Ministry of
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Open File Report 5894

Geology of the Grimsthorpe Area, Hastings and Lennox and Addington Counties, Grenville Province

1994

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ONTARIO GEOLOGICAL SURVEY

Open File Report 5894

Geology of the Grimsthorpe Area, Hastings and Lennox and Addington Counties, Grenville Province

By

R.M. Easton and F.D. Ford

1994

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FOREWORD

As part of the Ontario Geological Survey's ongoing program to improve detailed map coverage of the Grenville Province to assist both metallic and non-metallic mineral exploration, detailed mapping of the Grimsthorpe area was begun in 1990. Prior to 1990, only reconnaissance level geological information was available for the area, despite a reported abundance of mafic metavolcanic rocks and gold occurrences east and south of the map area.

The area includes some of the oldest rocks within the Central Metasedimentary Belt of the Grenville Province, and the area has had a geologic history that is distinct from neighbouring regions due east of the map area. The area has potential for gold, volcanogenic massive sulphide deposits, and ultramafic-hosted talc deposits. Gabbroic intrusions in the area may host Cu-Ni sulphide, oxide (magnetite, chromite, ilmenite), and PGE deposits. Plutonic rocks in the area have excellent potential for building stone.

J. Wood, Director
Ontario Geological Survey

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ABSTRACT

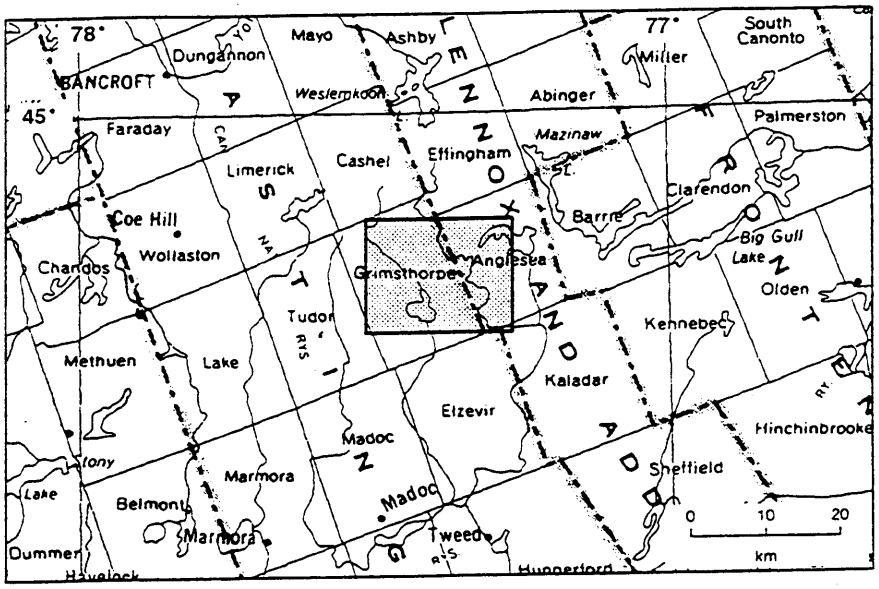

Figure 1: Location map of the study area.

The Grimsthorpe area lies 60 km north-northwest of the city of Napanee, and approximately 200 km northeast of Toronto and covers about 220 km^2. Bedrock is Middle Proterozoic in age, and lies within the Central Metasedimentary Belt of the Grenville Province. The area lies within the Grimsthorpe Domain of the Elzevir Terrane. Metamorphic grade in the area is dominantly upper greenschist facies, although middle amphibolite facies rocks are found adjacent to the Weslemkoon and Canniff tonalites. Deformation in the map area is generally low, but is locally concentrated in several shear zones and adjacent to the margins of the Weslemkoon and Canniff tonalites.

The Grimsthorpe Domain is one of the least complex domains of the Central Metasedimentary Belt and is composed of about 65% plutonic rocks and 35% supracrustal rocks. The stratigraphic succession consists of older tholeiitic flows and mafic intrusions (Canniff Complex) overlain by a volcaniclastic sequence (Grimsthorpe Group), which has been intruded by a younger ultramafic-mafic plutonic suite (Killer Gabbro Suite), in turn intruded by *ca.* 1270 Ma tonalite plutons of the Elzevir Suite (Canniff, Elzevir and Weslemkoon tonalites and the Lingham Lake pluton). Syenites of the *ca.* 1085 Ma Skootamatta Suite are also common within the domain. The most deformed rocks in the domain are the Canniff Complex. The volcaniclastic sequence (Grimsthorpe Group) and the gabbro and tonalite bodies preserve primary textures, including igneous layering. Plutons show semi-circular to oblate forms approximating original intrusive forms.

Precambrian rocks in the Grimsthorpe area are separated into an eastern and a western block by the north-northeast-trending Partridge Creek shear zone, which is coincident with the western margin of the Killer Creek Gabbro. In addition, another north-trending deformation zone, the Mooroton shear zone, lies just east of the map area, and separates rocks of the Grimsthorpe Domain from metavolcanic and metasedimentary rocks of the Marble Lake area (Mazinaw Terrane) to the east.

The western block is characterized by a package of mafic volcaniclastic and minor mafic flow rocks and minor siliceous clastic metasediments and pyritiferous metasediments (Grimsthorpe Group) intruded by gabbros of several ages and mafic to intermediate dikes, as well as gabbroic and dioritic rocks of the Lingham Lake pluton and the Weslemkoon and Canniff tonalites. A series of older protomylonitic gabbros and metavolcanic rocks are found along the margin of the Canniff Tonalite (Canniff Complex). Cobbles of these gabbros occur in tuffaceous conglomerates within the volcaniclastic sequence and the gabbros may have served as basement to part of the supracrustal succession in the area. Talc occurrences in the Grimsthorpe area, and in the Elzevir area to the south, are hosted within these older gabbros.

The eastern block consists mainly of gabbroic and ultramafic rocks of the Killer Creek Gabbro which have been intruded by the Elzevir Tonalite. Supracrustal rocks, mainly mafic volcanic rocks, occur locally along the northern margin of the Killer Creek Gabbro. The younger Skootamatta Syenite intrudes all of the above units and the Mooroton shear zone.

Assays of rusty schists, collected by field party personnel, which include gossaneous black schists (metamudstones) as well as gossan zones within tuffaceous conglomerates and gossan zones in siltstones and tuffaceous sandstones adjacent to mafic dikes, locally show very minor enrichments in copper, nickel, or zinc. Samples of quartz veins collected by field party personnel from throughout the map area were barren with respect to gold. Quartz veins are most abundant in the Weslemkoon Tonalite adjacent to an east-trending Paleozoic-age fault that parallels the Skootamatta road. Rock samples collected adjacent to this fault were locally anomalous for lead. Barite-carbonate-lead veins are associated with Paleozoic faults elsewhere in the Central Metasedimentary Belt in Ontario and the anomalous values found in the two samples from the fault zone may indicate the presence of this type of mineralization along this fault.

Hornblendite samples from the Killer Creek Gabbro show local enrichments in both copper and chromium, and locally, anomalous platinum and palladium contents. Some hornblendite samples also contain 15%-20% magnetite. The presence of igneous layering within the Killer Creek body, as well as high Cr, Fe and Ti contents, indicate that the body has potential for oxide and possibly platinum mineralization and warrants

additional exploration. Copper is also anomalous throughout the Killer Creek Gabbro, and the body has potential for hosting copper-nickel sulphide mineralization.

Gold occurrences east and west of the Grimsthorpe area, the abundance of mafic volcanic rocks as indicated on regional scale maps, and the lack of much previous exploration have all made the Grimsthorpe area a target area for gold exploration over the past few years. The Mooroton shear zone is significant from the standpoint that it separates the Mazinaw Terrane, which contains mainly calcalkalic volcanic sequences of basalt through rhyolite, extensive carbonate and siliceous clastic sedimentary sequences, and rocks of the Flinton Group, from the Grimsthorpe Domain of the Elzevir Terrane which consists mainly of mafic volcanic rocks, gabbroic rocks, and tonalite plutons. Exploration philosophies developed for the Mazinaw Terrane may not necessarily be applicable to the Grimsthorpe Domain because of different lithologic sequences and likely different geologic histories between the two areas. The Partridge Creek shear zone does not seem to juxtapose greatly different rock sequences, nevertheless, it is difficult to correlate across this zone. The shear zone does deform volcaniclastic and mafic plutonic rocks, and may make an interesting exploration target for gold.

The abundance of volcaniclastic sediments in the area, as opposed to mafic flows, may make the area less attractive for gold exploration. Gold occurrences in Cashel Township just north of the map area occur in the massive amphibolite units that may represent metaflows and not in volcaniclastic sediments. Gold properties east of the Mooroton shear zone are also hosted in deformed mafic metaflows. However, the United Reef Petroleums Limited properties are hosted by the volcaniclastic sequence and contain minor gold mineralization.

The volcaniclastic conglomerates might make good host rocks for volcanogenic massive sulphide (VMS) deposits, particularly as the intercalated rusty schist horizons might locally serve as good cap rocks. North and east of Partridge Creek is a zone of alteration, silicification and intrusion of felsites roughly 5 km in length and about 500 m wide that is coincident with a regional aeromagnetic high. This zone is depleted in a number of metals, and has been subjected to sodium metasomatism. The alteration zone is not associated with significant shearing, and no other zones of this scale or intensity were found elsewhere in the Grimsthorpe area.

Field party personnel located a new talc occurrence along the east margin of the Canniff Tonalite. It is part of a belt of talc occurrences that lie along the western margin of the Elzevir and Weslemkoon tonalites from highway 7 to Weslemkoon Lake. These talc occurrences are hosted in mafic and ultramafic rocks and occur within 2 km of the tonalite intrusions. Three factors may thus be responsible for talc mineralization in the Elzevir-Grimsthorpe area: (1) a favourable protolith which may have undergone an early deformation or alteration (protomylonitic gabbros of basaltic komatiite composition); (2)

metamorphism and fluid movement related to emplacement of tonalite plutons in the area; and (3) deformation associated either with, or subsequent to tonalite emplacement. Exploration should focus on areas where these three factors occur.

The Skootamatta Syenite, the Killer Creek Gabbro, and the Elzevir and Weslemkoon tonalites all have potentrial for building stone.

GEOLOGY OF THE GRIMSTHORPE AREA, HASTINGS AND LENNOX AND ADDINGTON COUNTIES, GRENVILLE PROVINCE

by

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GEOLOGY OF THE GRIMSTHORPE AREA, HASTINGS AND LENNOX AND ADDINGTON COUNTIES, GRENVILLE PROVINCE:

by R.M. Easton and F.D. Ford

INTRODUCTION

The Grimsthorpe area (NTS 31C/14SW) (Figure 1) is located 60 km north-northwest of the city of Napanee, and approximately 200 km northeast of Toronto. The map area covers about 220 km^2, and is bounded by lat. 44°45'N and 44°52'30''N and long. 77°15'W and 77°30'W. The area lies within parts of Hastings and Lennox and Addington Counties, and includes parts of Anglesea, Cashel, Effingham, and Grimsthorpe townships. The village of Cloyne is the nearest community to the map area and lies about 10 km east of the area. Bon Echo Provincial Park straddles the northeast corner of the map area.

There is no record of mineral production within the map area, and mineral exploration in the area has been minimal (*c.f.* Meen 1944, Assessment Files Research Office (AFRO), Ontario Geological Survey, Sudbury). Geological Data Inventory Folios (GDIFs) are available for Anglesea (OGS 1984c), Cashel (OGS 1986), Effingham (OGS 1984a), and Grimsthorpe (OGS 1984b) townships and show only a few mineral occurrences in the area. In contrast, similar lithologies south of the map area have been subject to detailed exploration for both talc and gold mineralization (*e.g.* Di Prisco 1989, LeBaron and van Haaften 1989), and mafic metavolcanic rocks due east of the map area have been extensively explored for gold (Meen 1944, Moore and Morton 1986). There has been an increase in exploration in the area over the past decade, coincident with increased access to the area as the result of the completion of the Skootamatta Road. Recent exploration activity has focussed on gold.

Access

Access is provided by highway 41 which lies parallel, and 10 km east of the eastern boundary of the map area, and the Skootamatta Road, an east-west forest access road that transects the northern half of the map area. Additional access is provided by cottage roads, powerline rights-of-way, numerous logging roads, and several trails.

Physiography

Relief in the map area is about 100 m, ranging from roughly 280 m above sea level near Lingham Lake to about 365 m above sea level in the north-central and southeast parts of the map area. Relief is more subdued in areas underlain by the Grimsthorpe Group and is most varied in the area underlain by the Canniff Complex and the Killer Creek Gabbro due to the gabbroic rocks forming steep ridges. The highest elevations in the map area correspond to the areas underlain by tonalite plutons and the Canniff Complex. The Skootamatta Syenite stands in relatively low relief, in contrast to the Mount Moriah Syenite 2 km southwest of the map area which forms a topographic high. This difference may be due to the abundance of more

Mount Moriah Syenite 2 km southwest of the map area which forms a topographic high. This difference may be due to the abundance of more easily weathered coarse-grained biotite syenite in the Skootamatta Syenite compared to the medium-grained, hornblende syenite that dominates the Mount Moriah Syenite.

The map area is drained by the Black River on the west side of the Weslemkoon Tonalite and by Partridge Creek on the east. Skootamatta Lake drains south via Skootamatta Creek which parallels the Mooroton shear zone. All three watercourses drain southward into Lake Ontario, and none are navigable for any distance. Glaciofluvial deposits are locally present along the Black River and Partridge Creek, and have locally been exploited for sand and gravel. In 1925, a large dam was built across the Black River in lot 16, concession V, Grimsthorpe Township, just south of the map area, producing a reservoir known as Lingham Lake (Meen 1944). Meen (1944) reports that the bed of the lake was the site of a large cranberry bog, which is consistent with the shallow nature of the lake.

Distribution of outcrop is varied. Exposure is poor (15-25%) throughout most of the map area, as moderate till and soil cover overlies most outcrops, and most of the map area is forested. Exposures are abundant (40-60%) in areas adjacent to the tonalite complexes underlain by Canniff Complex metavolcanics and gabbros. The Killer Creek Gabbro is also well-exposed (50-60%), with blocky outcrops of gabbro being present in even the most heavily forested parts of the pluton.

Logging has taken place in several areas within the past decade, and forest debris makes traversing in these areas difficult to impossible. Small, flat, glacially polished outcrops are commonly exposed along recent logging roads in the area, however, they quickly become soil covered and vegetated once logging has been completed.

Previous Geological Work

Systematic mapping of Anglesea Townships in the eastern half of the area at 1:63 360 scale did not take place until the early 1940s (Meen 1944). Lumbers (1968) mapped Cashel Township, which lies adjacent to the northwest corner of the map area, in detail (1:31 680 scale). Lumbers (1967) also mapped the western half of the area at 1:250 000 scale as part of a reconnaissance survey of the region. The map area is also included on the 1:126 720 scale compilation map of Hewitt (1964). Moore and Morton (1986) mapped the eastern margin of the map area at 1:31 680 scale. Di Prisco (1989) and Wolff (1982) have mapped the areas immediately south of the area at 1:20 000 and 1:31 680 scale respectively. An unpublished reconnaissance geologic map at 1:15 840 scale of Bon Echo Provincial Park, immediately northeast of the Grimsthorpe area, was prepared by van Haaften and Smedley (1979). Ayer (1979) mapped the area east of Pringle Lake, which is located adjacent to the northeast corner of the Grimsthorpe area.

Connelly (1985, 1986; Connelly *et al.* 1987) studied the emplacement history of the

Elzevir Tonalite, including detailed studies along the eastern margin of the pluton in the Bishop Corners area. Jim Cureton has recently undertaken a study of the Mooroton shear zone as part of a Master's degree program at the University of Michigan, Ann Arbor (*see also* Cureton *et al.* 1994). M. Harris of the University of Windsor conducted a petrologic study of the Skootamatta Syenite as part of a B.Sc. thesis (Harris 1991). Hanes *et al.* (1988) conducted an argon-argon cooling history survey over the Elzevir Tonalite and the Killer Creek Gabbro and most of their sampling occurred within the map area. In a geochemical study, Wu *et al.* (1991) compared the chemistry of the low and high metamorphic grade parts of the Weslemkoon Tonalite.

Geological Data Inventory Folios (GDIF) cover the entire map area, as follows: Anglesea Township (OGS 1984c), Cashel Township (OGS 1986), Effingham Township (OGS 1984a), and Grimsthorpe Township (OGS 1984b). Mineral deposit inventories of NTS 31C, including the Grimsthorpe area, are presented by Malzack *et al.* (1985) and LeBaron (1991). LeBaron and van Haaften (1989) and LeBaron *et al.* (1989) discuss several talc and building stone prospects, respectively, located in the Grimsthorpe area.

An aeromagnetic map at the scale of 1:50 000 of the Mazinaw area, including the Grimsthorpe area, was released by the Geological Survey of Canada in 1952 (GSC 1952). Results of a gravity survey conducted over the Elzevir Terrane, including parts of the map area, were published by Real and Thomas (1987).

The Quaternary geology of the Grimsthorpe area was studied by Henderson (1972). Aggregate resource inventories for townships in Hastings and Lennox and Addington townships are provided in MNR (1987b) and MNR (1987a) respectively.

Present Geological Survey

Open File Map 168 (back pocket, 1:20 000 scale) presents the results of the geological survey carried out by the authors and their assistants during the summer of 1990 (Project PU90-19). The authors mapped the geology of Bon Echo Provincial Park at 1:20 000 scale in 1991 during the course of mapping the Mazinaw area (Easton *et al.* 1991; Project PU91-08). Bon Echo Provincial Park straddles the northeast corner of the map area, and the geology of both areas is similar. The geology of Bon Echo Provincial Park is described by Easton (1994) and Easton *et al.* (1991).

A preliminary report on the geology of the Grimsthorpe area was given in the 1990 Summary of Field Work volume of the Ontario Geological Survey (Easton and Ford 1990a) and at the Ontario Geological Survey Geoscience Forum (Easton and Ford 1990b). Preliminary versions of the map of the Grimsthorpe area and Bon Echo Provincial Park were released at a scale of 1:20 000 in 1991 (Easton and Ford 1991a; Easton *et al.* 1991, respectively). A 1:50 000 scale compilation map of the Mazinaw area, which includes the map area was released on Open File in 1990, with a revised edition in preparation (Easton 1990a, in press).

Vertical aerial photographs at a scale of 1:10 000 were supplied by the Air Photo Library, Public Information Centre, Ontario Ministry of Natural Resources, and were used for mapping control. Acetate overlays were used to record data that was collected on traverses run by the pace and compass method. Geology was not tied to surveyed lines. Traverses were not spaced at regular intervals, but were designed to include as many of the major outcrop areas as possible, particularly in areas of complex geology and along contacts between major rock units. Traverse density was greater in areas underlain by supracrustal rocks than in areas underlain by large plutons.

Information from mapping was plotted on Ontario Basic Mapping (OBM) 1:10 000 base maps supplied by the Ontario Ministry of Natural Resources. Recent information with respect to roads, buildings, powerlines, rock and shoreline features were added to the base maps. The approximately 18 OBM base maps were mechanically stripped together, and photomechanically reduced, with the geological information, to produce the map accompanying this report.

Except where otherwise stated, all chemical analyses that appear in this report were done by the Geoscience Research Laboratories, Ontario Geological Survey, Toronto. Reference to specific locations (photographs, samples, *etc.*) in the text are given in UTM co-ordinates.

Acknowledgements

The writers were ably assisted in the mapping during the 1990 field season by Jill Bailey, Brenda McMurray and Michael Harris as junior assistants. During the 1991 field season, Melanie Cooke and Randy Stewart assisted in mapping parts of Bon Echo Provincial Park. Randy Stewart also assisted in processing geochemical data presented in this report and in drafting some of the figures. The assistance of various staff members at Bon Echo Provincial Park Headquarters, including superintendent E.M. Buck and park naturalist Denise Wilkins is greatly appreciated. Many land owners in the area kindly granted permission to inspect their properties, and their assistance is greatly appreciated. Jane Howe and Eric Grunsky assisted with correspondence and dynamic cluster analysis of some samples. Discussions with Brian Christie, Louise Corriveau, Paul Kingston, Peter LeBaron, and Steve van Haaften on the geology of the area also proved helpful.

