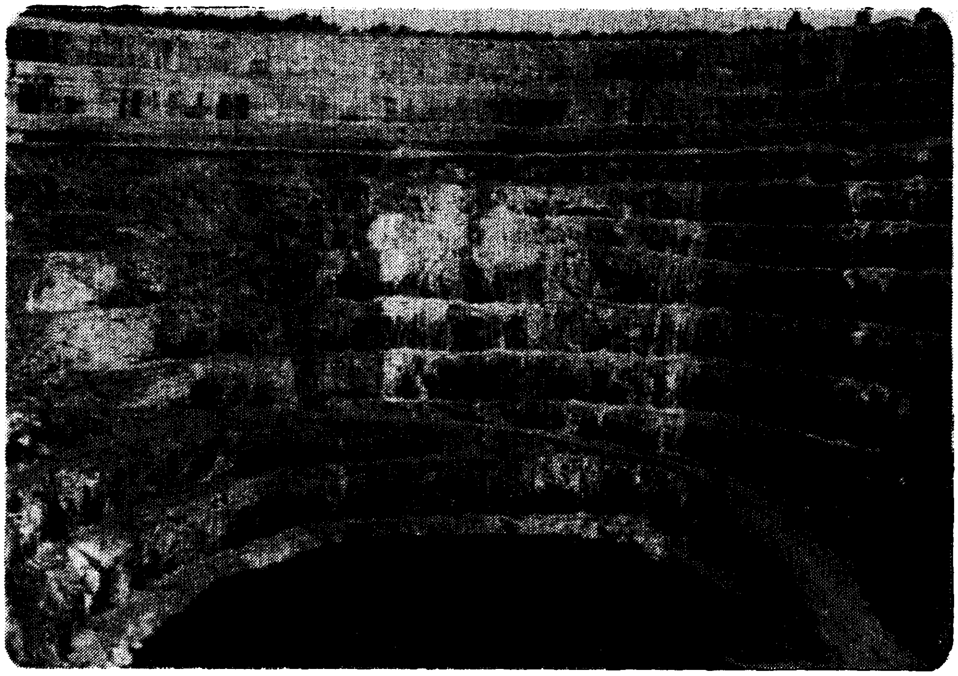


Photo 16. View north across open pit of Marmoraton Iron Mine, southern Marmora Township.

MARGINAL NOTES FOR FINAL MAP OF BELMONT, MARMORA AND S. METHUEN TWPS

LEGEND

PHANEROZOIC

CENOZOIC[a]

QUATERNARY

RECENT

Stream, lake and swamp deposits

PLEISTOCENE

Glacial, glaciofluvial, and glaciolacustrine deposits

UNCONFORMITY

PALEOZOIC

ORDOVICIAN

14	Unsubdivided
14a	Red conglomerate, siltstone, shale (Basal Group, Shadow Lake Formation)
14b	Interlayered limestone, sandy limestone, dolomitic limestone, shale (Simcoe Group?)
14c	Grey, chalky-weathering limestone (Simcoe Group)

UNCONFORMITY

PRECAMBRIAN[bc]

LATE PRECAMBRIAN

METAMORPHOSED INTRUSIVE ROCKS[d]

FELSIC INTRUSIVE ROCKS

13 Unsubdivided

13a Massive biotite granite

13b Porphyritic granite

13c Foliated granite

13d Pegmatite, granite, aplite dikes

13e Microgranite, porphyritic microgranite, syenite, quartz syenite, felsite

13f Massive medium- to coarse-grained amphibole-perthite granite

13g Fine-grained leucogranite

13h Massive, medium- to coarse-grained syenite to quartz syenite

13j Massive medium-grained muscovite leucogranite

13k Fine-grained and/or porphyritic leucodiorite, trondhjemite, syenite, felsite

12 Unsubdivided

12a Biotite granodiorite, quartz monzonite

12b Biotite granodiorite, quartz monzonite

INTERMEDIATE TO ULTRAMAFIC INTRUSIVE ROCKS

11 Unsubdivided

11a Diorite

11b Plagioclase-phyric diorite

11c Quartz diorite

INTRUSIVE CONTACT

10 Unsubdivided

10a Medium-grained to coarse-grained gabbro

10b Fine-grained gabbro

10c Plagioclase-phyric gabbro

10d Coarse-grained, oikocrystic gabbro

10e Leucogabbro (CI = 10-35)