Terminology

Precambrian Time-Scale

The Precambrian time scale as subdivided by Palmer (1983) is used. Precambrian time is divided into two eons; the Archean (older than 2500 Ma), and the Proterozoic (between 2500 and 570 Ma). The Proterozoic is divided into three eras; Early (2500 to 1600 Ma); Middle (1600 to 900 Ma); and Late (900 to 570 Ma).

Rock Classification

Terminology for all plutonic rocks in the area follows that of Streckeisen (1976). For metamorphic rocks, mineral prefixes are listed in order of relative abundance, starting with least abundant first. The following conventions are used regarding descriptive adjectives. A *gneissic granite* is a meta-igneous rock of granitic composition. A *granitic gneisses,* a *granite gneiss,* or a *gneiss of granitic composition* may be either a meta-igneous or a metasedimentary rock. Similarly, a *tonalitic gneiss* or a *tonalite gneiss* is a gneiss of tonalite modal composition, but may be of either meta-igneous or metasedimentary origin. A *gneissic meta-arkose* is a metasedimentary gneiss of overall granitic composition. Terminology for mylonites follows that of Higgins (1971).

The map area includes abundant metasedimentary rocks or volcanic provenance (*i.e.* volcaniclastic rocks). Terminology for such rocks is problematic, and no widely agreed upon classification scheme exists. The IUGS classification presented by Schmid (1981) divides mixed pyroclast-epiclastic rocks into three types, pyroclastic, tuffites (mixed pyroclastic-epiclastic) and epiclastic (volcanic and/or nonvolcanic). Clastic rocks within the map area probably represent all three types. Tuffs are certainly present, as are tuffaceous sandstones (mixture of tuff and epiclastic sands), and volcanic-derived sandstones. However, metamorphism and the difficulty in establishing the degree of reworking present in epiclastic debris derived from a pyroclastic source make it impossible to apply the IUGS classification precisely. As a consequence, the following modification of the IUGS terminology is used.

Pyroclastic (volcanic)	Volcaniclastic (epiclastic rocks of mainly volcanic provenance)	Epiclastic (minor volcanic component)	Avg. clast size (mm)
Pyroclastic breccia	tuffaceous conglomerate tuffaceous breccia	congolmerate breccia	64
Lapilli tuff	tuffaceous sandstone	sandstone	2
Tuff - coarse - fine	tuffaceous siltstone tuffaceous mudstone	siltstone mudstone/shale	1/16 1/256
100%	75%	25%	0% by volume

Peperites are volcaniclastic rocks similar to hyaloclastites that form subaqueously and are cemented by various chemical precipitates. Usage of the term herein follows that proposed by Brooks *et al.* (1982), namely a peperite is formed by:

> "interaction of intrusive magma and water-soaked sediment or ash. Intrusion of magma into wet sediment or ash must be demonstrated; the coarser volcanic fragments in peperites are not of pyroclastic or other extrusive origin, and they are clearly not epiclastically derived. The method of fragmentation of freezing magma

is not specified, nor is the depositional environment (the type example in central France formed in an Oligocene fresh-water lake)."

The term metamorphic grade is used in the case where bulk-rock composition or other factors prevent a more detailed assignment of metamorphic conditions. The metamorphic grade scheme used in this report is shown in Figure 2. Where metamorphic conditions can be outlined more precisely, the metamorphic facies terminology of Turner (1981) is used.

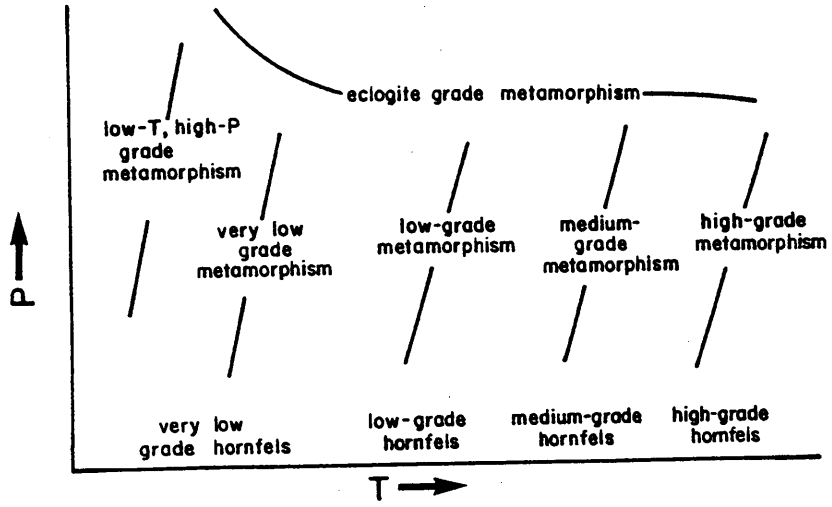


Figure 2: Metamorphic grade classification scheme used in this report (Easton 1990b).

Foliation, Schistosity, Gneissosity, Cleavage

Foliation is used to describe all types of megascopically recognizable structural surfaces of metamorphic origin (Turner and Weiss 1963). Several distinguishable types of foliation include compositional layering and preferred orientation of mineral grains. Bedding and schistosity are the most common varieties of foliation in the map area. Schistosity is a planar structure in a metamorphic rock due to abundant, preferentially oriented grains, especially micas. Schistosity is accompanied by a fissility in the rock, and is best developed in micaceous rocks. Gneissosity denotes a layering of metamorphic origin, defined by the alternation of layers, streaks, or lenticles on contrasting mineralogy or texture. The steaks or lenticles may be discontinuous. Cleavage denotes a parting in the rock resulting from the parallel growth of micaceous or elongated minerals in fine- to medium-grained rocks.

Layering Thickness Terms

Layering thickness terms used in this report are listed below. These terms apply to bedded, layered and gneissic rocks.

Very thinly layered	<3 cm
Thinly layered	3 to 10 cm
Medium layered	10 to 30 cm
Thickly layered	30 to 100 cm (1 m)
Very thickly layered	1 to 3 m
Extremely thickly layered	>3 m

GENERAL GEOLOGY

Introduction

The Grimsthorpe area is underlain by Precambrian rocks of Middle Proterozoic age which form part of the Central Metasedimentary Belt of the Grenville Province. The area lies within the Grimsthorpe Domain of the Elzevir Terrane of the Central Metasedimentary Belt (Figure 3) (Easton and Ford 1991b, Easton 1992a, 1992b). East-trending, Paleozoic faults, possibly related to the Ottawa-Bonnechere graben system, cut the northern half of the map area (Figure 4). Metamorphic grade in the area is upper greenschist facies, although middle amphibolite facies rocks are found adjacent to the Weslemkoon and Canniff tonalites. Deformation in the map area is generally low, but is locally concentrated in several shear zones and adjacent to the margins of the Weslemkoon and Canniff tonalites. The general stratigraphic succession of rocks in the Grimsthorpe area is given in Table 1. Figure 3 shows the regional geologic setting of the map area, and Figure 4 is a generalized map of the area simplified from OFM 168 (Back pocket). Figure 5 shows the major tectonic features and distribution of metamorphic grade within the Grimsthorpe area. Figure 6 shows the location of samples collected for chemistry, thin section, or both, within the map area.

The Grimsthorpe domain is one of the least complex Elzevirian domains and is composed of about 65% plutonic rocks with supracrustal rocks comprising the remainder (Easton 1992a). The stratigraphic succession consists of older tholeiitic flows and mafic intrusions (Canniff Complex) overlain by a volcaniclastic sequence (Grimsthorpe Group), which has been intruded by a younger ultramafic-mafic plutonic suite (Killer Gabbro Suite), in turn intruded by *ca.* 1270 Ma tonalite plutons of the Elzevir Suite (Easton 1992a). Syenites of the *ca.* 1085 Ma Skootamatta Suite are also common within the domain. The most deformed rocks in the domain are the older Canniff Complex. The volcaniclastic sequence (Grimsthorpe Group) and the gabbro and tonalite bodies preserve primary textures, including igneous layering. Plutons show semi-circular to oblate forms approximating original intrusive forms. Metamorphism varies from middle greenschist to upper amphibolite facies. Isotopic resetting of Rb-Sr systems in the area

TABLE 1: Table of Lithologic Units for the Grimsthorpe Area.

PHANEROZOIC
CENOZOIC
QUATERNARY
PLEISTOCENE AND RECENT
Sand, gravel, glaciofluvial deposits, till, ground moraines, and organic swamp deposits

UNCONFORMITY

PALEOZOIC
Fault gouge, hematite, hematized sandstone

UNCONFORMITY

PRECAMBRIAN
LATE PROTEROZOIC
LATE TECTONIC TO POSTTECTONIC INTRUSIVE ROCKS
Felsic Intrusive Rocks
Undeformed and deformed, coarse-grained to pegmatitic, biotite-magnetite-quartz-orthoclase dikes and veins

INTRUSIVE CONTACT

Mafic Intrusive Rocks
Fine-grained, weakly metamorphosed, diabase dikes (*ca.* 900 Ma Kingston (Frontenac) dike swarm)

INTRUSIVE CONTACT

MIDDLE TO LATE PROTEROZOIC
ELZEVIR TERRANE - GRIMSTHORPE DOMAIN
Alkalic Intrusive Rocks (*ca.* 1085 Ma)
Fine- to coarse-grained biotite syenite, lamprophyre, medium-grained biotite-hornblende monzonite

INTRUSIVE CONTACT

Intermediate to Felsic Intrusive Rocks (*ca.* 1270 Ma)
Elzevir Tonalite Suite
Tonalite to trondhjemite, granodiorite, melanodiorite, quartz diorite, monzogranite to syenogranite, migmatite formed by tonalite veins and screens of country rock, intrusion breccia, fine-grained, sugary-textured tonalite dikes, aplite, and derived mylonites

Mafic Intrusive Rocks (>1280 Ma)
Dioritic to Gabbroic Rocks (Killer Creek Gabbro Suite)
Fine- to coarse-grained gabbro, melanocratic gabbro, gabbroic anorthosite, fine- to medium grained feldspar porphyritic gabbro, hornblendite, mylonitic gabbro

INTRUSIVE CONTACT

METAVOLCANIC ROCKS
Felsic to Intermediate Metavolcanic Rocks
Felsic tuffs, massive felsic flows, felsic breccias, andesite tuffs, massive andesite flows, andesite breccias, and their mylonitized equivalents

FAULTED CONTACT?

Mafic Intrusive Rocks (>1280 Ma)
Dioritic to Gabbroic Rocks
Fine- to coarse-grained gabbro, melanocratic gabbro, anorthosite, anorthositic gabbro, gabbroic anorthosite, hornblendite, commonly magnetite-bearing, fine-grained gabbro dikes with well-developed cooling joints, mylonitic gabbro, gabbroic intrusion breccia

INTRUSIVE CONTACT

GRENVILLE SUPERGROUP - Grimsthorpe Group
METASEDIMENTARY ROCKS
Siliceous Clastic Metasedimentary Rocks
Meta-arenite, metaquartzarenite, metawacke, metasilstone, metapelite, rusty schist, polymictic, clast- and matrix-supported metaconglomerate, carbonate clast metaconglomerate, calcarenite

Siliceous Clastic Metasedimentary Rocks, may include Felsic and Intermediate Metatuffs and Metasedimentary Rocks of Mainly Volcanic Provenance
Hornblende-plagioclase gneiss ("para-amphibolite"), biotite-hornblende-quartz-plagioclase gneiss (mafic meta-arenite, mafic metawacke), hornblende-plagioclase schist and gneiss (metatuff), volcanic wackes, arkose (intermediate to felsic metalitharenite), fine- to medium-grained, thinly layered amphibole-dolomite gneiss, brown to black weathering (mafic calc-arenite, possibly tectonic in origin), polymictic, matrix-supported conglomerate, with mafic matrix, heterolitihic, matrix-supported, conglomerate with mafic matrix and abundant gabbro (mainly Canniff Complex) and mafic metavolcanic clasts (possible debris flow, basal conglomerate), grey to dark grey, massive, biotite-hornblende-quartz-plagioclase gneiss, commonly with magnetite porphyroblasts (possible metawacke), calc-silicate rocks, rusty schist, minor pillow basalt and massive basalt flows, albitized and silicified metavolcanic rocks

UNCONFORMITY?

CANNIFF COMPLEX (>1290 Ma)
Gabbroic and Talcose Rocks

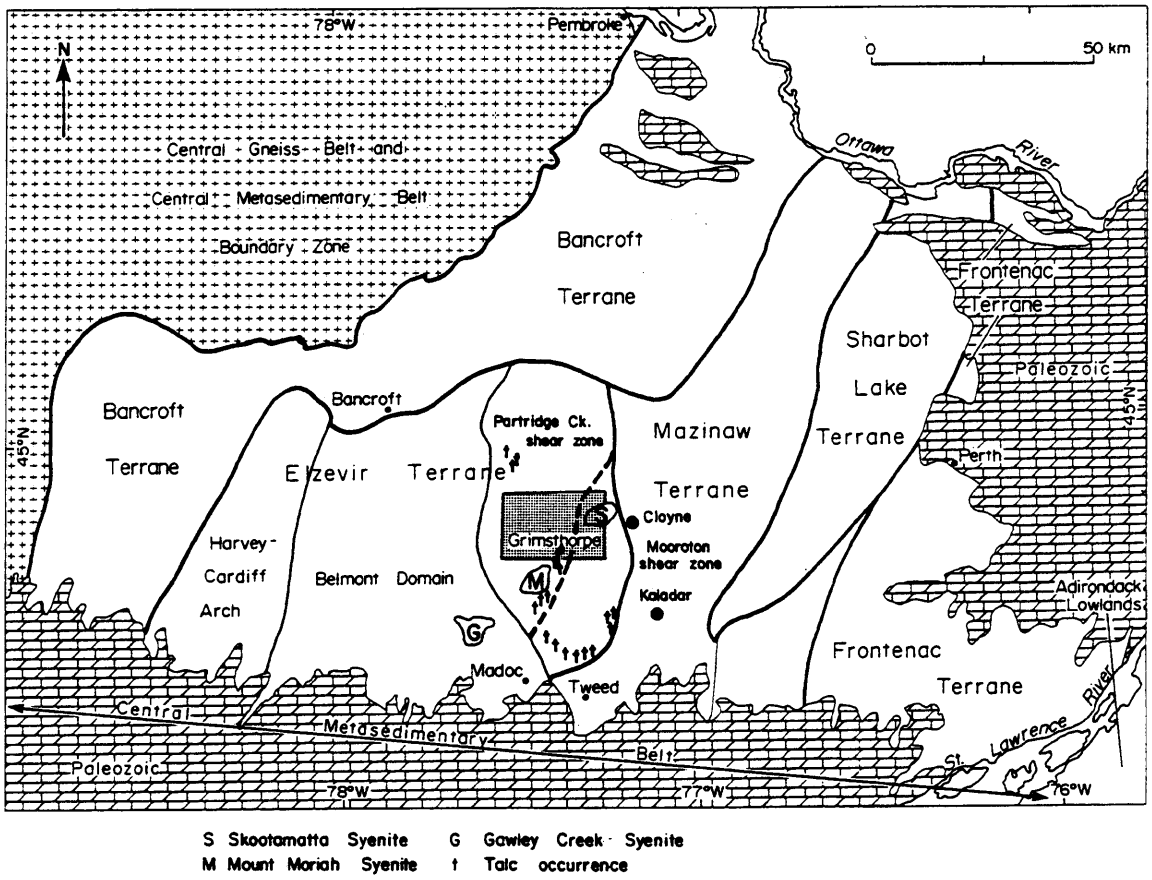
Protomylonitic, medium-grained gabbro, massive to schistose, brown-red talcose rocks, with varied amounts of hematite, magnetite, carbonate, chlorite, serpentine derived from mafic intrusives, massive to schistose, soft, pitted weathered surface, green-grey to white talcose rocks, with minor carbonate, chlorite, serpentine derived from mafic intrusives

INTRUSIVE CONTACT

CANNIFF COMPLEX
METAVOLCANIC ROCKS
Mafic Metavolcanic Rocks

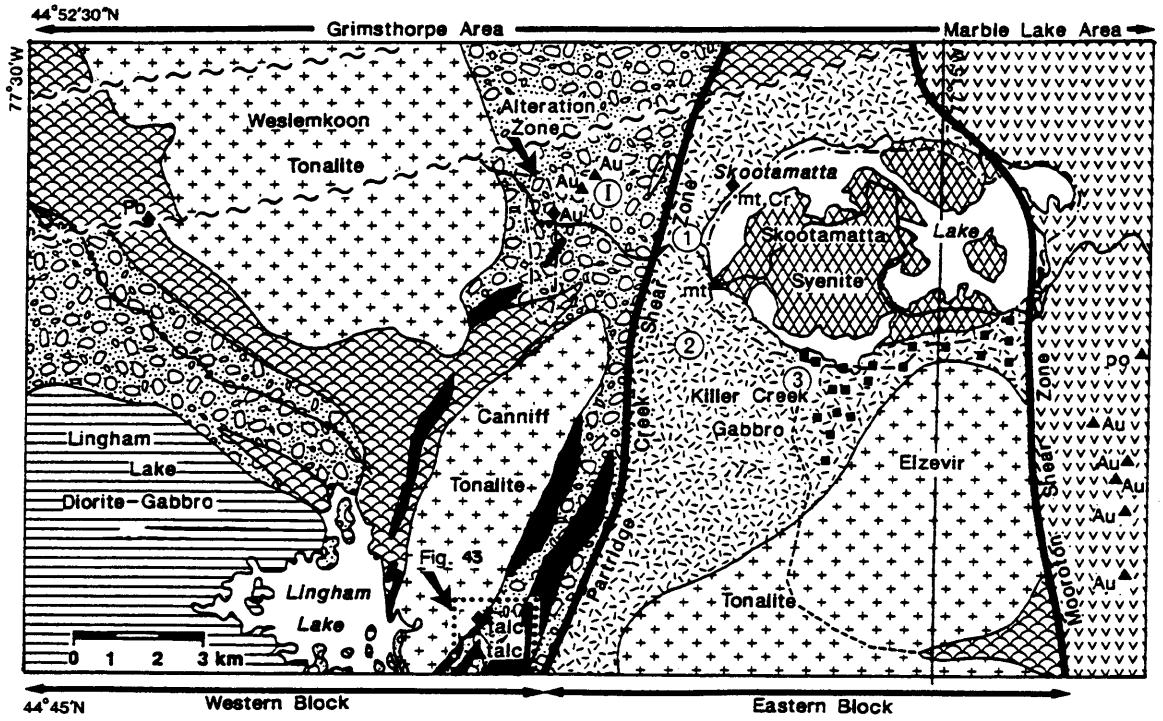
Massive, fine-grained, amphibolite (massive flow?), pillowed, fine-grained amphibolite (pillowed flow), microfractured to microbrecciated, fine-grained amphibolite (brecciated flow?), Massive, fine to medium-grained, diabasic-textured amphibolite (thick flows or gabbro sills), fine-grained chlorite-amphibole schist, layered to bedded, fine-grained, amphibolite (tuff, locally lapilli tuff), breccia, tuff breccia, hyaloclastite, fine-grained amphibolite with feather amphibolite texture, mylonitic amphibolite, feldspar porphyritic fine-grained amphibolite, gossan zones & rusty schist horizons, amphibolite with pervasive ferroan carbonate.

Figure 3: Regional geologic setting of the Grimsthorpe area, showing regional tectonic features and major lithotectonic divisions of the Central Metasedimentary Belt in Ontario. The box outlines the Grimsthorpe area.



S Skootamatta Syenite G Gawley Creek Syenite
M Mount Moriah Syenite t Talc occurrence

Figure 4: General geology of the Grimsthorpe Area, simplified from OFM 168, *back pocket, showing major structural elements, crustal blocks, and mineral occurrences.*



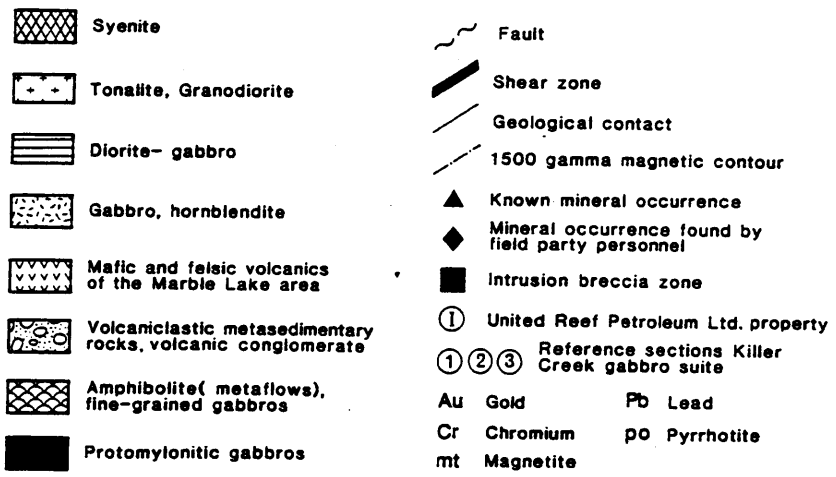


Figure 5: Distribution of metamorphic grade and major tectonic features in the Grimsthorpe area.

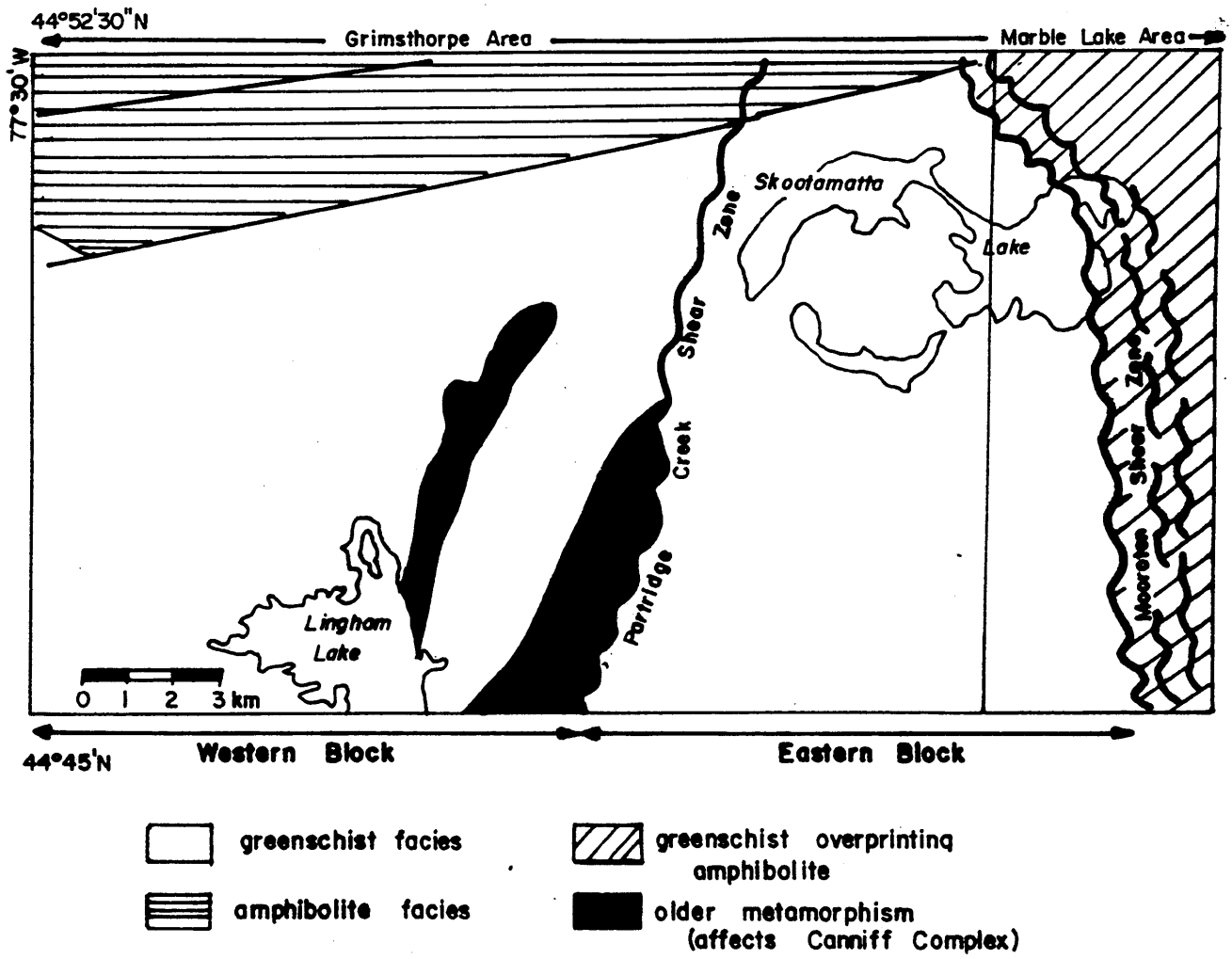
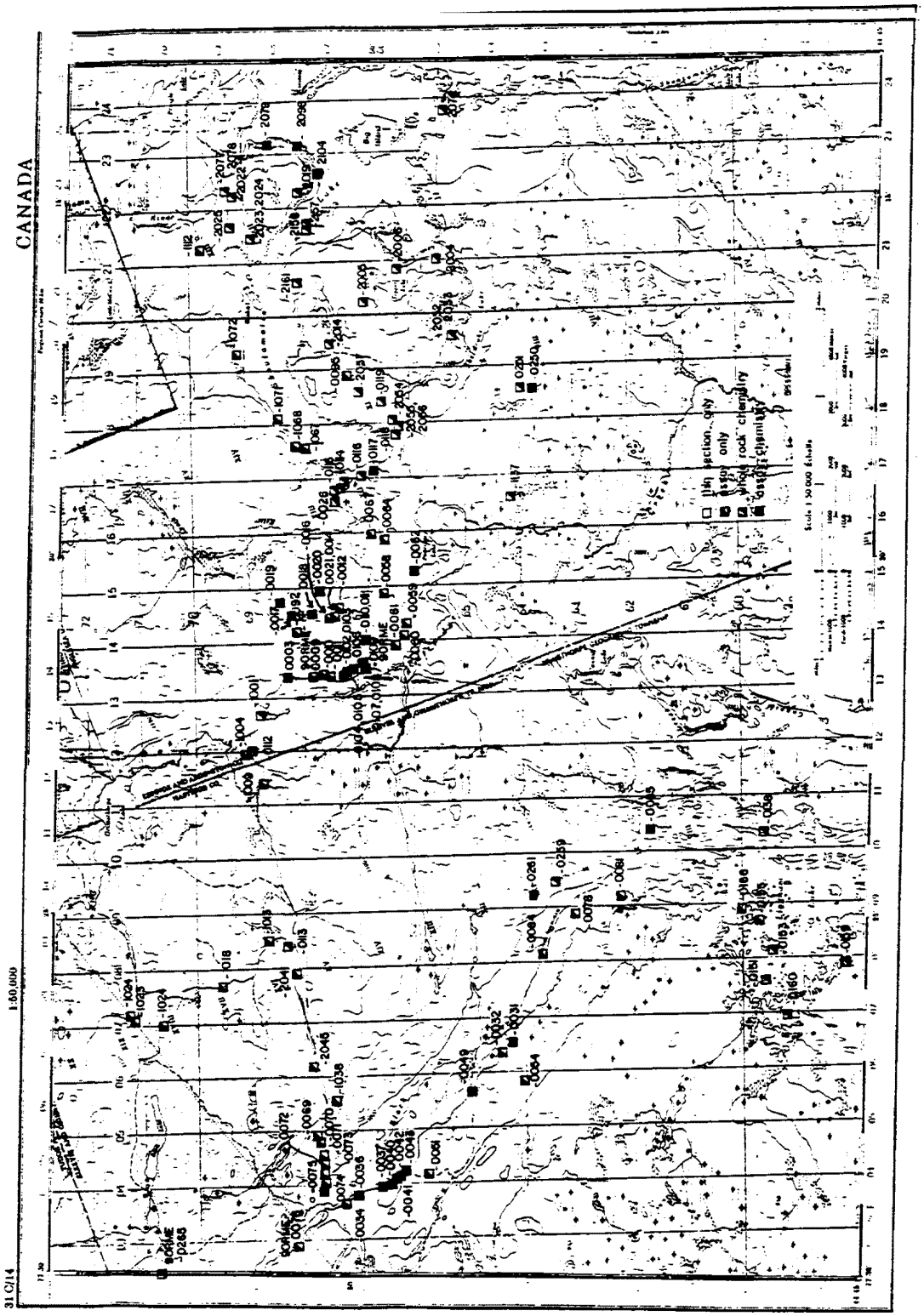


Figure 6: Location of samples collected for chemistry, thin section, or both within the Grimsthorpe and northern Elzevir map area.



is incomplete (*e.g.* Rb-Sr age (1240+/-50 Ma) on the Elzevir Tonalite is only slightly younger than the zircon age of 1270 Ma).

Precambrian rocks in the Grimsthorpe area are separated into an eastern and a western block by the north-northeast-trending Partridge Creek shear zone, which is coincident with the western margin of the Killer Creek Gabbro (Figure 4). In addition, another north-trending deformation zone, termed the Mooroton shear zone, lies just east of the map area, and separates rocks of the Grimsthorpe domain from metavolcanic and metasedimentary rocks of the Marble Lake area (Mazinaw Terrane) to the east (Moore and Morton 1986).

The western block is characterized by a package of mafic volcaniclastic and minor mafic flow rocks and minor siliceous clastic metasediments and pyritiferous metasediments (Grimsthorpe Group, units 3 and 4) intruded by gabbros of several ages (units 5, 7) and mafic to intermediate dikes, as well as gabbroic and dioritic rocks of the Lingham Lake pluton and tonalite and granodiorite of the Weslemkoon and Canniff tonalites (unit 8). A series of older protomylonitic gabbros and metavolcanic rocks are found along the margin of the Canniff Tonalite (units 1 & 2, Canniff Complex). Cobbles of these gabbros occur in tuffaceous conglomerates within the volcaniclastic sequence and the gabbros may have served as basement to part of the supracrustal succession in the area. Talc occurrences in the Grimsthorpe area, and in the Elzevir area to the south, are hosted within these older gabbros (unit 2). As discussed in detail later in this report, the Canniff Complex may represent a partially preserved ophiolite based on tectonic setting and geochemistry.

The eastern block consists mainly of gabbroic and ultramafic rocks of the Killer Creek Gabbro (formerly termed the Skootamatta complex, unit 7) which have been intruded by the Elzevir Tonalite (unit 8). Supracrustal rocks, mainly mafic volcanic rocks, occur locally along the northern margin of the Killer Creek Gabbro, however, the relationship of these volcanic rocks to compositionally similar rocks in the western block is undetermined. The younger Skootamatta Syenite (unit 9) intrudes all of the above units and the Mooroton shear zone.

Rocks of the Flinton Group (Moore and Thompson 1980), which crop out in the Marble Lake area due east of the Grimsthorpe area (Figure 3; Moore and Morton 1986), do not occur within the map area and they are not known to occur elsewhere west of the Mooroton shear zone. The Mooroton shear zone marks the Mazinaw and Elzevir Terrane boundary.

Eastern Block

The eastern block consists predominantly of plutonic rocks (Figure 4). Supracrustal rocks, consisting mainly of massive to layered amphibolites (possibly flows) (unit 1) and minor conglomerate of overall basaltic composition (unit 3), both intruded by fine- to

medium-grained gabbro sills and dikes (unit 5, 7), occur only in the northern part of the eastern block. Primary textures were not observed in the amphibolites. The supracrustal rocks in the eastern block are truncated immediately north of the map area by the Mooroton shear zone (Figure 4) and the Partridge Creek shear zone separates them from lithologically similar rocks in the western block.

The supracrustal rocks and the gabbroic rocks that intrude them are cut by the Killer Creek Gabbro (unit 7), a pluton that ranges from hornblendite through gabbro through gabbroic anorthosite to anorthosite in composition. The core of the pluton is little deformed, and locally is only partly recrystallized with primary plagioclase laths and pyroxene cores locally preserved. Spectacular igneous layering is preserved in several places in the pluton south of the Skootamatta road. The western margin of the pluton is mylonitized along the Partridge Creek shear zone, and rocks similar to the Killer Creek Gabbro Suite are not present in the western block. The body extends roughly 2 km further south into the Elzevir area (Di Prisco 1989) where it wedges out against the Elzevir Tonalite and the Partridge Creek shear zone.

The Elzevir Tonalite (unit 8) consists of two main plutonic masses in the map area. The northeasterly mass consists of roughly equal proportions of coarse-grained tonalite and granodiorite both containing large quartz clots. This mass intrudes the Killer Creek Gabbro and as the contact with the tonalite is approached, diking becomes more abundant in the gabbroic rocks, and a sharp contact between the two bodies is difficult to define. This is particularly true south of Sheldrake and Skootamatta lakes where a complex intrusion breccia zone is found between the Elzevir Tonalite and the Killer Creek Gabbro. The hornblendites and melanocratic gabbros of the Killer Creek Gabbro Suite are particularly abundant in this intrusion breccia zone.

The southerly mass, which extends south into the Elzevir area, is a medium-grained tonalite, with only very localized granodioritic patches, and which lacks the distinctive quartz clots of the northerly mass. The southerly mass has a sharp contact with the gabbros, and diking into the gabbros and gabbro xenoliths are much less abundant along the tonalite-gabbro contact in this part of the area.

Fine-grained tonalite and plagioclase porphyritic dikes of tonalite composition cut gabbroic and tonalitic rocks in the eastern block and volcaniclastic sediments of the western block. Several of these younger dikes are found in the vicinity of the United Reef Petroleums Limited gold property (Figure 4) and may in part be related to the gold mineralization. In addition, Moore and Morton (1986) reported "dacite" dikes from the Marble Lake area which are similar to these dikes that cut tonalites in the eastern block. Connelly *et al.* (1987) dated fine-grained tonalite dikes adjacent to the Elzevir Tonalite at 1229 +11/-4 Ma. This age is roughly 40 Ma younger than the age of the Elzevir Tonalite (1267 Ma, L. Heaman, geochronologist, Royal Ontario Museum, Toronto, Ontario, personal communication 1989). These younger tonalite dikes in the Grimsthorpe area

may be equivalent of the dikes dated by Connelly *et al.* (1987). If so, then they represent an event common to the eastern and western blocks and the Marble Lake area.

The contact of the Skootamatta Syenite roughly follows the shape of Skootamatta and Sheldrake lakes, and is coincident with the 1500 gamma contour on the regional aeromagnetic map (GSC 1952). The body has a well-defined aeromagnetic signature distinct from other plutons in the Grimsthorpe area, but similar to the nearby Mount Moriah and Gawley Creek Syenites (Figure 3). Two main phases are present in the body; a grey, medium-grained to coarse-grained biotite-hornblende-monzodiorite to monzonite phase that is found locally throughout the body which appears to be cut by a pink, medium-grained to coarse-grained biotite syenite phase that makes up the bulk of the intrusion. Fine-grained syenite dikes also occur throughout the intrusion. As far as could be determined, there was no systematic variation in rock types between the core and margin of the intrusions. Contacts with the country rocks are sharp, and syenite dikes were not found more than a kilometre from the contact. Xenoliths of the country rocks are rare. Some metasomatism may have occurred along the contact, as gabbroic rocks of the Killer Creek Gabbro locally become biotite-bearing adjacent to the contact, and secondary feldspar and feldspathoid growth occurs in some gabbros near the contact with the syenite. In terms of rock types and textures, the Skootamatta Syenite most closely resembles the Gawley Creek Syenite. The Skootamatta, Mount Moriah and Gawley Creek syenites are part of a suite of roughly 1090-1075 Ma old potassic and ultrapotassic plutons that are found in the Central Metasedimentary Belt in Ontario and Quebec, termed the Skootamatta Suite by Easton (1992a).

The Mooroton shear zone lies largely outside of the map area, and was only mapped in a reconnaissance fashion. It is well exposed along Skootamatta Creek north of Skootamatta Lake and along the northeast and east shores of Skootamatta Lake. It consists of straight and irregularly layered gneisses which contain pods of deformed Killer Creek Gabbro and tonalite. Metamorphic grade also appears to increase from west to east across the zone, from upper greenschist to lower amphibolite in the west to middle to upper amphibolite in the east. In addition, in the Grimsthorpe area, deformation is concentrated along the block boundaries, whereas in the Marble Lake area (east of the Mooroton shear zone) deformation is more widespread and intense deformation is uniformly distributed across the Marble Lake area. Syenite dikes cut the Mooroton shear zone on the east shore of Skootamatta Lake, indicating that shear zone is probably older than 1075-1090 Ma. As shown in Figure 3, the Mooroton shear zone is a regionally important structure that separates the Elzevir and Mazinaw terranes (see also Easton 1992a, Easton and Ford 1991b).

Western Block

Supracrustal rocks are much more abundant in the western than the eastern block, and it is possible that the eastern block is simply a more deeply eroded equivalent of the

western block. Supracrustal rocks consist mainly of volcaniclastic sediments of basaltic composition (Grimsthorpe Group, units 3 and 4), although as indicated in Figure 4, there are areas of more massive amphibolites (possible metaflows) in parts of the western block, particularly along the western margin of the Weslemkoon Tonalite. As discussed below however, it is not possible to easily distinguish Canniff Complex and Grimsthorpe Group metaflows in the field. The bulk of the metaflows appear to belong to the Canniff Complex.

The volcaniclastic rocks are well exposed along the Skootamatta road and on the shores of Lingham Lake. A crude stratigraphic sequence seems to be present, which, in the Lingham Lake area, forms an apparently homoclinal succession. This succession consists, from east to west, of gabbro-clast tuffaceous conglomerates which grade upward into conglomerates consisting of basaltic volcanic detritus. These conglomerates are locally intercalated with a few rare pillowed flows, in turn overlain by basaltic composition tuffaceous sandstones and pebble conglomerates, overlain by basaltic composition mudstones with some tuffaceous conglomerate and volcaniclastic sandstone lenses, which then grade into more aluminous siltstones and mudstones, and metawackes and meta-arenites. Graded bedding in the tuffaceous sandstones and the conglomerates provide top indications throughout the sequence. Rusty schists with associated gossan zones are common in all of the above rock types, but primarily in the tuffaceous mudstones and conglomerates. The top of the section is truncated by the Lingham Lake pluton. The base of the section consists of protomylonitic gabbros described in greater detail below. This homoclinal sequence can be traced to the north, but the amount of volcaniclastic sediment decreases, and a thick sequence of massive and layered amphibolite (possibly metaflows) are found near the base of the homoclinal sequence adjacent to the Weslemkoon Tonalite (Figure 4). The amphibolites are more deformed and metamorphosed than the volcaniclastic sediments and they do not retain primary textures. This greater degree of deformation and metamorphism is in part related to the emplacement of the tonalite bodies, but it may also reflect a relative age difference between the flow rocks and the volcaniclastic sediments, as is the case for the protomylonitic gabbros which shed clasts into the lower part of the volcaniclastic sequence.

The volcaniclastic rocks are little deformed, with volcanic, and where present, protomylonitic gabbro, cobbles being well rounded and showing no vertical or horizontal stretching. Individual conglomerate units can be traced along strike for up to a kilometre in areas of good exposure. However, good top indicators are generally only seen along roads or lakeshores, and repetition of the section through folding is probable. There is no structural evidence that the supracrustal rocks are preserved in synclinal troughs between the tonalite plutons. In the Lingham Lake area, units consistently face to the west. In the Killer Creek area, units face east.