10f Anorthosite (CL<10)

10g Trondhjemite, diorite (small intrusions)

10h Syenite, granite, granophyre intrusions

10j Biotite lamprophyre

10k Pyroxenite

INTRUSIVE CONTACT

GRENVILLE SUPERGROUP[e]

METASEDIMENTS

CLASTIC METASEDIMENTS

9a Cobble to granule, polymictic conglomerate; felsic and intermediate volcanic detritus dominant

9b Cobble to granule, polymictic conglomerate; siliceous sedimentary detritus dominant

9c Cobble to granule, polymictic conglomerate; mafic volcanic detritus dominant

9d Cobble to granule, polymictic conglomerate; carbonate sedimentary detritus dominant

9e Dark red sandstone, siltstone

9f Dark grey siltstone, claystone, graphitic

	claystone
9g	Dark grey dolomitic marble, carbonate-bearing clastic metasediments
9h	Grey sandstone
	MINOR UNCONFORMITY

CARBONATE METASEDIMENTS

8	Unsubdivided
8a	Dolomitic marble
8b	Calcitic marble
8c	Interlayered calcitic, dolomitic marble
8d	Dolomitic marble with abundant lenses and layers of chert
8e	Tremolite marble
8f	Skarn

INTERLAYERED CARBONATE AND SILICEOUS METASEDIMENTS

7	Unsubdivided
7a	Interlayered siliceous clastic metasediments (minor chert), dark calcitic marble
7as	Siliceous layers dominant
7am	Marble layers dominant
7b	Interlayered carbonate and non-carbonate-bearing siliceous metasediments (centimetres-scale layering dominant)
7c	Dark calcitic marble with interbeds of siliceous metasediment and calcsilicate

rocks

7d Carbonate-bearing wacke, arenite, mudstone

7e Regularly layered and laminated cherty, fine clastic metasediments, and fine calcitic marble

SILICEOUS CLASTIC METASEDIMENTS

6 Unsubdivided

6a Arenite, wacke

6b Mudstone, sandy mudstone, phyllite, mica schist

6c Garnet-bearing schist

6d Cummingtonite-bearing schist

6e Magnetite-bearing schist

6f Interlayered cherty mudstone and chert

6g Pyritic, rusty-weathering mudstone, schist

6h Quartzofeldspathic schist gneiss of probable sedimentary origin

LITHIC CLASTIC METASEDIMENTS

5a Lithic wacke, volcanic detritus dominant

5b Conglomerate, volcanic detritus dominant

5c Intermediate, mafic schist/gneiss of probable sedimentary origin

SILICEOUS CHEMICAL METASEDIMENTS

4a Chert

4b Magnetite-bearing chert

4c Magnetite ironstone

METAVOLCANICS

FELSIC METAVOLCANICS

3	Unsubdivided
3a	Feldspar-phyric, quartz-feldspar-phyric extrusive rocks
3b	Flow breccia
3c	Pyroclastic breccia, tuff-breccia
3d	Tuff, lapilli-tuff, lapillistone
3e	Dykes, sills, small intrusions
3f	Chlorite- and/or biotite-quartz-feldspar schist/gneiss of probable volcanic origin

INTERMEDIATE METAVOLCANICS

2	Unsubdivided
2a	Flows
2b	Pillowed flows, flow breccia
2c	Pyroclastic breccia, tuff-breccia
2d	Tuff, lapilli-tuff, lapillistone
2e	Dykes, sills, small intrusions
2f	Biotite-hornblende and/or chlorite schist of probable volcanic origin

MAFIC METAVOLCANICS

1	Unsubdivided
1a	Flows
1b	Amygdaloidal flows
1c	Plagioclase-phyric flows
1d	Pillowed flows, pillow breccia, hyaloclastite
1e	Flow breccia

1f Pyroclastic breccia, tuff-breccia

1g Tuff lapilli-tuff lapillistone

1h Dikes, sills, small intrusions

1j Plagioclase-phyric dikes, sills small intrusions

1k Chlorite schist, chlorite-amphibole schist, amphibole schist of probable volcanic origin

1m Flows of basaltic composition; typically plagioclase phyric and amygdaloidal

NOTES:

a) Unconsolidated deposits. Cenozoic deposits are represented by the lighter coloured and uncoloured parts of the map.

b) Bedrock geology. Outcrops and inferred extensions of each rock map unit are shown respectively in deep and light tones of the same colour.

c) All Precambrian rocks, including plutons, have been subjected to regional metamorphism; many non-metamorphic terms are used for the sake of brevity where the protolith is established.

d) Succession of intrusive rock units is not in general established.

e) Numerical succession does not imply order or deposition; many units are repeated stratigraphically, or are laterally equivalent.