At least three, most likely four, and possibly five, ages of gabbroic rocks are present

in the western block. The oldest gabbroic rocks (unit 2) consist of several bodies of protomylonitic, medium- to coarse-grained gabbro that occur along the margins of the Canniff Tonalite and extend northward toward Killer Lake. In addition to being more deformed than other units in the area, these oldest gabbros also show complex relationships with the apparently overlying volcaniclastic rocks (unit 3). Matrix and clast-supported conglomerates consisting of 10% to 50% gabbro clasts in a basaltic composition matrix are abundant in the metasedimentary sequence adjacent to the gabbros. In some instances, the gabbros seem to be disintegrating in place to form conglomerates, and it is possible that some of these complex contacts may represent paleoregoliths. The conglomerates and the contacts with the gabbros are virtually undeformed, and clearly contrast with the well developed shear zones present elsewhere in the map area. Whether the gabbros represent true basement to the volcaniclastic succession, or are simply an older unit that shed localized conglomerates during an early thrusting event has yet to be determined. As noted in Table 2, a summary of relative and absolute age relationships in the Grimsthorpe area, in either case, the protomylonitic gabbros are older than most of the classical Grenville Supergroup.

The volcaniclastic metasediments (units 3 and 4) are in turn intruded by a suite of medium-grained gabbros (unit 5), which are now bedding-foliation parallel units that contact metamorphosed the adjacent metasediments. The volcaniclastic metasediments exhibit locally spectacular, but generally barren (*see Economic Geology section*) gossan zones. These gossan zones are generally too small to show on Figure 4. Just north of the map area, and in the northern part of the eastern block, larger, fine- to medium-grained texturally heterogeneous gabbro masses are present which include xenoliths of the volcanic and volcaniclastic rocks and which may represent sub-volcanic magma chambers or shallow-level intrusions. It is not known if these larger gabbro masses are different in age from the smaller gabbro sills.

Although Killer Creek Suite gabbros are not found in the western block, the Killer Creek Gabbro (unit 7) intrudes heterogeneous gabbros similar to those found in the western block, and is cut by the Elzevir Tonalite (unit 8) which most workers have regarded as being similar in age and origin to the Weslemkoon (and the Canniff?) Tonalite.

A variety of cross-cutting, fine- to medium-grained gabbroic and mafic dikes (unit 5) generally trending 055^{o} to 060^{o} cut all rock units in the western block. Mafic and gabbroic dikes of several ages are present, but it was not possible to map them systematically at the mapping scale of the project. A particularly distinctive dike is a grey, basaltic andesite dike that displays prominent joints developed perpendicular to the dike margins. This type has only been observed cutting volcaniclastic rocks, and was not seen cutting the tonalites in the area. In areas of poor outcrop, it is commonly difficult to distinguish between some of the massive amphibolites, and the gabbros of

TABLE 2: Relative and absolute ages of rock units in the Grimsthorpe area.

Elzevir Terrane		**Mazinaw Terrane**	
Western Block	Eastern Block	Marble Lake area	
absent?	absent?	regional metamorphism (M_2) *ca. 1030-1020 Ma*	
Mount Moriah Syenite	Skootamatta Syenite (ca. 1075-1090 Ma)	absent	
absent	absent	Flinton Gp. (*ca.* 1150 Ma)	*post-Grenville Supergroup supracrustals*
		unconformity	
absent	absent	granitic plutons *ca.* 1240-1230 Ma	
tonalite dikes	tonalite dikes (1229+11/-4 Ma)	"dacite" dikes and Cross Lake tonalite (*ca.* 1235 Ma)	
gabbro dikes	gabbro dikes	absent?	
Canniff & Weslemkoon Lingham Lk. * Diorite-Gabbro Suite	Elzevir Tonalite (*ca.* 1270 Ma)	tonalites (may be faulted in)	
absent	Killer Creek Gabbro Suite	diorites gabbros	
absent	absent	carbonate & siliceous clastic metasedimentary rocks; volcaniclastic meta-sedimentary rocks; mafic intermediate, & felsic volcanic rocks (*ca.* 1275 Ma)	*Grenville Supergroup supracrustals (Kashwakamak Fm.)*
gabbro intrusions	gabbro intrusions	absent?	
volcaniclastic sediments **unconformity**	volcaniclastic sediments **unconformity**?	absent?	*(Grimsthorpe Group)*
amphibolites (metaflows?)	amphibolites (metaflows?)	absent?	*pre-Grenville Supergroup supracrustals (Canniff Complex)*
protomylonitic gabbros	absent?	absent	

various ages in the area. This may be one reason why previous workers characterized the area as being dominated by amphibolite (*i.e.* metaflows).

In addition, weakly metamorphosed, fine-grained diabase dikes (unit 10) also are present in both the volcaniclastic sediments and in the tonalites and may represent equivalents of the *ca.* 900 Ma Kingston (Frontenac) Swarm dikes.

The Lingham Lake pluton (Lingham Lake Complex of Lumbers 1969) underlies the southeast corner of the map area. It consists of two major phases, an older phase consisting of fine- to medium-grained gabbro (unit 5) exhibiting a wide range of textures and a slightly younger, medium-grained diorite (unit 8) which locally contains abundant mafic schlieren or partly assimilated country rock and gabbroic xenoliths. The diorite varies from mesocratic to leucocratic in colour. Lumbers (1969) reported pyroxenite from the Lingham Lake pluton but none was observed within the map area. Much of the core of the Lingham Lake pluton is inaccessible on foot due to an abundance of swamps and distance from roads and watercourses.

Two tonalite intrusions (unit 8) are present in the western block. The Canniff Tonalite is a fine- to medium-grained tonalite, which locally is transitional into granodiorite, particularly along the western margin of the pluton. The other is the Weslemkoon Tonalite, of which only the southern lobe is present. It consists mainly of medium-grained tonalite with coarse quartz clots. Apart from being slightly finer-grained, it is similar to the northern lobe of the Elzevir Tonalite in the eastern block.

Economic Geology

Assays of rusty schists, collected by field party personnel (*see Economic Geology section)*, which include gossaneous black schists (metamudstones) as well as gossan zones within tuffaceous conglomerates and gossan zones in siltstones and tuffaceous sandstones adjacent to mafic dikes, locally show very minor enrichments in copper, nickel, or zinc (*see Economic Geology section for details).*

Samples of quartz veins collected by field party personnel from throughout the map area were barren with respect to gold (*see Economic Geology section).* Quartz veins are most abundant in the Weslemkoon Tonalite adjacent to an east-trending Paleozoic-age fault that parallels the Skootamatta road. Rock samples collected adjacent to this fault were locally anomalous for lead. Barite-carbonate-lead veins are associated with Paleozoic faults elsewhere in the Central Metasedimentary Belt in Ontario and the anomalous values found in the two samples from the fault zone may indicate the presence of this type of mineralization along this fault.

Hornblendite samples from the Killer Creek Gabbro show local enrichments in both copper and chromium, and Easton and Ford (1991b) reported anomalous platinum and palladium results from a Killer Creek Gabbro sample collected in Bon Echo Provincial

Park. Some hornblendite samples also contain 15%-20% magnetite. The presence of igneous layering within the Killer Creek body, as well as ilmenite and magnetite-rich layers, and local high chromium values, indicate that the body has potential for oxide and possibly platinum mineralization and warrants additional exploration. Copper is also anomalous throughout the Killer Creek Gabbro, and the body has potential for hosting copper-nickel sulphide mineralization.

The presence of known gold occurrences east and west of the Grimsthorpe area, the abundance of mafic volcanic rocks as indicated on regional scale maps, and the lack of much previous exploration have all made the Grimsthorpe area a target area for gold exploration over the past few years. Two factors to be accounted for in any future exploration are the significance of the Mooroton and Partridge Creek shear zones and the abundance of mafic volcaniclastic rocks in the area. The Mooroton shear zone is significant from the standpoint that it separates the Mazinaw Terrane (Figure 3), which contains mainly calcalkalic volcanic sequences of basalt through rhyolite, extensive carbonate and siliceous clastic sedimentary sequences, and rocks of the Flinton Group, from the Grimsthorpe Domain of the Elzevir Terrane which consists mainly of mafic volcanic rocks, gabbroic rocks, and tonalite plutons. Exploration philosophies derived for the Mazinaw Terrane may not necessarily be applicable to the Grimsthorpe Domain because of different lithologic sequences and likely different geologic histories between the two areas. The Partridge Creek shear zone does not seem to juxtapose greatly different rock sequences, nevertheless, it is difficult to correlate across this zone. The shear zone does deform volcaniclastic and mafic plutonic rocks, and may make an interesting exploration target for gold.

The abundance of volcaniclastic sediments in the area, as opposed to mafic flows, may make the area less attractive for gold exploration. Gold occurrences previously reported in Cashel Township just north of the map area (Lumbers 1968) occur in the massive amphibolite units that may represent metaflows and not in volcaniclastic sediments. Gold properties east of the Mooroton shear zone are also hosted in deformed mafic metaflows. However, the United Reef Petroleums Limited properties are hosted by the volcaniclastic sequence and have found some gold mineralization (*see Economic Geology section*).

The volcaniclastic conglomerates might make good host rocks for volcanogenic massive sulphide (VMS) deposits, particularly as the intercalated rusty schist horizons might locally serve as good cap rocks. North and east of Partridge Creek is a zone of alteration, silicification, sodium depletion, and intrusion of felsites (Figure 4) roughly 5 km in length and about 500 m wide that is coincident with an anomaly on the regional aeromagnetic map of the area (GSC 1952). In several places, most notably just south of Partridge Creek, this anomaly is intense enough to deflect compass readings by up to 90 degrees. Assay results presented in the *Economic Geology section* indicate that samples from this zone are depleted in a number of metals, and that Na-metasomatism

relative to the host-rocks has occurred. The zone is not associated with any significant shearing, and no other zones of this scale or intensity were found elsewhere in the Grimsthorpe area.

Field party personnel located a new talc occurrence along the east margin of the Canniff Tonalite at UTM 312200E, 4958810N. This occurrence is north of the Grimsthorpe 1 and 2 occurrences described by LeBaron and van Haaften (1989), and consists of a body of coarsely crystalline, pale green talc associated with anthophyllite-rich rocks. All three talc occurrences noted above are part of a belt of talc occurrences that lie along the western margin of the Elzevir and Weslemkoon tonalites from highway 7 in the south to Weslemkoon Lake in the north (Figure 3). These talc occurrences are hosted in mafic and ultramafic rocks and occur within 2 km of the tonalite intrusions. The talc occurrences are found only in areas where the older gabbros (Figure 4) occur along the pluton margins. In particular, they occur as isolated pods lying adjacent to larger bodies of the older gabbro, generally in areas that have been more intensely deformed. They are closely associated with gabbro clast conglomerates of the volcaniclastic succession. The greater abundance of talc bodies in the Elzevir area to the south might reflect better exploration, however, deformation does become more intense to the south, possibly related to the intrusion of the Mount Moriah Syenite and a narrowing of the belt of protomylonitic gabbros and supracrustal rocks, and might be a factor in talc mineralization. Three factors may thus be responsible for talc mineralization in the Elzevir-Grimsthorpe area: (1) a favourable protolith which may have undergone an early deformation or alteration (protomylonitic gabbros of basaltic komatiite composition); (2) metamorphism and fluid movement related to emplacement of tonalite plutons in the area; and (3) deformation associated either with, or subsequent to tonalite emplacement. Exploration should focus on areas where these three factors occur.

Although the Skootamatta Syenite is close to major roads in the area, it is commonly fractured and jointed and field party personnel did not locate any areas that appeared to be reasonable prospects for extracting the syenite as a building stone. LeBaron *et al.* (1989) describe two prospects from the Skootamatta Syenite.

The Killer Creek Gabbro contains a variety of textures and colours, and might make attractive stone products. The best prospects are located north and south of Killer Creek adjacent to the reference localities shown in Figure 4. LeBaron *et al.* (1989) describe the potential of one site along the Skootamatta road by Killer Creek.

Most tonalite prospects lie far from existing roads. This, combined with the fact that several stone prospects are present in the Elzevir Tonalite to the south of the map area (LeBaron *et al.* 1989)) make the building stone potential of the Elzevir, Weslemkoon and Canniff tonalites in the Grimsthorpe area unattractive at this time. LeBaron *et al.* (1989) describe two potential sites in the Weslemkoon Tonalite.

PRECAMBRIAN

MIDDLE PROTEROZOIC

CANNIFF COMPLEX (units 1 and 2)

Introduction

The Canniff Complex (Easton 1992a) includes deformed mafic metavolcanic rocks (unit 1), protomylonitic gabbros (unit 2a), and talcose schists (units 2b, 2t) that may be among the oldest rocks in the Central Metasedimentary Belt (Easton 1992a). Type areas for the Complex are indicated in Table 3. Although in the field it was possible to distinguish Canniff Complex metagabbros from other metagabbros in the map area, it was not always possible in the field to correctly assign metavolcanic rocks to the Canniff Complex or to the slightly younger Grimsthorpe Group. As a consequence, OFM 168 (back pocket) is a lithologic, not a stratigraphic, map. On the Map, and in the discussion that follows, it should be realized that although most mafic metavolcanic rocks (unit 1) in the area constitute part of the Canniff Complex, some mafic metavolcanics (unit 1) occur within the Grimsthorpe Group.

Mafic Metavolcanic Rocks (unit 1)

A variety of mafic (basaltic) metavolcanic rocks occur throughout the Grimsthorpe area, however, they are mostly found adjacent to the margins of Elzevir Suite tonalitic intrusions within the map area. The largest outcrop areas are located in the central and western part of the map area, between the Canniff and Weslemkoon tonalites and along the western margin of the Weslemkoon tonalite (Figure 4).

Most exposures are of a massive, fine-grained, dark green to black weathering amphibolite (Photo 1a) (unit 1a). These rocks are commonly fractured, cut by astamosing, narrow (1-10 mm wide) quartz and plagioclase veins (Photo 1a, 1b). In outcrop, these rocks are not fresh in appearance, and primary textures are not well preserved. These rocks most likely represent massive flows. Also present are massive, fine- to medium-grained, dark green, ophitic-textured amphibolite (unit 1d) (Photo 1b) that may represent thick flows or gabbroic sills. In small outcrops, or in dense forest, it is often difficult to distinguish between unit 1a, 1d, and fine-grained phases of unit 5. Locally, massive, fine-grained, dark green to black weathering, feldspar porphyritic amphibolite (unit 1p) is present, intercalated with unit 1a, leading creedence to suggestion that these amphibolites indeed represent metaflows.

Rarely, fine-grained, dark green to black weathering, pillowed amphibolite (unit 1b) (Photo 1a) is present within the metavolcanic succession. These units are characterized by extremely thin selvedges, and little hyaloclastite between the selvedges. Pillow breccia zones or hyaloclastite between flows was not recognized within Canniff Complex flows. The thin selvedges make it difficult to recognize the presence of pillows in all but the cleanest outcrop exposures, and it is likely that the abundance of pillowed flows within the section is under represented on the map.

A variety of intercalated tuffaceous material of mafic (basaltic) composition is also present within the metavolcanic succession of the Canniff Complex, although tuffaceous rocks are more characteristic of the Grimsthorpe Group (Photo 1c). These include layered to bedded, fine-grained, dark green to black amphibolite (unit 1f), probably tuff or locally lapilli tuff. In the south-central part of the map area, several kilometres distant from tonalite intrusions, these same units are represented by fine-grained, dark green to black, chlorite-actinolite schists (unit 1e) and rusty schist horizons (unit 1r). Locally, fine-grained, dark green to black, amphibolite with well developed feather amphibolite texture (unit 1k) is present, and may represent tuffaceous rocks recrystallized during metamorphism.

As noted briefly above, mafic metavolcanic rocks of the Canniff Complex appear more deformed, more altered, have less well developed primary textures, have only minor intercalated tuffaceous and rusty schist horizons, and are generally massive amphibolites (compare Photos 1a and 1d). In contrast, mafic metavolcanic rocks of the Grimsthorpe Group are more likely to be tuffaceous in character, flow rocks are commonly pillowed (unit 1b, Photo 1d), hyaloclastite (unit 1h) is locally present, as are microbrecciated (unit 1c) flow rocks (Photo 2) and tuff breccias (unit 1g).

As noted in the *Terminology section,* within the map area it is commonly difficult to distinguish between pyroclastic, mixed pyroclastic-epiclastic, and epiclastic rocks. Unit 1g represents mafic volcaniclastic rocks containing coarse, angular to sub-angular fragments. This unit is locally transitional into, and commonly interbedded with tuffaceous conglomeratic units (unit 3f, 3g) of the Grimsthorpe Group (unit 3f, 3g).

A distinctive unit found only in the Grimsthorpe Group metavolcanic rocks is unit 1c, which consists of microfractured to microbrecciated, fine-grained, dark green to black weathering, amphibolite (Photo 2). Similar rocks are present in the Elzevir area to the south (Easton unpublished data, Di Prisco 1989). The origin of these rocks is uncertain. In some outcrops, these rocks have textures similar to ball and pillow structures found in sandstones (Photo 2a, 2c). Roep and Everts (1992) have recently described pillow-bed structure in water-laden metasediments resulting from seismic reworking of sedimentary material. The textures that they describe resemble some, but not all, of the structures seen within unit 1c. In other outcrops, there is a similarity to hyaloclastite and pillow breccia debris (Photo 2b), although distinct pillow fragments cannot be recognized. In most outcrops however, the texture appears to be one of internal brecciation either during or after emplacement, and, as such, does not represent a pyroclastic, hyaloclastic, or volcaniclastic origin.

In thin section, the mafic metavolcanic rocks are characterized by hornblende-plagioclase-actinolite assemblages with minor epidote and oxides. Plagioclase is typically oligoclase in composition. Grain boundaries are typically diffuse, with amphibole forming radiating fan-shaped aggregates, and feldspar has been uniformaly

recrystallized into fine-grained aggregates. This is especially evident in feldspar porphyritic rocks. In contrast, most Grimsthorpe group rocks are characterized by fine- to medium-grained, euhedral hornblende and plagioclase, and it is possible to distinguish between rocks of the Canniff Complex and the Grimsthorpe Group on a textural basis.

Garnet is not a typical consistuent of the metavolcanic sequence, and few garnetifierous amphibolites were observed in the field. In thin section, a few basalt samples contain relict garnet crystals, now partially altered to oxide-red biotite-actinolite aggregates.

Altered equivalents of the mafic metavolcanic occur in three main forms. These include very thinly layered, very fine-grained, pale green, mylonites (unit 1m) derived from unit 1 rocks and which are most commonly found along the Partridge Creek shear zone; unit 1 rocks cut by ferroan dolomite veins (unit 1s), which occur most commonly along east-trending, late faults within the map area (*e.g.* along the western Skootamatta Road); and albitized and silicified rocks of units 1 and 3 (unit 1z) (Photo 3) present north of Partridge Creek (alteration zone shown in Figure 4 and on Map).

TABLE 3: Stratigraphic Usage in the Grimsthorpe Domain, Elzevir Terrane. Units listed in approximate stratigraphic order from oldest to youngest. From Easton (1992a).

Grimsthorpe Group intruded by *ca.* 1270 Ma and younger plutons.

Grimsthorpe Group (new term) - Metasediments derived from mafic volcanic and gabbroic source region, minor metabasalt flows. Matrix- and clast-supported metaconglomerate, gabbro cobble metaconglomerate, meta-arenite, metawacke, minor metasiltstone, metapelite, rusty schists. Minor pillowed and massive tholeiitic metabasalt flows. Named for Grimsthorpe Township, where the unit is well exposed at low metamorphic grade and where most lithologic types within the unit are exposed. Type areas are: (1) the islands in the east-central part of Lingham Lake; (2) along the forest access road located between the Skootamatta Road and Lingham Lake; and (3) along the Skootamatta Road between Killer Creek and Partridge Creek.

unconformity?

Canniff Complex (new term) - Massive and pillowed tholeiitic metabasalts, spilitic metabasalts; protomylonitic metagabbro and metaperidotite. Ultramafic rocks commonly altered to talc+/-anthophyllite+/-actinolite rocks. (Note: Kaladar Complex of Chappell (1978) included elements of the Canniff Complex, Grimsthorpe Group and Older Gabbro Suite metagabbros - detailed subdivision into component elements is preferred to use of the term Kaladar Complex). Named for Canniff Creek along which gabbroic members of the unit are well exposed. Type areas are: (1) the area east of the Canniff Tonalite along Canniff Creek, (2) the area between the southern lobe of the Weslemkoon Tonalite and the Canniff Tonalite, and (3) the northeast shore of Lingham Lake.

In thin section, many of the altered mafic metavolcanic rocks, and mafic metasedimentary rocks of the Grimsthorpe Group contain secondary, red biotite crystals and phenocrysts. Secondary red biotite is also common within the Partridge Creek alteration zone and in the vicinity of the United Reef Petroleums gold property.

Geochemistry of the Mafic Metavolcanic Rocks

Figures 7-10 and Table 4 present geochemical data on metavolcanic rocks of unit 1. The dataset utilized includes samples collected by the authors, samples collected by G. Di Prisco from the Elzevir area due south of the Grimsthorpe area, and data from Chappell's (1978) Ph.D. thesis, as outlined in Table 4. All are tholeiitic basalts, and no geochemical distinction can be made between mafic metavolcanic rocks of the Canniff Complex and Grimsthorpe Group given the current, small, dataset and the tight clustering of the data. The only sample that is distinct is a sample from Pringle Lake collected by Ayer (1979), which in the field can be seen to be strongly epidotized. Trace element data is summarized in Figures 8 and 9. The Pearce and Cann plot (Figure 7) shows a tight clustering of the data, with all points plotting in the ocean-floor basalt field. The Ti *versus* V plot (Figure 9) also shows a tight clustering of the data in the ocean-floor basalt field. Figure 10 is a spidergram plot normalized to primitive mantle. Most elemental abundances are roughly 10 times primitive mantle abundances, as would be expected for oceanic basalts.

Figure 7: A) AFM plot of metavolcanic rocks from the Grimsthorpe area. B) Jensen plot of metavolcanic rocks from the Grimsthorpe area. Both figures includes data from Table 4 as well as from the OGS PETROCH database and Ayer (1979).

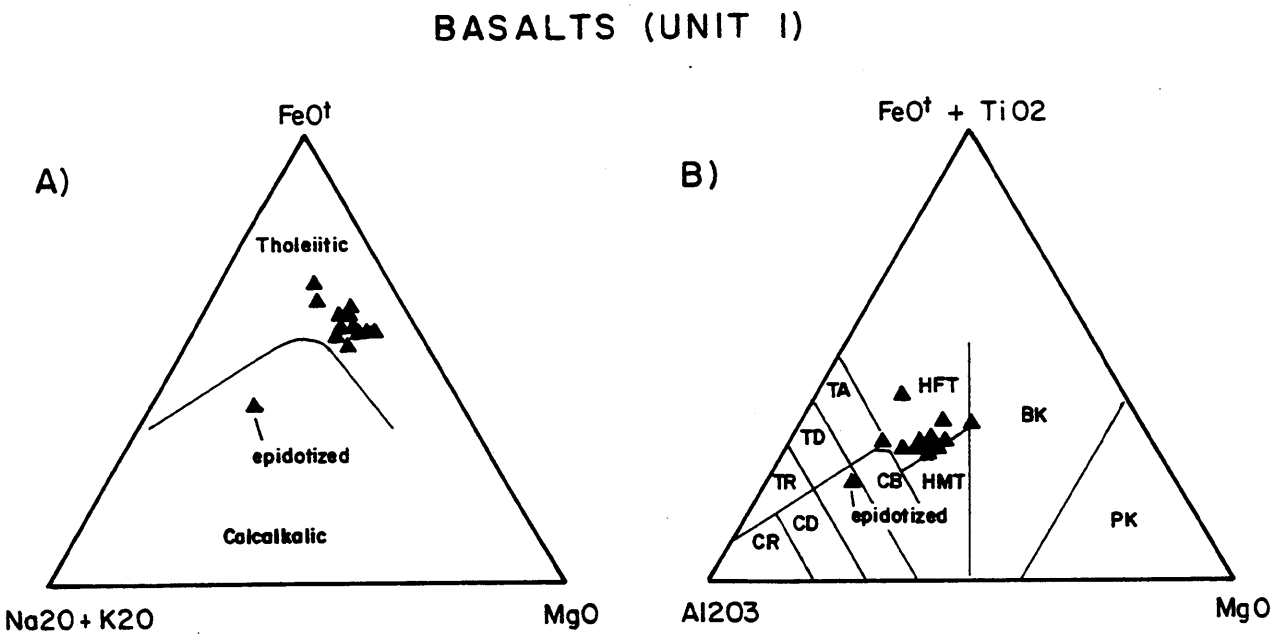
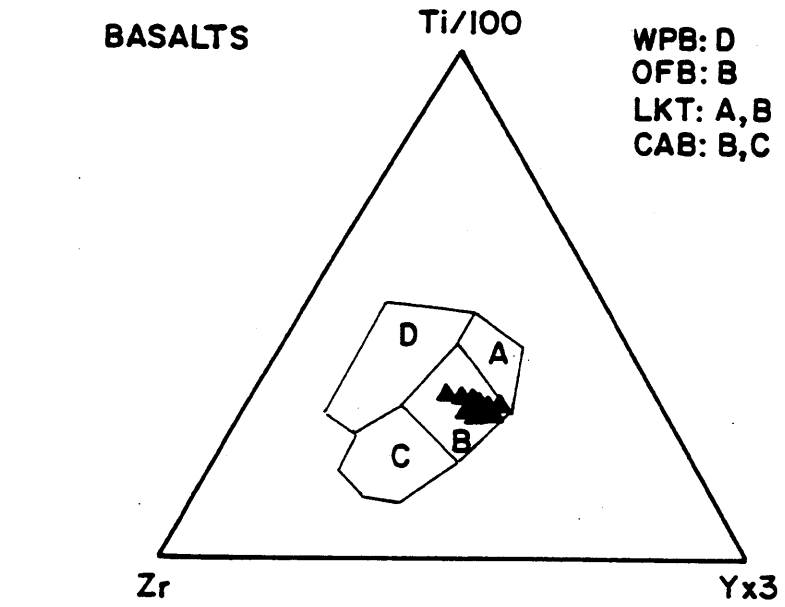
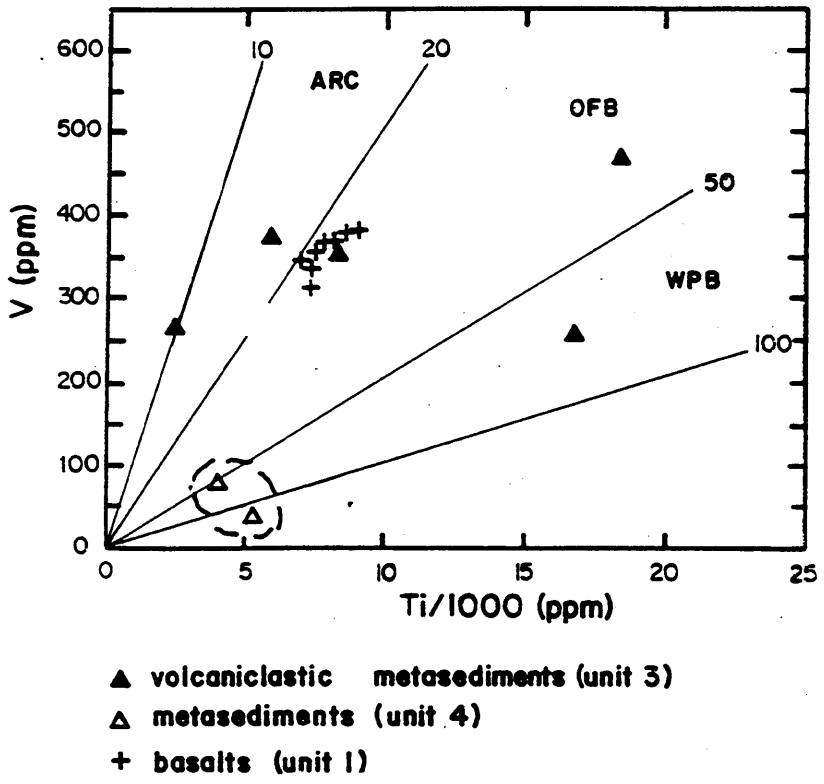


Figure 8: Pearce and Cann (1973) plot for mafic metavolcanic rocks from the Grimsthorpe area. Note tight clustering of data in the ocean-floor basalt field.





▲ **volcaniclastic metasediments (unit 3)**

△ **metasediments (unit 4)**

\+ **basalts (unit 1)**

Figure 9: Ti versus V plot after Shervais (1982) for mafic metavolcanic and metasedimentary rocks from the Grimsthorpe Domain. Basalts cluster closely together in the oceanic basalt field. Volcaniclastic metasediments show a wider range of compositions, reflecting differences in provenance, although V contents suggest mafic source regions (note more aluminous unit 4 metasediments have low V contents). Abbreviations: OFB = ocean-floor basalts; WPB = within-plate basalts.

Figure 10: Spidergram plot normalized to primitive mantle of mafic metavolcanic rocks from the Grimsthorpe area. Note tight clustering of data. Field of seven samples from the Elzevir area is shown by pattern and overlaps the range of Grimsthorpe area samples.

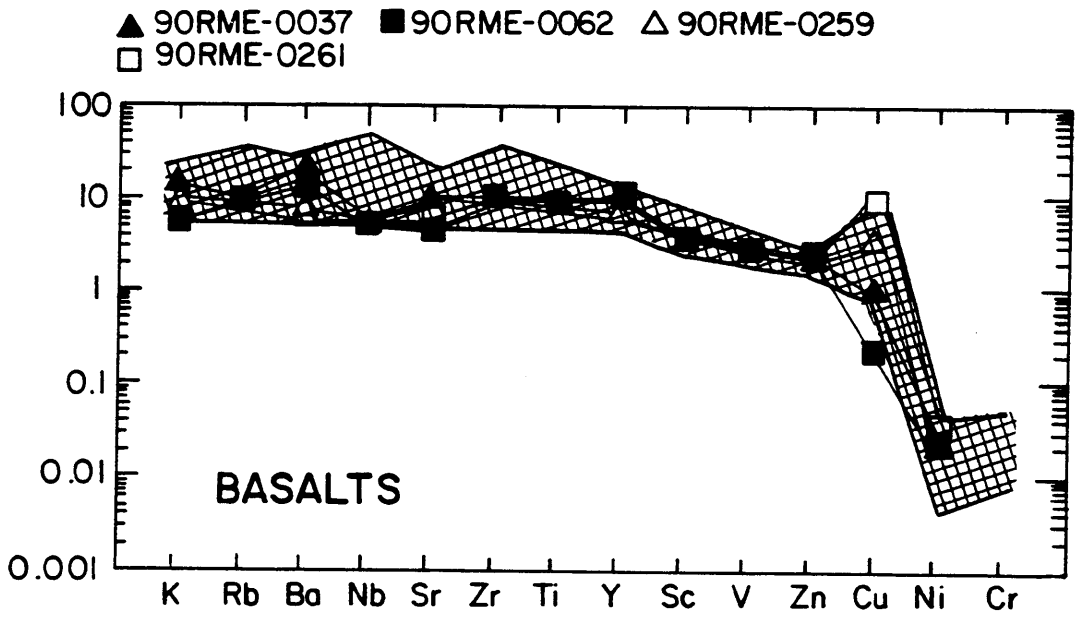


TABLE 4: Chemical analyses of metavolcanic rocks from the Grimsthorpe and Elzevir areas.

wt%.	1	2	3	4	5	6
SiO_2	48.08	48.99	48.82	47.63	54.60	48.40
TiO_2	1.39	1.48	1.36	1.26	0.53	1.14
Al_2O_3	14.17	13.59	13.60	14.73	15.03	16.10
Fe_2O_3	2.75	2.17	1.96	3.54	1.20	1.10
FeO	10.24	12.11	11.08	9.11	11.70	11.90
MgO	6.94	8.13	6.16	7.38	4.16	5.91
MnO	0.24	0.24	0.18	0.20	0.23	0.18
CaO	10.61	7.93	10.45	10.24	7.56	8.11
Na_2O	2.38	2.83	2.26	2.12	2.91	2.63
K_2O	0.28	0.12	0.21	0.15	0.36	0.18
P_2O_5	0.12	0.12	0.10	0.10	0.05	0.10
CO_2	0.96	0.14	0.81	0.43	0.15	0.63
S	0.04	0.00	0.06	0.20	0.11	0.10
H_2O^+	1.47	1.73	ND	ND	1.27	1.73
H_2O-	0.08	0.15	ND	ND	0.07	0.12
LOI	1.40	0.80	1.10	1.20	0.50	1.40
Total	99.75	99.73	97.05	97.09	100.20	98.40
Mg#	49.31	50.74	46.08	51.66	36.71	44.97
Density	ND	ND	ND	ND	2.98	2.99
Ba	107	67	47	30	ND	ND
Be	<1	<1	<1	<1	<1	<1
Co	47	46	42	44	39	40
Cr	ND	ND	ND	ND	ND	
Cu	29	6	96	240	91	65
Mo	<10	<10	<10	<10	<10	<10
Nb	3	3	3	3	<3	<3
Ni	47	69	60	67	10	37
Rb	<5	<5	<5	6	9	6
Sc	50	46	44	40	43	46
Sr	174	79	186	133	88	332
Th	<10	<10	<10	<10	<10	<10
V	362	385	369	364	306	350
Y	34	40	27	25	15	26
Zn	107	136	97	93	94	120
Zr	85	89	89	82	29	72

ND = not determined, bd = below detection limits

Sample No.	Sample Location	Rock Type	Unit	Reference
1) 90RME-0037	303975E 4966760N	basalt	1c	this study
2) 90RME-0062	315200E 4965975N	pillow basalt	1b	this study
3) 90RME-0259	309895E 4963405N	basalt	1a	this study
4) 90RME-0261	309080E 4963805N	gabbro	5a to 1d	this study
5) 89GDP-0093	316150E 4936150N	basalt	1a	Di Prisco 1989
6) 89GDP-3389	308375E 4939690N	basalt	1a	Di Prisco 1989

TABLE 4: (continued)

wt%.	7	8	9	10	11	12	13
SiO_2	50.10	47.70	49.10	46.07	46.99	51.70	55.00
TiO_2	1.21	4.1	1.27	2.17	1.38	1.43	1.69
Al_2O_3	13.20	13.50	13.70	11.09	11.88	14.60	18.10
Fe_2O_3	1.30	1.20	1.00	3.58	3.62	ND	ND
FeO	11.10	13.80	13.10	11.51	11.67	12.20	7.44
MgO	7.40	4.02	6.88	9.10	6.77	6.25	3.76
MnO	0.21	0.14	0.24	0.23	0.24	0.23	0.07
CaO	9.29	7.78	8.77	9.47	11.59	9.65	5.98
Na_2O	3.06	3.14	3.44	2.10	2.28	3.09	4.66
K_2O	0.47	0.17	0.18	0.33	0.24	0.67	2.61
P_2O_5	0.10	0.43	0.09	0.22	0.22	0.14	0.51
CO_2	0.40	0.80	0.28	0.55	1.22	ND	ND
S	0.02	0.50	0.04	0.49	0.04	ND	ND
H_2O^+	1.40	1.40	1.30	ND	ND	ND	ND
H_2O-	0.08	0.09	0.07	ND	ND	ND	ND
LOI	0.80	1.10	0.40	ND	ND	ND	ND
Total	99.30	98.80	99.40	96.91	98.14	99.96	99.82
Mg#	51.80	32.50	46.99	52.40	44.70	47.72	47.38
Density	3.03	3.05	3.12	ND	ND	ND	ND
Ba	ND	ND	ND	85	72	ND	ND
Be	<1	<1	<1	ND	ND	ND	ND
Co	41	43	40	72	64	ND	ND
Cr	ND	ND	ND	149	37	ND	ND
Cu	20	260	26	91	21	ND	ND
Mo	<10	<10	<10	ND	ND	ND	ND
Nb	3	3	3	4	4	ND	ND
Ni	64	56	55	61	27	ND	ND
Rb	18	9	<5	6	<5	ND	ND
Sc	45	29	49	ND	ND	ND	ND
Sr	145	294	47	125	193	ND	ND
Th	<10	<10	<10	ND	ND	ND	ND
V	20	260	26	91	21	ND	ND
Y	31	43	38	54	29	ND	ND
Zn	162	125	130	130	116	ND	ND
Zr	73	341	77	144	39	ND	ND

ND = not determined, bd = below detection limits

Sample No.	Sample Location	Rock Type	Unit	Reference
7) 89GDP-3613	319220E 4944870N	basalt	1a	Di Prisco 1989
8) 89GDP-3734	302550E 4949450N	basalt	1a	Di Prisco 1989
9) 89GDP-3750	310155E 4957390N	basalt	1a	Di Prisco 1989
10) C74-111		amphibolite	1a	Chappell 1978
11) C74-226		amphibolite	1a	Chappell 1978
12) JA-40		basalt	1a	Ayer 1979
13) JA-48		epidotized basalt	1z	Ayer 1979

Mafic to Ultramafic Intrusive Rocks (unit 2)

Unit 2 consists of gabbroic and talcose rocks, the later probably representing ultramafic intrusive phases that have subsequently been altered to actinolite, anthophyllite and talc. These gabbroic rocks occur in a similar setting to the mafic metavolcanic rocks described above, namely, adjacent to the margins of the tonalite intrusions found throughout the map area. The bulk of the exposed area of these rocks consists of a distinctive, protomylonitic, medium-grained gabbro (unit 2a) (Photo 4a, 4b, 4c). This unit is also common in the Elzevir area to the south (Di Prisco 1989), where it occurs in a similar stratigraphic and structural setting.

Photo 4 illustrates some important features of this gabbroic unit. The unit is homogeneous over large outcrop areas. Photo 4a is from an outcrop within the Elzevir area, some 25 km south of the map area, but is representative of most 2a outcrops within the Grimsthorpe area. Photo 4b shows a fine-grained mafic dike injected into unit 2 gabbros. This mafic dikes is similar to mafic dikes (unit 5) that cross-cut the Grimsthorpe Group and establishes that unit 2 gabbros are among the oldest rocks in the area. Photo 4c illustrates a more intensely deformed unit 2 gabbro, however, the distinctive interlocking amphibole and feldspar texture of the unit is still present (compare Photo 4a and 4c). Finally, 4d shows a sharp, possibly unconformable contact, between unit 2 metagabbro (left) and gabbro-cobble-bearing tuffaceous metaconglomerate of the Grimsthorpe Group (unit 3g). The contact is indicated by an arrow, lying under the centre of the hammer handle. No shearing is present in the conglomerate at this locality, nor is a fine-grained chill margin present in the gabbro. As a consequence, at this locality, a tectonic contact is not suspected.

Photo 5 illustrates additional relationships relevant to understanding the age relationships of the metagabbroic rocks of the Canniff Complex. Photo 5b shows typical unit 2 metagabbro grading upward in undeformed tuffaceous metaconglomerate of unit 3g. The conglomerate itself shows no apparent deformation, in contrast to the protomylonitic character of unit 2. In addition, it appears that weathering along shear bands within the gabbro is responsible for the disaggregation of the gabbro into subround cobbles which are then incorporated into the conglomerate. The outcrop shown in Photo 5b is therefore interpreted as an unconformity, in part preserving a paleosol developed on unit 2 metagabbro, and indicating that deformation of the metagabbro mainly occurred before conglomerate deposition. Evidence for this latter relationship is also illustrated in Photo 5d, where a clast showing a shear band is preserved in the conglomerate. It should be noted that the weathering process shown in Photo 5b would make such clasts uncommon. Gabbro clast conglomerates are most abundant adjacent to outcrop areas of unit 2, with the highest gabbro clast proportions (up to 75%) found immediately adjacent to unit 2 outcrops. Where contacts have been observed, they typically resemble that shown in Photo 5b. An alternative explanation to the texture shown in Photo 5b is that we are seeing a peperite which formed by intrusion of gabbro into wet-sediment, with resultant stream explosions serving to fragment the

contact margin of the gabbro. In most instances, this scenario is not favoured, because of the lack of any apparent chilling of the gabbro, the lack of angular fragments, and the discrepancy in degree of deformation present in the gabbro and the conglomerates. In the Lingham Lake area, peperites may occur, however they seem to be the result of younger gabbros (unit 5) intruding the Grimsthorpe Group.