PROPERTIES

PRODUCERS

1) Armbro Ltd.
2) Belmont Granite
3) Cordova Gold Mines
4) 3M Canada Inc.

PAST PRODUCERS

5) Belmont Iron Mine
6) Blairton Iron Mine
7) Bonter, W.F. and Company
8) Canada Consolidated Mine
9) Cook Mine
10) Crowe River Marble Quarries
11) Dean and Williams Mine
12) Deloro Mine
13) Gatling Five Acres Mine
14) Gladstone Mine
15) Hastville
16) Ledyard Gold Mine
17) Malone Mine
18) Marmoraton Mine
19) Pearce Mine
20) Sovereign Mine
21) Stocklosar IV

OCCURRENCES

22) Ackerman
23) Belmont Calcite (Whitney Property)
24) Beloporine Creek
25) Beninger
26) Bonter, R.E.
27) Campbell-Blomfield
28) Crowe River Iron
29) Crowe River Trap Rock
30) Daust, A.P.
31) Demars Occurrence
32) Dominion Gulf
33) Dostanko I
34) Dostanko II
35) Dostanko III
36) Dostanko IV
37) Dostanko V
38) Gawley No.1
39) Gawley No.2
40) Gillen Occurrence
41) Harrington, J.
42) Hawkeye
43) Horse Lake (Trap) Property
44) Maloney

45) Mattagami Lake Mines

46) Methuen Lead

47) Moira River

48) Neill, Bob Occurrence

49) Pershing

50) Round Lake Dolomite

51) Round Lake Sulphide

52) Stocklosar

53) Sudbury Contact

54) Vansickle Marble

55) Young-Cumming Property I

56) Young-Cumming Property II

57) Young-Phillips

58) Young-Purdy

ABBREVIATIONS

Ag	Silver
As	Arsenic
asp	Arsenopyrite
Au	Gold
ba	Barite
bruc	Brucite
calc	Calcite
cp	Chalcopyrite
Co	Cobalt
Cr	Chromium
Cu	Copper
diop	Diopside
Fe	Iron
fl	Fluorite
gn	Galena
gt	Garnet
hem	Hematite
ky	Kyanite
lst	Limestone
mag	Magnetite
mar	Marcasite
mb	Marble
Ni	Nickel
Pb	Lead
po	Pyrrhotite

py	Pyrite
Sb	Antimony
serp	Serpentine
sp	Sphalerite
st	Stone
Ti	Titanium
tour	Tourmaline
trem	Tremolite
V	Vanadium
Zn	Zinc

Sources of Information

N.T.S. Reference 31 C/5 and 31C/12

Geology by J.R. Bartlett, J.M. Moore, Jr., and assistants, 1980, 1981.

Minor detailed geology by J.R. Bartlett, 1982, 1983.

Aeromagnetic maps 8390G, 103G, 14G, GSC.

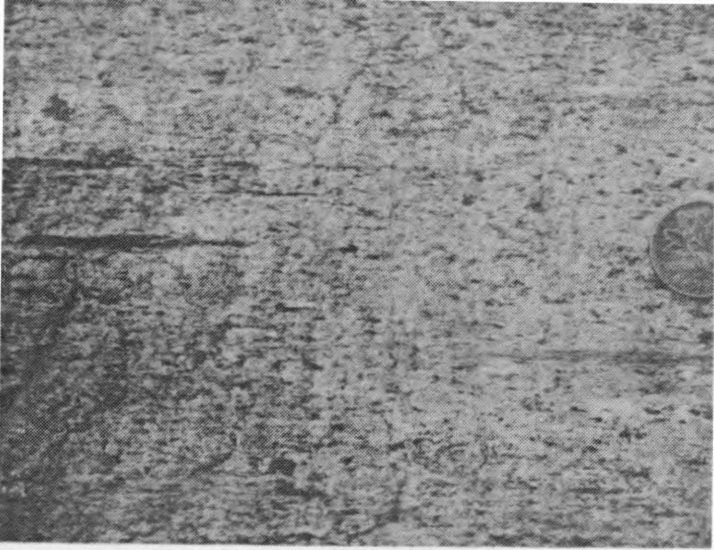
Assessment Files Research Office, Ontario Geological Survey, Toronto.

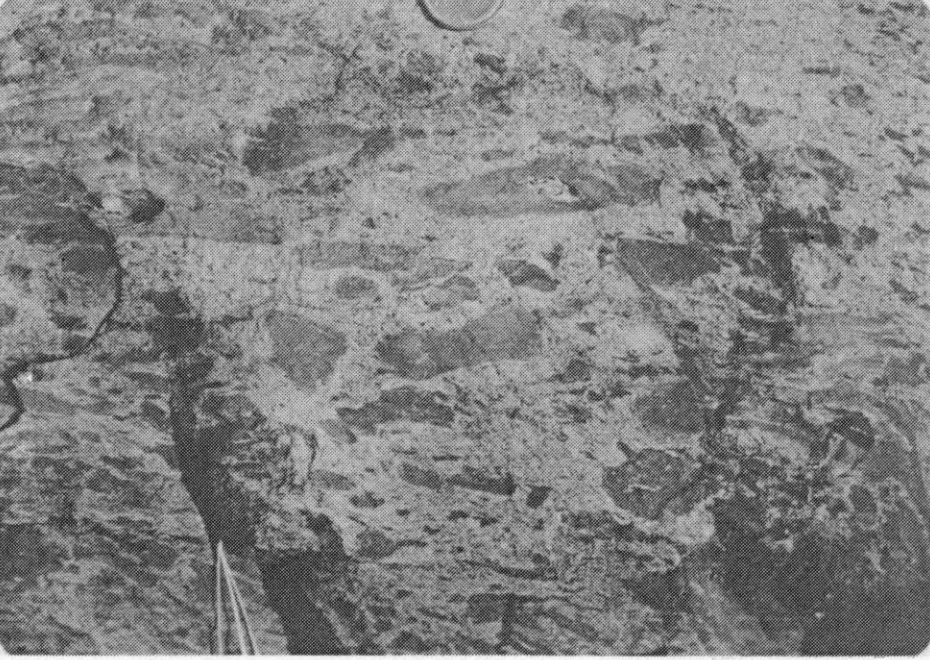
Personal Files of C.R. Young, Havelock, Ontario.

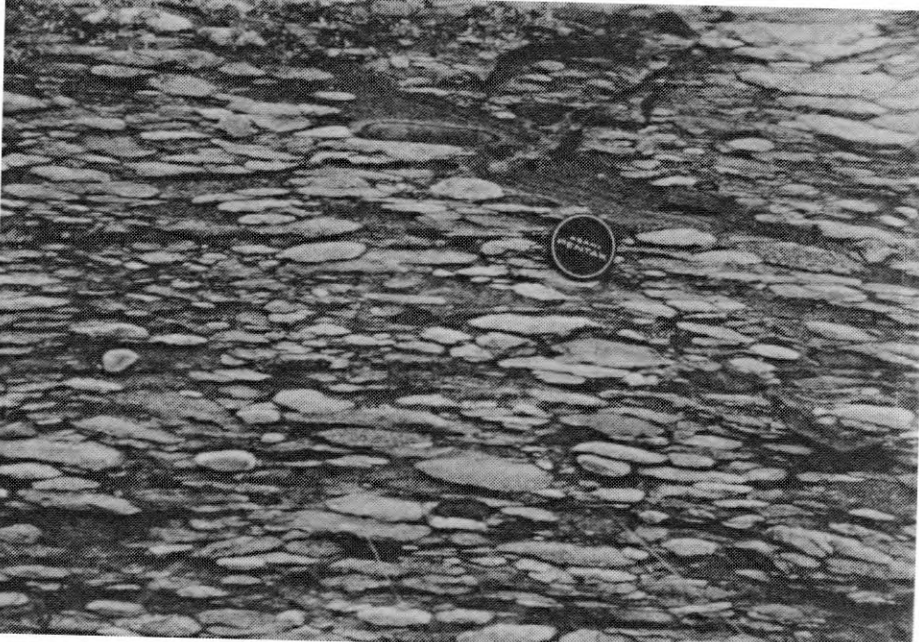
Some contacts in northern Belmont and southern Methuen Townships are based in part on Hewitt (1960), Heidecker (1963), and Beavon (1967). Several contacts along the northern boundary of Marmora Township are based on Laakso (1968). Information in the Malone-Deloro area augmented by data of J. Siddiqui (graduate student, University of Ottawa, Ontario), T.R. Carter (Ministry of Natural Resources, Resident Geologist, Wingham, Ontario), and Wilson (1940).