Found in association with the gabbroic unit, but rarely seen in direct contact, are massive to schistose, brown-red talcose rocks, with varied amounts of hematite, magnetite, carbonate, chlorite, serpentine (unit 2s) and massive to schistose, soft, pitted weathered surface, green-grey to white talcose rocks, with minor carbonate, chlorite, serpentine derived from mafic intrusions (unit 2t). LeBaron and van Haaften (1989) suggested that unit 2s was transitional into unit 2t, with the more promising talc prospects consisting mainly of unit 2t. In association with these talcose rocks are a variety of ultramafic rocks, consisting of mixtures of anthophyllite-amphibole-plagioclase and talc and actinolite-carbonate-talc rocks. In some outcrops, the talc occurs as veinlets cutting more massive actinolite-talc-carbonate rocks. Contact relations between the talcose rocks and the protomylonitic gabbros are not well exposed, nevertheless, there is a spatial relationship between unit 2 gabbros, talcose rocks, and gabbro-clast tuffaceous conglomerates (unit 3g). Although the talc appears to mainly occur in ultramafic pods hosted in unit 2 metagabbroic rocks, analagous to the sporadic distribution of hornblendite pods in the better preserved Killer Creek Gabbro, at one locality, talcose clasts are present in metaconglomerate. It could not be determined if these clasts were detrital, or whether they represented *in-situ* alteration of ultramafic cobbles in the conglomerate.

In thin-section, Canniff Complex gabbroic rocks show the same mineralogy and textures as the mafic metavolcanic rocks, namely medium- to coarse-grained aggegrates of hornblendle-plagioclase (typically oligioclase)-actinolite with minor epidote and oxides. Grain boundaries are typically diffuse, with amphibole forming radiating fan-shaped aggregates, and feldspar has been uniformaly recrystallized into fine-grained aggregates. This is especially evident in feldspar porphyritic rocks. These textures are also preserved in gabbroic clasts present within the Grimsthorpe Group rocks, which in thin-section are texturally and mineralogically distinct from the matrix. This textural evidence suggests that the Canniff Complex may have undergone a metamorphic episode distinct from that experienced from the Grimsthorpe Group, and that the textures produced during this earlier metamorphism may be partially preserved.

Geochemistry of the Mafic to Ultramafic Intrusive Rocks

Figures 11-18 and Table 5 present geochemical data on mafic intrusive rocks of unit 2. The dataset utilized herein includes samples collected by the authors, samples collected by G. Di Prisco from the Elzevir area due south of the Grimsthorpe area, and data from Chappell's (1978) Ph.D. thesis, as outlined in Table 5. All are tholeiitic in composition, ranging from ultramafic to gabbroic compositions. Also shown on Figures

11-18 are samples of the Killer Creek Gabbro for comparison. The Killer Creek Gabbro is slightly more calcalkalic in composition, and has much higher abundances of TiO_2 and P_2O_5. As shown in Figure 11a and 12a, the AFM plots, the unit 2 gabbros show a differentiation trend from high Mg to high Fe contents, with little increase in alkalis. In addition, the higher-Fe members of the unit 2 gabbros overlap with the tholeiitic basalt field for metavolcanics from the Grimsthorpe domain. On the other hand, the Killer Creek Gabbro (unit 7) shows two differentiation trends, a high-Mg to high-Fe trend (hornblendite to gabbro) and an alkaline enrichment trend (gabbro to anorthosite) (Figure 11b). Unit 2 and Killer Creek gabbros are also distinct on Jensen plots (Figure 9b and 12b), with the Killer Creek gabbros having higher Fe/Ti contents (excepting the anorthosites). Killer Creek gabbros (unit 7) also show a more extensive range of composition than do the unit 2 gabbros (Figure 11a, 11b). This could be a sampling artifact, as LeBaron and van Haaften (1989) show a wide range of composition in their plots. However, the dataset used by LeBaron and van Haaften includes volcanic and gabbroic rocks, thus, direct comparison with their study is not possible. Other gabbroic rocks from the Grimsthorpe area (unit 5) are compared with unit 2 gabbros in Figure 11. These rocks appear most similar to the Killer Creek gabbros.

The distinction between the two gabbros is well illustrated by the FeO + MgO *versus* FeO/MgO plot shown in Figure 13. This plot is useful for determining fractionation trends in basaltic rocks, and illustrates that the Killer Creek Gabbro followed a different fractional crystallization path. On the other hand, the plot shows that the Canniff Complex metagabbros and mafic metavolcanics may be genetically related.

Trace element plots (Figures 14-16) also highlight the distinctive nature of the Canniff Complex metagabbros and their possible affinity with the mafic metavolcanic rocks. Again, the Killer Creek Gabbro is clearly distinct. Figure 17 shows that the Killer Creek Gabbro has much higher TiO_2 contents than the Canniff Complex metagabbros. Higher TiO_2 contents are more typical of arc-derived gabbroic rocks (Middlemost 1985). In summary, geochemistry supports a distinction between units 2 and 7, and confirms field evidence that the protomylonitic gabbros of unit 2 are not simply more deformed and altered equivalents of units 5 or 7.

As shown in Figure 11b and 12b, most samples of unit 2 plot in the high magnesium tholeiite field on a Jensen plot, with talcose samples falling in the ultramafic komatiite field, as noted by Lebaron and van Haaften (1989). LeBaron *et al.* (1987), Lebaron (1988), and LeBaron and van Haaften (1989) have argued, primarily on geochemical grounds, that rocks of the Canniff Group represent a komatiite sucession lying at the base of, and intercalated with, tholeiitic lavas of the Grenville Supergroup (*i.e.* Tudor Formation metavolcanics). The unit 2 samples collected by the author, by Di Prisco, and LeBaron, are however, all poor in Cr and Ni compared to typical komatiites. One problem with the samples of LeBaron and van Haaften (1989) is that all contain over 10% loss on ignition, and as a consequence, the reliability of the Grenville data is poor.

In an attempt to circumvent this problem, correspondence analysis was used to compare the samples collected by Lebaron and van Haaften (1989) to samples in the OGS komatiite database (Howe *et al.* 1987). Using such analysis, the effects of alteration can be compensated for to some degree, and if the Grenville rocks were komatiites, this should be detected. The details of this statistical treatment are described in Grunsky *et al.* (1987, 1992) and Easton *et al.* (1988). Results are illustrated in Figure 18 and Tables 6 and 7. As noted in Table 6, the 100 samples of LeBaron and van Haaften (1989) fall into 8 groups, of which 3 account for 72% of the samples. Figure 18a shows the chemical variation of these three groups. Group 1 consists of talcose samples with MgO and LOI controlling the chemical variation; Group 2 consists of Canniff Complex metagabbros, with Ca controlling chemical variation, and Group 3 consists of metavolcanic rocks and Grimsthorpe Group volcaniclastic metasediments, with Na and Ti controlling the chemical variation. Table 7 shows the close correspondence between the group means and representative samples from the Grimsthorpe area. The results of this analyses showed no correlation between samples in the komatiite database and the Grenville samples. This is shown clearly in Figure 18b, where there is little overlap between the field of Archean komatiites (including high Mg and high Fe types) and talcose rocks from the Grimsthorpe Domain. This suggests that these rocks are not komatiites, although they are undoubtedly ultramafic in composition. In Figure 18b and 18c, Canniff Complex and Grimsthorpe Group volcaniclastic metasediments plot as one group, overlapping the field of Archean tholeiites. There is a trend toward high Ti contents in the Grenville samples, probably a reflection of the fact that the group includes meta-igneous and metasedimentary rocks.

In summary, although unit 2 consists of mafic and ultramafic rocks, some of which are extensively altered to talc, our field observations and geochemical studies suggest that unit 2 represents only intrusive rocks, and does not include komatiites.

Figure 11: A) AFM plot of metagabbroic rocks from the Canniff Complex (unit 2). Extent of Grimsthorpe Domain metabasalts is shown for comparison. Note iron-enrichment trend present in the Canniff Complex metagabbros. B) Jensen plot of metagabbroic rocks from the Canniff Complex and Grimsthorpe Domain metabasalts. Both figures include data from Table 5 as well as from the OGS PETROCH database and Ayer (1979).

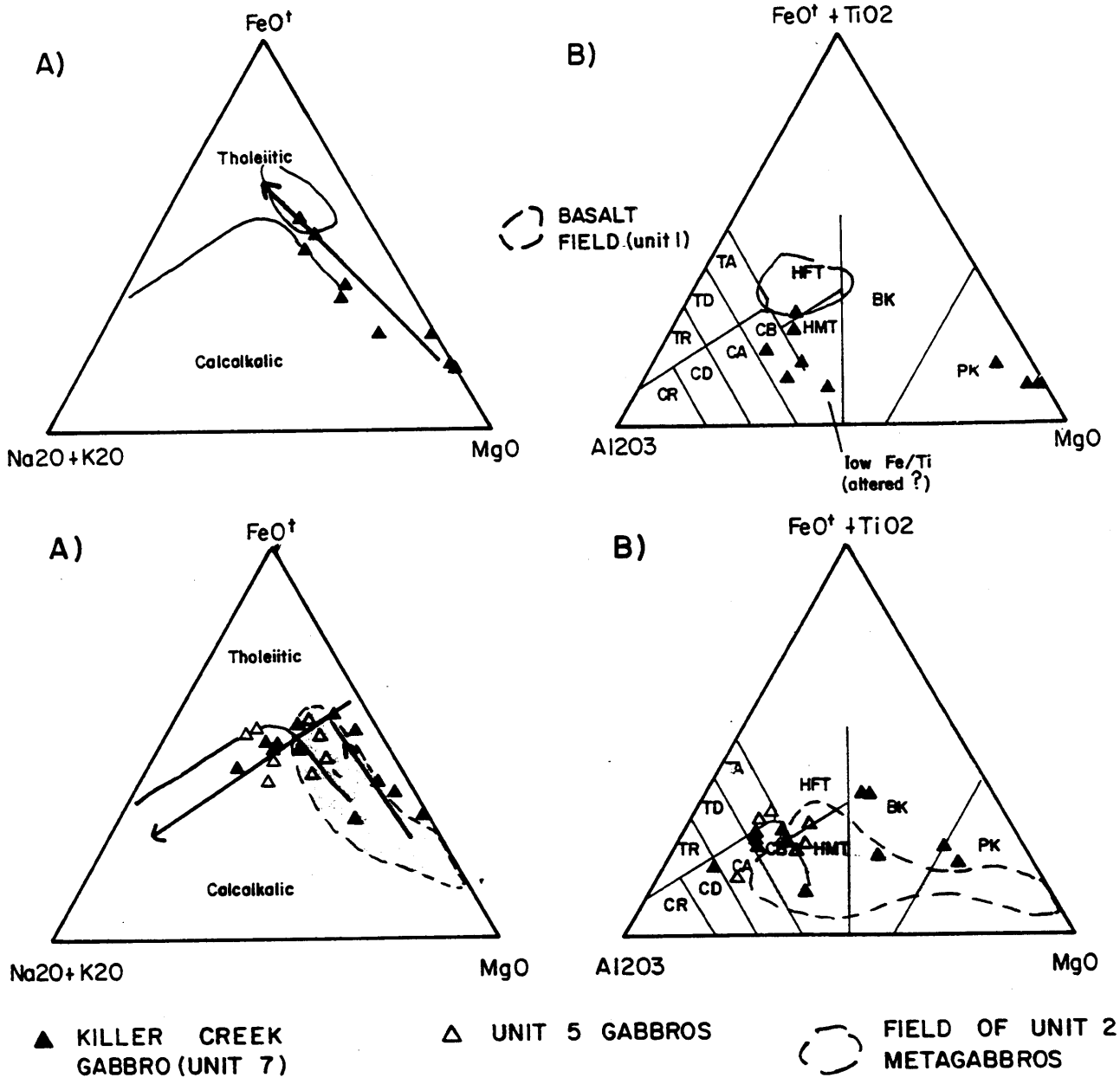


Figure 12: A) AFM plot of metagabbroic rocks from the Grimsthorpe area. Note strong iron-enrichment trend in Canniff Complex (unit 2) metagabbros. B) Jensen plot of metagabbroic rocks from the Grimsthorpe area. Note generally high Fe-Ti values for the Killer Creek Gabbro samples. Both figures include data from Table 5 as well as from the OGS PETROCH database and Ayer (1979).

Figure 13: FeO + MgO versus FeO/Mgo plot (after Macdonald and Katsura 1964) of metagabbroic rocks from the Canniff Complex (unit 2) and the Killer Creek Gabbro (unit 7) and mafic metavolcanic rocks (unit 1). Note unit 2 gabbros show fractination trend dominanted by olivine precipitation in the initial stages, and plagioclase, olivine and clinopyroxene in the latter stages. Mafic metavolcanic rocks show plagioclase-dominated fractination, as would be expected from oceanic basalts. The Killer Creek Gabbro shows a very different fractination trend, probably the result of plagioclase and clinopyroxene fractination throughout its evolution. The significantly different trends suggest the unit 2 and unit 7 gabbros developed from distinct magma sources.

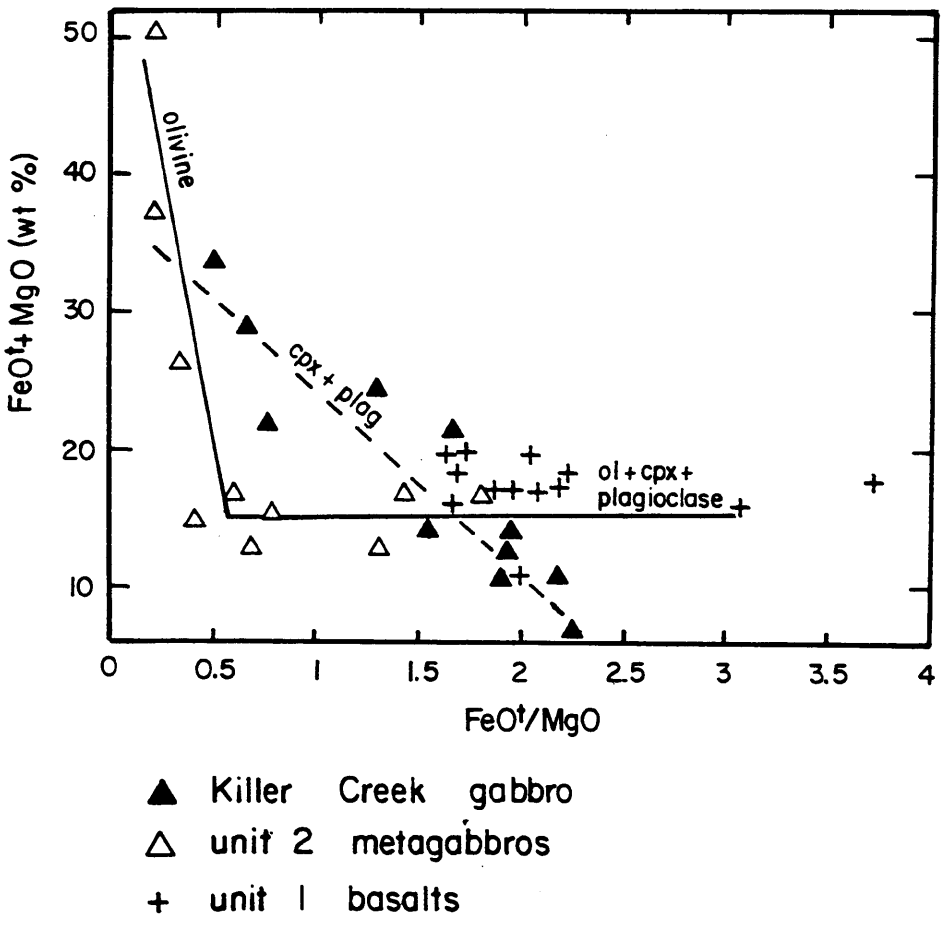


Figure 14: Pearce and Cann (1973) plot for metagabbroic rocks from the Grimsthorpe area. Note clustering of Canniff Complex (unit 2) metagabbros in the ocean-floor basalt field. Killer Creek Gabbros show a wider dispersion indicating an extensive fractional crystallization history. Note, plot was originally developed for basalt classification. As the gabbos have had a varied fractional crystillization history, tectonic classification using this plot is problematical.

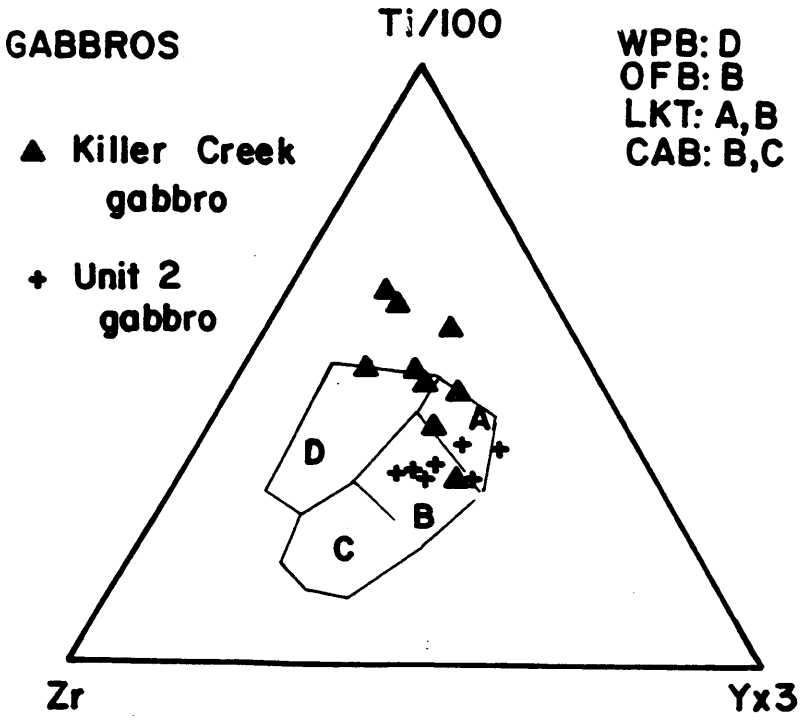


Figure 15: Ti versus V plot after Shervais (1982) for metagabbroic rocks from the Grimsthorpe area. Note clustering of Canniff Complex (unit 2) metagabbros in the ocean-floor basalt field and overlap with basalt field. Killer Creek Gabbros show a different pattern, with hornblendites having the highest Ti contents. Note, plot was originally developed for basalt classification. As the gabbros have had a varied fractional crystallization history, tectonic classification using this plot is problematical.