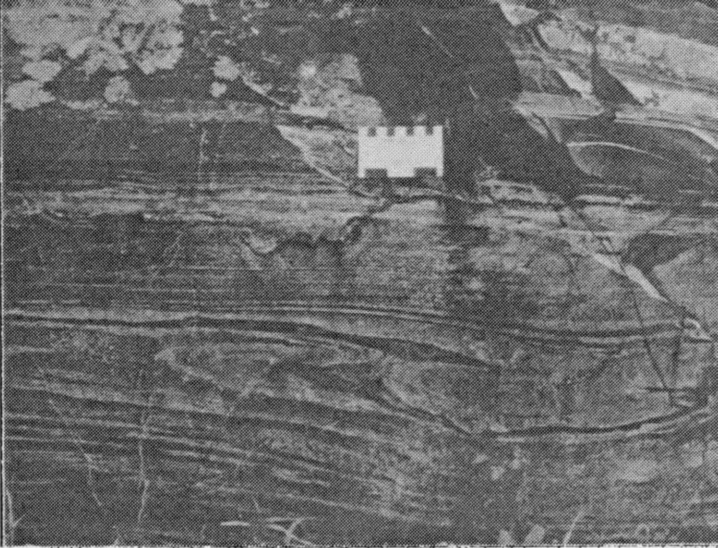
Magnetic declination 10°30' in 1984.


CENTIMETRE
INCH







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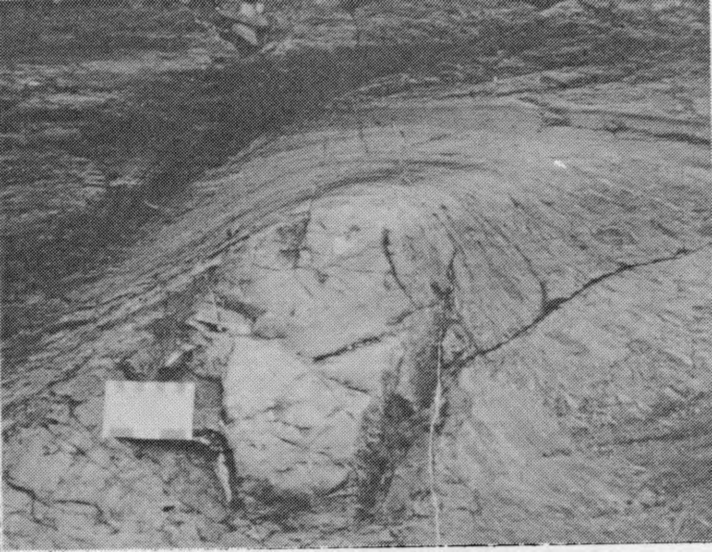