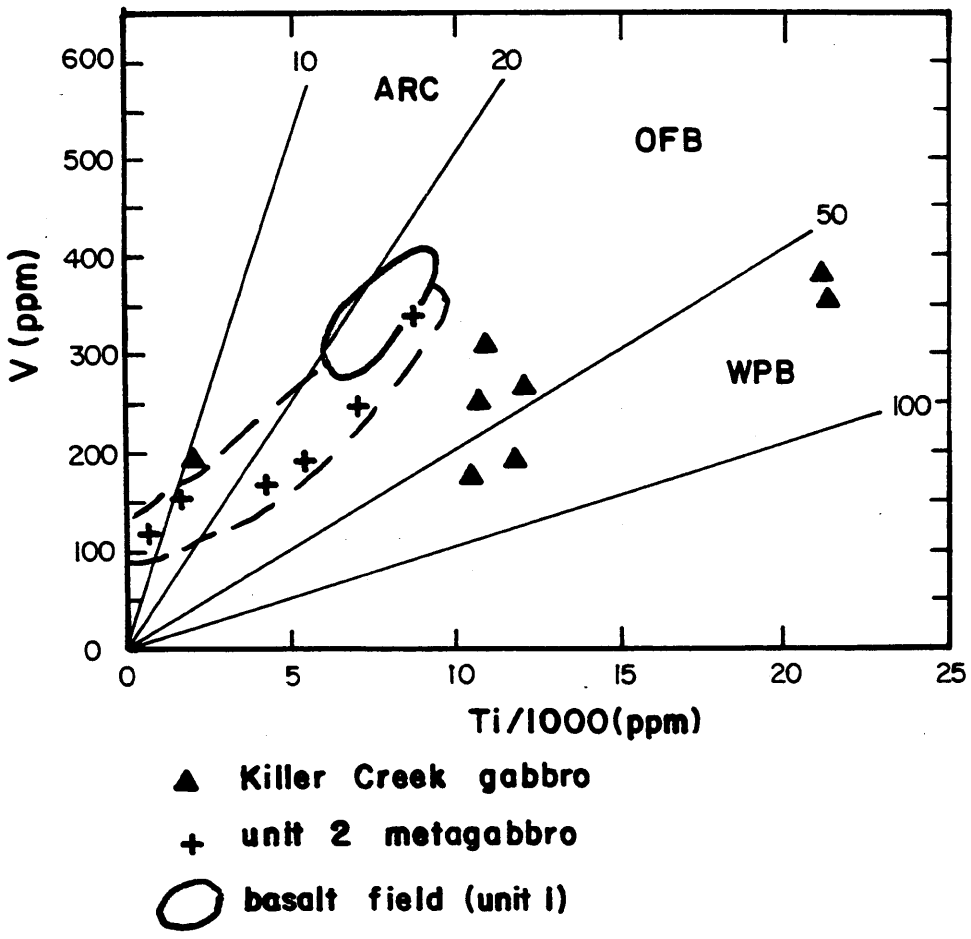


Figure 16: Spidergram plot normalized to primitive mantle for metagabbroic rocks from the Grimsthorpe area. The fields overlap slightly, however, Canniff Complex (unit 2) metagabbros have a distinctive depleted Zr-Ti-Y signature relative to the Killer Creek Gabbro (unit 7).

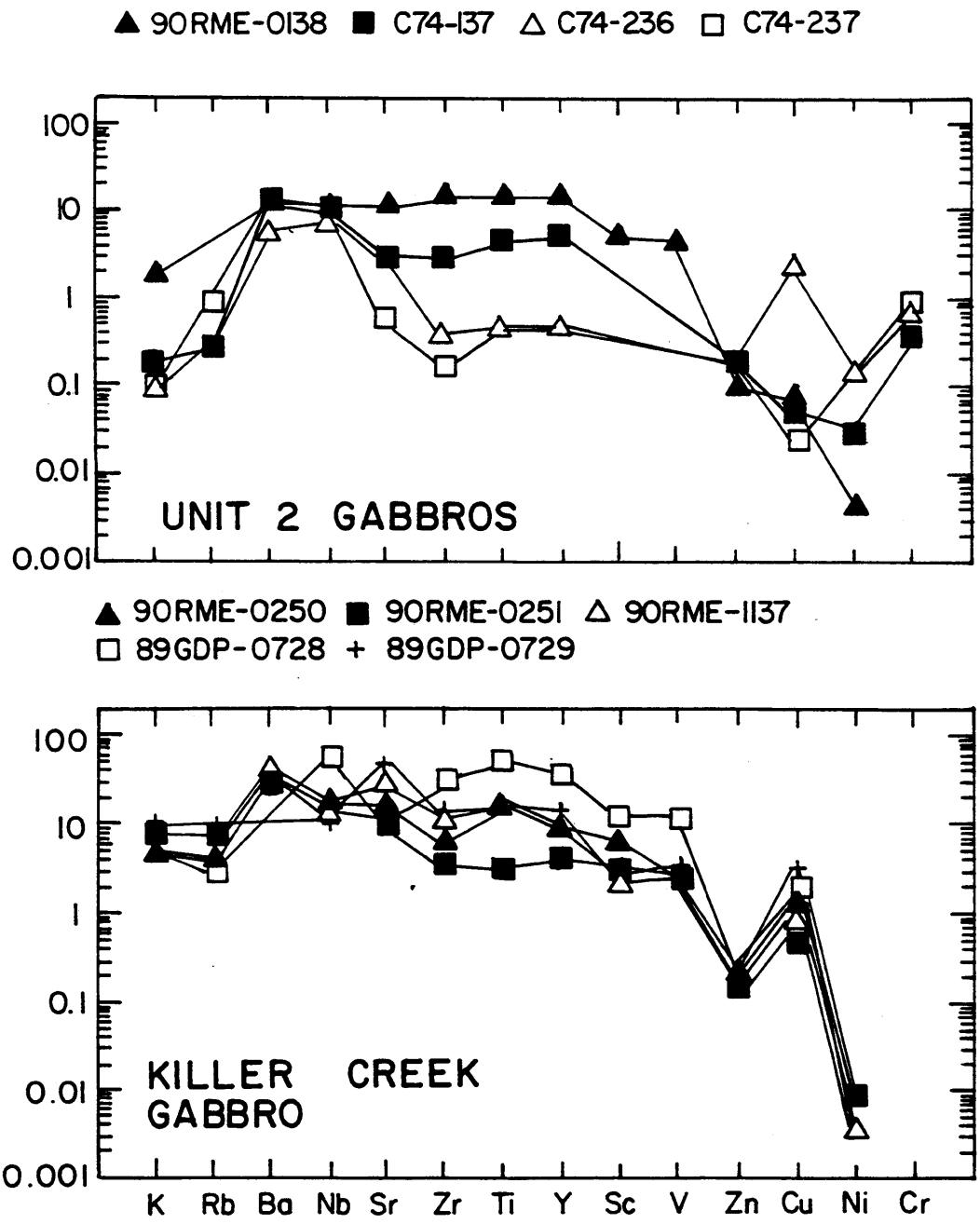


Figure 17: TiO2 versus SiO2 plot for metagabbroic rocks from the Grimsthorpe area. Note clustering of unit 2 metagabbros (patterned area) and generally higher Ti contents of Killer Creek and unit 5 gabbros. Overlap between Canniff Complex (unit 2) metagabbros and Killer Creek Gabbro (unit 7) fields reflects the presence of anorthositic rocks within the Killer Creek Gabbro. No overlap would occur if the anorthosites were omitted from the plot.

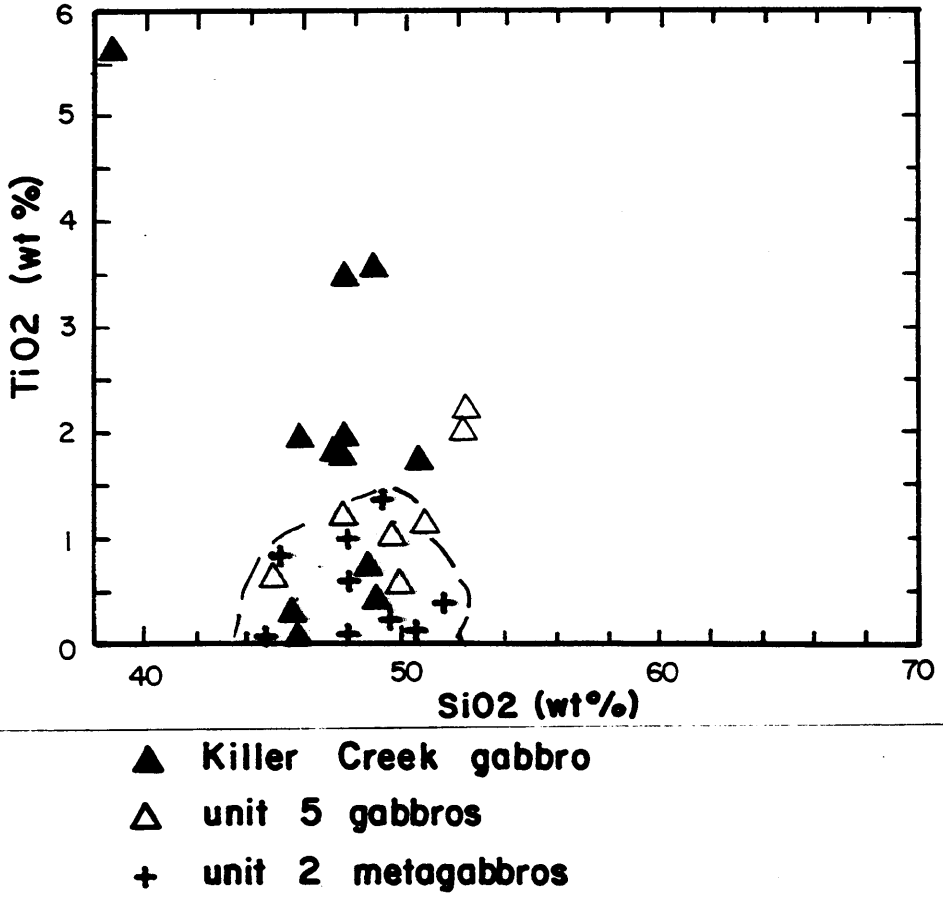


Figure 18: (page 42) Results of correspondence analysis of 100 samples of the "Tudor Formation" reported in LeBaron and van Haaften (1989). Dataset includes mafic metavolcanics, Canniff Complex metagabbros, talcose rocks, and Grimsthorpe Group volcaniclastic metasediments.
A) Projection of sample and variable scores of F3 and F1 factor planes from correspondence analysis of 100 "Tudor Formation" samples. All groups are listed in Table 6. Only 3 main groups are illustrated here for clarity.
B) Projection of sample and variable scores of F3 and F1 factor planes from correspondence analysis of 100 "Tudor Formation" samples and 600 Archean tholeiite, komatiite and calc-alkalic volcanic samples, showing comparison with Archean komatiites. Note that Grimsthorpe Domain talcose samples do not overlap Archean komatiite field. Groups 2 and 3 in Figure 11a fall plot as one group in this representation.
C) Projection of sample and variable scores of F3 and F1 factor planes from correspondence analysis of 100 "Tudor Formation" samples and 600 Archean tholeiite, komatiite and calc-alkalic volcanic samples, showing comparison with Archean tholeiites. Groups 2 and 3 in Figure 11a fall plot as one group in this representation. Trend toward high Ti contents in Grimsthorpe Domain samples may reflect presence of volcaniclastic metasediments in this group.

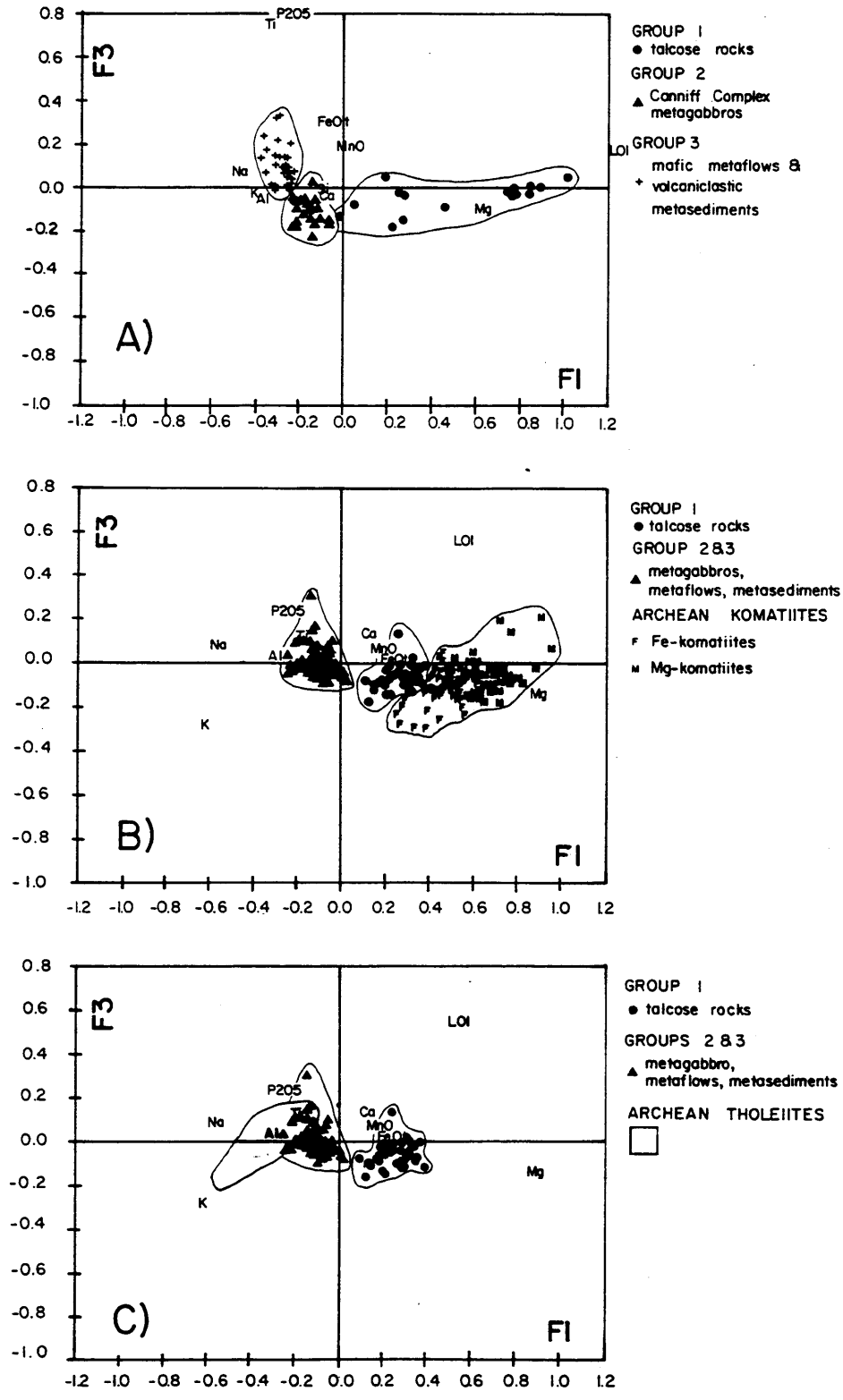

A)
F3
F1
P2O5
Ti
FeOt
MnO
LOI
Na
K
Al
Ca
Mg
GROUP 1
talcose rocks
GROUP 2
Canniff Complex metagabbros
GROUP 3
mafic metaflows & volcaniclastic metasediments
B)
F3
F1
LOI
P2O5
Na
K
Al
Ca
MnO
FeOt
Mg
GROUP 1
talcose rocks
GROUP 2&3
metagabbros, metaflows, metasediments
ARCHEAN KOMATIITES
Fe-komatiites
Mg-komatiites
C)
F3
F1
LOI
P2O5
Na
K
Al
Ca
MnO
FeOt
Mg
GROUP 1
talcose rocks
GROUPS 2&3
metagabbro, metaflows, metasediments
ARCHEAN THOLEIITES

TABLE 5: Chemical analyses of metagabbroic rocks (unit 2, 5 and 7) from the Grimsthorpe and Elzevir areas.

Canniff Complex (unit 2) Metagabbros

wt%.	1	2	3	4	5	6	7	8	9
SiO_2	50.34	49.79	48.88	51.78	51.33	49.98	53.78	54.02	44.60
TiO_2	1.48	0.96	1.19	0.08	0.26	0.73	0.50	0.06	0.05
Al_2O_3	15.43	19.68	17.08	16.44	18.56	18.01	3.09	0.89	2.38
Fe_2O_3	2.21	0.25	0.82	0.23	0.33	0.29	1.73	1.64	2.28
FeO	10.27	8.06	9.96	4.30	5.27	6.79	5.63	5.85	7.14
MgO	6.81	6.34	7.49	11.10	8.20	9.12	21.81	35.98	43.25
MnO	0.16	0.11	0.19	0.11	0.11	0.14	0.17	0.09	0.17
CaO	9.87	11.61	11.42	13.77	13.27	12.39	12.88	1.41	0.04
Na_2O	3.14	3.05	2.63	1.79	2.22	2.16	0.36	0.02	0.08
K_2O	0.18	0.09	0.23	0.41	0.45	0.38	0.02	0.01	0.01
P_2O_5	0.11	0.05	0.09	0.00	0.00	0.04	0.04	0.02	0.00
CO_2	0.18	3.89	0.79	0.87	0.71	0.58	1.20	2.52	0.00
S	0.01	0.01	0.11	0.12	0.02	0.01	0.02	0.24	0.21
H_2O^+	ND	4.03	2.06	1.88	1.35	1.79	2.64	8.64	ND
H_2O-	ND	0.14	0.11	0.10	0.07	0.09	ND	ND	ND
LOI	0.60	7.80	1.70	2.00	1.70	1.70	5.15	ND	ND
Total	98.07	98.50	100.20	100.30	98.60	98.50	99.83	100.11	100.11
Mg#	49.77	57.66	55.50	81.43	72.42	69.74	84.41	89.74	89.35
Density	2.68	2.92	2.82	2.92	2.94	2.98	2.72	2.75	2.87
Ba	43	ND	ND	ND	ND	ND	45	24	37
Be	1	<1	<1	<1	<1	<1	ND	ND	ND
Co	39	32	39	35	32	35	69	115	ND
Cr	ND	ND	ND	ND	ND	ND	1605	3524	3251
Cu	12	15	87	231	84	6	9	492	4
Mo	<10	<10	<10	<10	<10	<10	ND	ND	ND
Nb	<3	<3	<3	<3	<3	<3	4	3	4
Ni	68	39	49	121	127	111	492	2462	2341
Rb	<5	8	9	9	10	14	1	1	1
Sc	42	41	46	33	40	35	ND	ND	ND
Sr	136	217	207	109	166	177	33	43	7
Th	<10	<10	<10	<10	<10	<10	ND	ND	ND
V	353	217	258	124	163	179	ND	ND	ND
Y	33	19	25	<5	7	17	12	1	<1
Zn	37	73	83	34	45	59	93	79	83
Zr	82	65	72	9	13	46	17	2	1

ND = not determined, bd = below detection limits

Sample No.	Sample Location	Rock Type	Unit	Reference
1) 90RME-0138	310240E 4959460N	gabbro	2	this study
2) 89GDP-0452	304700E 4943470N	gabbro	2	Di Prisco 1989
3) 89GDP-0558	305390E 4942520N	gabbro	2	Di Prisco 1989
4) 89GDP-0671	306680E 4949425N	gabbro	2	Di Prisco 1989
5) 89GDP-3257	311865E 4939035N	gabbro	2	Di Prisco 1989
6) 89GDP-3698	310730E 4952550N	basalt	2	Di Prisco 1989
7) C74-137		actinolite schist	2	Chappell 1978
8) C74-236		talc schist	2	Chappell 1978
9) C74-237		serpentinite	2	Chappell 1978

TABLE 5 (continued): Killer Creek (unit 7) Metagabbros.