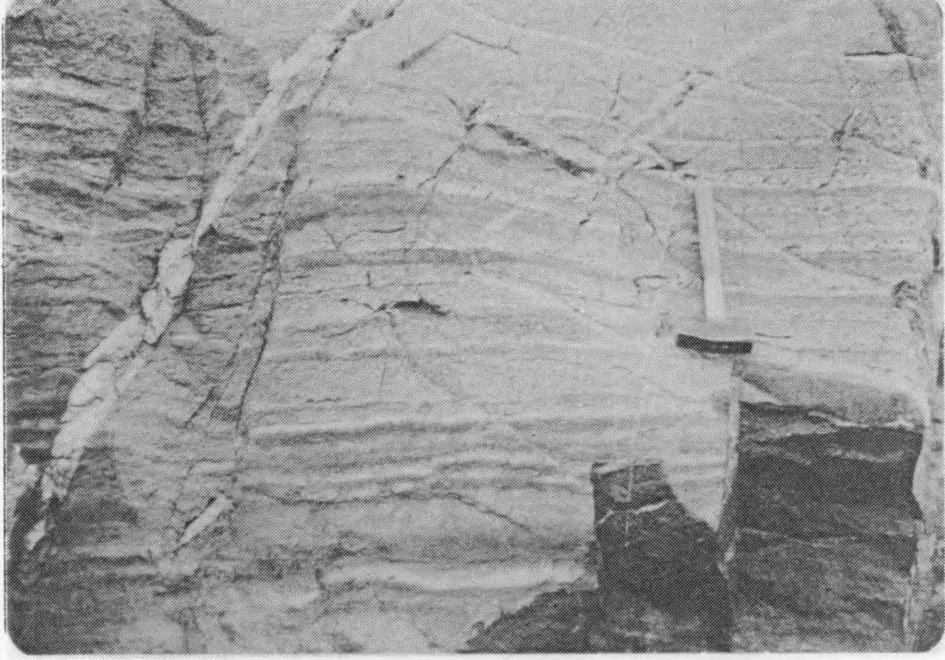

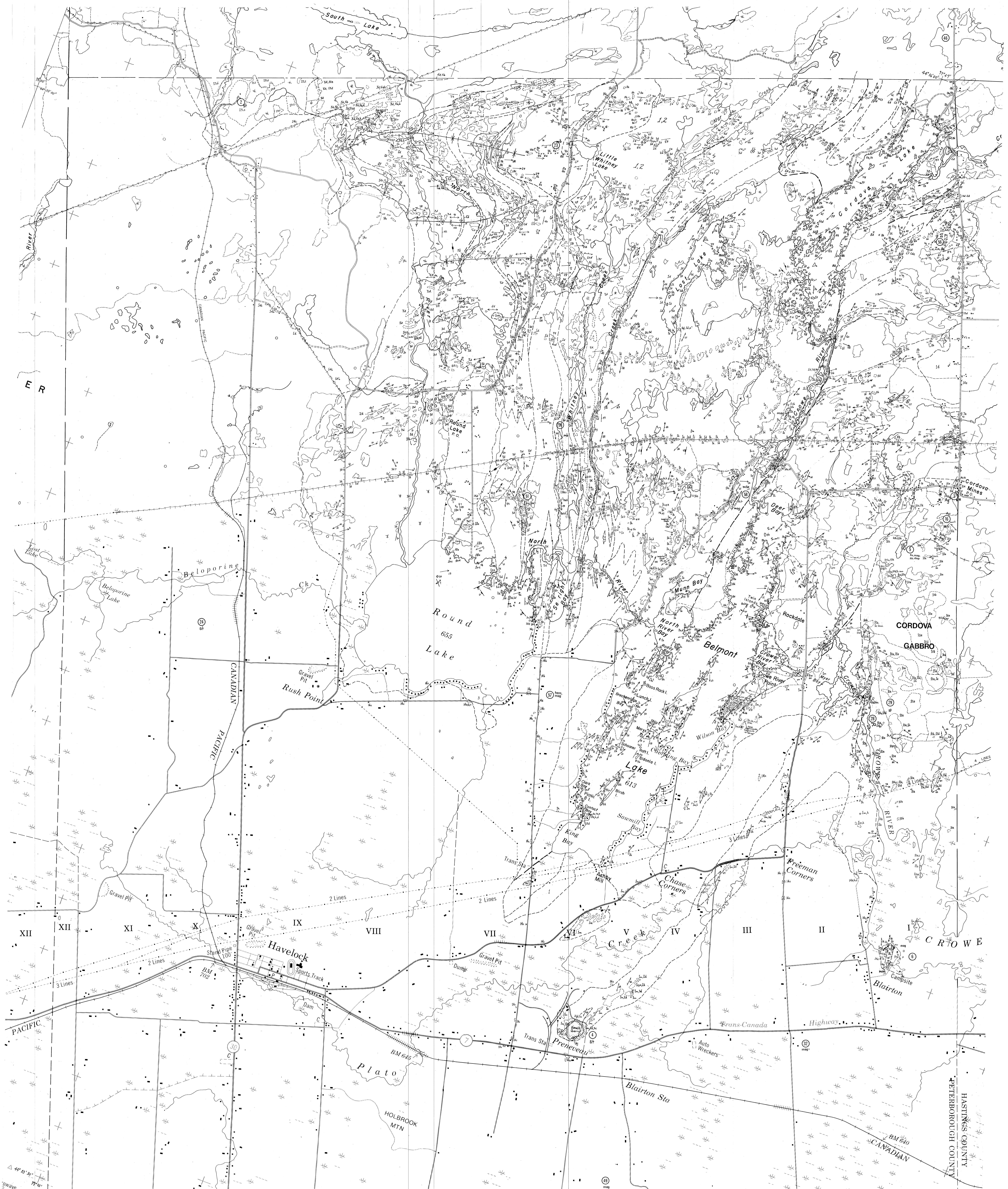

BELMONT TP

Scale 1 inch to 1/4 mile

SMC 14657

OFR5537

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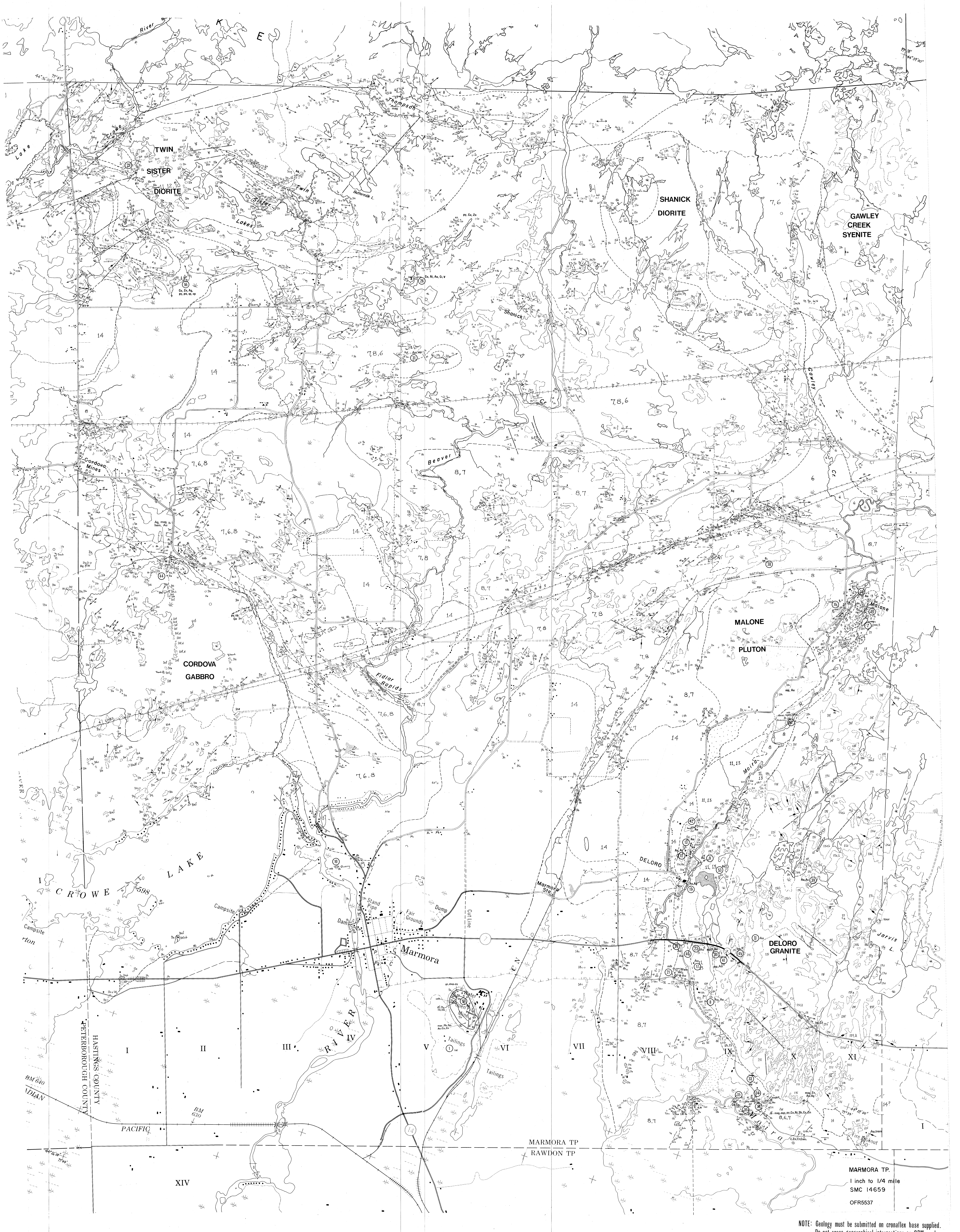
Do not erase geographical intersections or ODM number.
All geographical names are CPCGN approved.



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METHUEN TP

Scale 1 inch to 1/4 mile

SMC 14658

OFR5537

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