wt%.	10	11	12	13	14	15	16	17
SiO_2	47.36	48.78	47.70	50.52	45.89	45.64	47.57	38.60
TiO_2	1.83	3.59	3.53	1.77	1.98	0.34	2.00	5.66
Al_2O_3	17.73	18.76	18.72	21.69	10.25	12.21	17.69	10.30
Fe_2O_3	1.93	1.73	2.21	2.17	4.81	1.99	3.37	0.40
FeO	8.01	6.61	7.06	4.08	11.85	8.40	8.56	13.60
MgO	6.32	4.31	4.15	2.69	9.77	13.53	6.00	10.90
MnO	0.14	0.10	0.12	0.09	0.28	0.20	0.17	0.18
CaO	9.75	9.49	8.97	9.01	10.21	11.84	9.07	12.90
Na_2O	3.41	3.53	3.77	3.78	1.56	0.78	2.97	0.67
K_2O	0.53	0.68	0.88	1.14	0.47	0.82	0.55	0.48
P_2O_5	1.13	0.70	0.98	0.61	0.10	0.01	0.39	2.68
CO_2	0.06	0.28	0.12	0.36	0.10	1.01	0.18	0.40
S	0.01	0.01	0.02	0.01	0.06	0.04	0.01	0.03
H_2O^+	1.29	0.98	0.98	0.81	ND	ND	ND	2.44
H_2O-	0.14	0.07	0.08	0.11	ND	ND	ND	0.17
LOI	0.50	0.40	0.30	0.70	0.90	2.90	0.60	1.50
Total	99.64	99.62	99.29	98.84	97.33	96.81	98.53	99.40
Mg#	53.61	48.47	44.97	44.28	51.83	70.29	47.98	58.18
Density	2.66	2.62	2.63	2.55	2.77	2.74	2.67	3.22
Ba	206	263	293	354	114	108	152	ND
Be	<1	<1	<1	<1	<1	<1	<1	<1
Co	35	22	23	16	41	50	37	49
Cr	ND	ND	ND	ND	ND	ND	ND	ND
Cu	165	72	324	117	170	80	227	319
Mo	<10	<10	<10	<10	<10	<10	<10	<10
Nb	3	6	8	3	7	<3	6	21
Ni	70	44	65	27	146	144	64	166
Rb	11	12	21	27	15	23	14	11
Sc	20	25	21	13	56	28	21	101
Sr	546	555	609	633	193	120	368	120
Th	<10	<10	<10	<10	<10	<10	<10	<10
V	258	358	381	181	192	196	267	1080
Y	21	17	20	13	19	9	21	82
Zn	80	65	70	58	117	81	106	85
Zr	59	81	82	70	37	19	64	162

ND = not determined, bd = below detection limits

Sample No.	Sample Location	Rock Type	Unit	Reference
10) 90RME-0114	316900E 4967220N	gabbro	7g	this study
11) 90RME-0115	316940E 4967200N	gabbro	7a	this study
12) 90RME-0116	316975E 4967180N	gabbro	7a	this study
13) 90RME-0117	317090E 4966730N	anorthosite	7c	this study
14) 90RME-0250	318460E 4963825N	hornblendite	7h	this study
15) 90RME-0251	318465E 4963928N	hornblendite	7h	this study
16) 90RME-1137	316525E 4964048N	gabbro	7a	this study
17) 89GDP-0728	312720E 4956490N	hornblendite	7h	Di Prisco 1989

TABLE 5 (continued): Killer Creek (unit 7) Metagabbros.

wt%.	18	19	20	21
SiO_2	47.50	48.60	49.10	45.80
TiO_2	1.80	0.80	0.47	0.09
Al_2O_3	19.00	7.59	6.86	21.80
Fe_2O_3	0.42	ND	ND	ND
FeO	8.43	11.20	11.90	6.40
MgO	4.58	23.60	18.40	10.90
MnO	0.13	0.22	0.31	0.10
CaO	9.60	7.13	11.30	11.40
Na_2O	3.07	0.25	0.97	1.67
K_2O	1.10	0.03	0.31	1.62
P_2O_5	1.33	0.16	0.03	0.01
CO_2	0.52	ND	ND	ND
S	0.06	ND	ND	ND
H_2O^+	1.54	ND	ND	ND
H_2O-	0.11	ND	ND	ND
LOI	1.40	ND	ND	ND
Total	99.20	99.58	99.65	99.79
Mg#	48.10	78.97	73.37	75.22
Density	2.96	2.81	2.80	2.67
Ba	ND			
Be	<1			
Co	23			
Cu	496			
Mo	<10			
Nb	4			
Ni	71			
Rb	33			
Sc	20			
Sr	600			
Th	<10			
V	314			
Y	29			
Zn	78			
Zr	75			

ND = not determined, bd = below detection limits

Sample No.	Sample Location	Rock Type	Unit	Reference
18) 89GDP-0729	312760E 4956470N	gabbro	7a	Di Prisco 1989
19) JA-35		gabbro	7a	Ayer 1979
20) JA-57		gabbro	7a	Ayer 1979
21) JA-58		anorthosite	7c	Ayer 1979

TABLE 5 (continued): Other Metagabbros (unit 5).

wt%.	22	23	24	25	26	27	28
SiO_2	47.63	49.80	44.70	51.10	49.50	52.20	52.30
TiO_2	1.26	0.64	0.74	1.22	1.07	2.09	2.33
Al_2O_3	14.73	20.90	15.90	16.20	16.20	16.80	15.60
Fe_2O_3	3.54	0.52	0.80	ND	ND	ND	ND
FeO	9.11	6.07	10.10	8.81	10.20	10.90	11.80
MgO	7.38	4.44	5.65	7.21	7.83	3.75	4.23
MnO	0.20	0.13	0.17	0.15	0.16	0.16	0.17
CaO	10.24	9.54	6.47	10.90	11.00	7.38	6.50
Na_2O	2.12	4.54	5.00	3.39	2.09	4.02	3.36
K_2O	0.15	0.59	0.74	0.55	1.08	1.84	2.75
P_2O_5	0.10	0.03	0.08	0.19	0.17	0.52	0.60
CO_2	0.43	0.72	7.41	ND	ND	ND	ND
S	0.02	0.02	0.01	ND	ND	ND	ND
H_2O^+	ND	1.32	1.61	ND	ND	ND	2.44
H_2O-	0.07	0.05	0.09	ND	ND	ND	0.17
LOI	1.20	1.60	7.50	ND	ND	ND	ND
Total	97.09	99.30	99.50	99.72	99.30	99.66	99.64
Mg#	51.68	54.75	48.20	59.32	57.77	38.01	38.98
Density	2.69	2.89	2.84	2.65	2.69	2.62	2.63
Ba	30	ND	ND	ND	ND	ND	ND
Be	1	<1	<1				
Co	44	22	51				
Cu	240	9	<5				
Mo	<10	<10	<10				
Nb	3	<3	<3				
Ni	67	19	44				
Rb	6	15	38				
Sc	40	25	47				
Sr	133	312	110				
Th	<10	<10	<10				
V	264	150	227				
Y	25	9	22				
Zn	93	66	96				
Zr	82	42	47				

ND = not determined, bd = below detection limits

Sample No.	Sample Location	Rock Type	Unit	Reference
22) 90RME-0261	309080E 4963805N	gabbro	5a	this study
23) 89GDP-0944	307260E 49344490N	gabbro	5a	Di Prisco 1989
24) 89GDP-3271	309095E 49344395N	gabbro	5a	Di Prisco 1989
25) JA-37		gabbro	5a	Ayer 1979
26) JA-38		gabbro	5a	Ayer 1979
27) JA-53		gabbro	5a	Ayer 1979
28) JA-54		gabbro	5a	Ayer 1979

TABLE 6: Results of correspondence and dynamic cluster analyses of "Tudor Formation" rocks from the Grimsthorpe Domain. Dataset of LeBaron and van Haaften (1989).

Mean Scores of the Groups

Group	Size	Factors 1	2	3	4	5
1 (talcose)	17	0.5311	0.0779	-0.0483	0.0586	-0.0117
2 (unit 2)	23	-0.1573	-0.0068	-0.1120	0.0223	0.0229
3 (unit 1 & 3)	32	-0.2829	0.0423	0.1004	0.0146	-0.0260
4 (misc)	6	0.6366	0.2988	0.0236	-0.1928	0.0558
5 (misc)	6	0.1011	-0.1588	0.0748	0.1434	0.1103
6 (alt. rocks)	14	-0.1568	-0.1529	-0.0403	-0.1180	-0.0407
7 (talcose)	1	0.3953	-0.4638	0.0742	-0.1620	-0.0794
8 (talcose)	1	1.0520	-0.7516	0.0866	0.1381	0.1553

Mean Composition and Coefficient of Variation (CV)

Group	Si	CV	Al	CV	FeOt	CV	Mg	CV
1	41.60	15.96	3.85	101.76	7.69	26.02	25.13	15.70
2	49.01	3.82	14.93	10.36	7.94	22.84	11.15	15.94
3	50.06	5.17	14.26	8.83	12.86	17.89	6.94	23.53
4	35.84	14.83	7.52	87.87	8.52	28.11	32.03	1.54
5	39.81	21.38	10.84	70.14	11.86	20.33	11.60	59.54
6	48.08	5.00	17.66	21.32	7.38	47.77	6.90	30.80
7	36.25	0	12.66	0	6.42	0	10.31	0
8	22.73	0	0.53	0	2.53	0	18.89	0

Group	Ca	CV	Na	CV	K	CV	Ti	CV
1	8.68	26.80	0.33	115.28	0.04	146.58	0.32	159.14
2	12.07	13.81	1.93	32.53	0.31	70.43	0.52	65.52
3	9.95	11.12	2.75	20.81	0.32	73.68	1.71	44.17
4	1.09	49.05	0.28	59.30	0.01	81.65	1.73	147.41
5	16.11	15.08	0.43	91.63	0.11	113.34	0.76	90.84
6	10.52	18.79	2.70	32.30	0.61	100.75	0.75	88.62
7	12.25	0	2.17	0	0.95	0	0.18	0
8	24.60	0	0.23	0	0.00	0	0.03	0

Group	P	CV	LOI	CV
1	0.04	175.34	12.00	60.46
2	0.03	78.92	1.91	55.09
3	0.15	64.25	0.78	52.33
4	0.17	148.21	12.43	23.91
5	0.06	91.40	8.00	112.34
6	0.07	93.91	5.17	69.14
7	0.01	0	18.58	0
8	0.01	0	30.10	0

TABLE 7: Comparison of chemistry of group means with representative samples from the Grimsthorpe area.

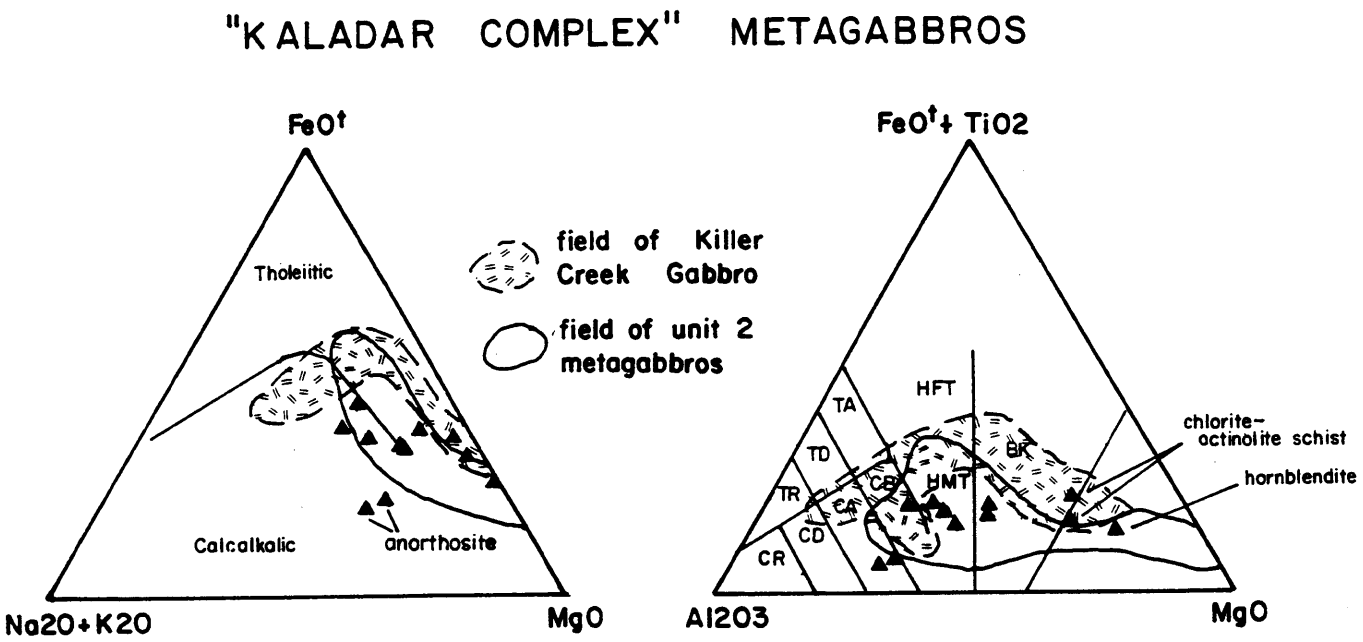
	Group 2	(unit 2) 90RME-0138	Group 3	(unit 1c) 90RME-0037
Si	49.01	50.26	50.06	48.20
Al	14.93	15.40	14.26	14.21
Fe	7.94	12.70	12.86	13.33
Mg	11.15	6.80	6.94	6.96
Ca	12.07	9.85	9.95	10.64
Na	1.93	3.13	2.75	2.39
K	0.31	0.18	0.32	0.28
Ti	0.52	1.48	1.71	1.39
P	0.03	0.11	0.15	0.12
LOI	1.91	0.6	0.78	1.4

Relationship between the Canniff Complex and the Kaladar Complex

Miller and Knight (1914) first described the Kaladar Complex as a body of "gneissic syenite" occupying several square miles south and southwest of Flinton and noted that it was intruded by dikes of "fundamental granite gneiss" (*i.e. Elzevir Tonalite) (Note: the photograph of the Kaladar Complex in their report shows textures typical of the Killer Creek Gabbro).* Later workers (Harding 1944; Lumbers 1967) did not distinguish it from the Elzevir Tonalite, until Thompson (1972) mapped part of it as hornblende diorite during the course of mapping the Flinton Group. Chappell (1978) mapped the complex in detail as Appendix V of his Ph.D. thesis, in large part because he discovered Kaladar Complex fragments within the "Tudor metavolcanics". Wolff (1982) mapped part of the Kaladar Complex in detail, and noted the heterogenous nature of the body, but did not use the term Kaladar Complex in his report.

Chappell (1978) recognized 3 main units within the Kaladar Complex, of which his metagabbro (*his* unit 3) and metadiorite (*his* unit 4) units were dominant. Also present were ultramafic rocks, namely talc schists and serpentinites (*his* unit 2a) and chlorite-actinolite schists representing altered hornblendites (*his* unit 2b). His unit 4 also included anorthositic gabbros (*his* unit 4a). He included gabbro cobble-bearing conglomerate units (compare *his* Plate 7b with Photos 5a-5d) within the "Tudor metavolcanics". Chappell (1978) also studied the geochemistry of the Kaladar Complex, and his results are compared with data from this study in Table 5 and Figure 19. As shown in Figure 19, the Kaldar Complex metagabbros plot in both the fields outlined earlier for unit 2 and unit 7 gabbros. This is not surprising, as the Kaladar Complex contains both rock types. It is possible using Chappell's (1978) map to distinguish between the two types of gabbros. All probable unit 2 metagabbros (based on sample locations) in the Kaladar Complex fall within the unit 2 metagabbro field shown in Figure 19, similarly for the probable Killer Gabbro equivalents.

Figure 19: A) AFM plot of metagabbroic rocks from the Kaladar Complex. Note overlap between both Canniff Complex (unit 2) and Killer Creek gabbro fields. This result is not unexpected as the Kaladar Complex likely icontains gabbros of both units. B) Jensen plot of metagabbroic rocks from the Grimsthorpe area. Data from Chappell (1978).



Chappell (1978) correctly recognized the significance of gabbro cobbles within volcanic conglomerates of what is now termed the Grimsthorpe Group, and that the Kaladar Complex was older than the Elzevir Tonalite and in part older than the "Tudor metavolcanics". Chappell (1978) also recognized that the Complex probably represented the oldest rocks within the Elzevir Terrane. He did *not* recognize that two gabbroic bodies were present, namely the protomylonitic gabbros of the Canniff Group (*his* unit 2a and parts of *his* unit 3) and younger, less deformed, but still pre-Elzevir Tonalite, hornblendites, melano- and leucogabbros, and anorthositic gabbros of the Killer Creek Gabbro (*see below*, *his* units 2b and 4 and parts of *his* unit 3). Chappell (1978) also reports intrusion breccias within the Elzevir Tonalite that incorporate Killer Creek Gabbro fragments, similar to that observed south of Skootamatta Lake within the Grimsthorpe area (*see below*). Fortunately, Chappell's (1978) detailed rock descriptions, photographs, geochemistry and map make it possible to reinterpret his map in light of the data uncovered during the course of mapping the Grimsthorpe area.

As a result, it is suggested herein, and in Easton (1992a), that the term Kaladar Complex be abandonded as a formal stratigraphic unit, mainly because it lumps together too many units of different ages and origins, and that the new terms introduced herein and in Easton (1992a) be applied. Thus, the Kaladar Complex consists of rocks of the Canniff Complex, the Grimsthorpe Group, and the Killer Creek Gabbro.

It is significant that the Killer Creek Gabbro is found on both flanks of the Elzevir Tonalite, as it means the Killer Creek Gabbro was an areally extensive intrusive complex as shown in Figure 20 and that the Moorton shear zone has not completely obscured and truncated contact relationships along the eastern flank of the Elzevir Tonalite.

Is the Canniff Complex an Ophiolite?

Brown *et al.* (1975) suggested that the Kaladar Complex may represent an ophiolite complex preserved within the Grenville Orogen. Field and geochemical observations reported herein suggest that the Canniff Complex is indeed older than the classical Grenville Supergroup and is geochemically similar to oceanic crust. The association of pillowed tholeiitic basalts, massive tholeiitic basalts (possibly including dikes), and gabbroic to ultramafic plutonic rocks within the Canniff Complex is consistent with interpretation of the Canniff Complex as a partially preserved ophiolite fragment.

The overall setting of the Canniff Complex and its related talc bodies is similar to Late Proterozoic ophiolites and listwanites found within the Pan African belts of the Arabian shield (Figure 21). The Arabian Shield consists of metasedimentary and metavolcanic sequences, with diorite and granodiorite intrusions, less than 1,000 Ma in age, that were weakly folded and intruded by granites during the Pan-African Orogeny in a greenschist facies metamorphic regime at *ca.* 680-635 Ma (Buisson and Leblanc 1986). The supracrustal succession is interpreted to represent an accreted terrane consisting of several island arcs. Three ultramafic-mafic belts are present in the Shield (Figure 21),

but typical Phanerozoic ophiolite complexes have only been recognized in the western belt. The other belts contain incomplete ophiolite sequences. A model of autochtonous ophiolite emplacement along listric faults into the island-arc sequence has been proposed (*cf.* Buisson and Leblanc 1986). Associated with these mafic-ultramafic belts are zones of listwanites (carbonatized ultramafics, including talc-carbonate lenses), locally auriferous.

As illustrated in Figure 21, the scale and general geologic setting of the ultramafic belts and listwanites in the Arabian Shield resembles that observed in the Grimsthorpe Domain. Important similarities with the Arabian shield are:
- occurrence of talcose rocks in association with ultramafic rocks in high-strain zones
- tectonic contacts of talcose rocks and ultramafic rocks with surrounding country rocks
- ultramafic rocks are not coeval with adjacent country rocks
- association with granodioritic intrusions
- local association of gold vein mineralization with the ultramafic belts and carbonate alteration.

These similarities suggest that the listwanite model for gold mineralization (Buisson and Leblanc 1986; Nixon and Hammack 1991) may be applicable this region. Several gold occurrences associated with carbonatization of mafic rocks are known in the Elzevir area (*e.g.* Barry occurrence and Sophia Mine, Malczak *et al.* 1985) and may represent listwanite-type gold mineralization.

An important difference between the Grimsthorpe area occurrences and the Arabian listwanites relates to metamorphic conditions. The Arabian listwanites all contain low metamorphic grade assemblages, and have not been subjected to regional metamorphic events. In contrast, the Grimsthorpe area talc occurrences show higher metamorphic grade assemblages and have been subjected to regional metamorphism. If the listwanite model is valid for the Grimsthorpe area, then the early, low-grade metamorphism may be significant in preconditioning the rocks for subsequent recrystallization during regional metamorphism.

Figure 20: Sketch showing the possible extent of Canniff Complex and Killer Creek Gabbro Suite rocks within the Grimsthorpe Domain.

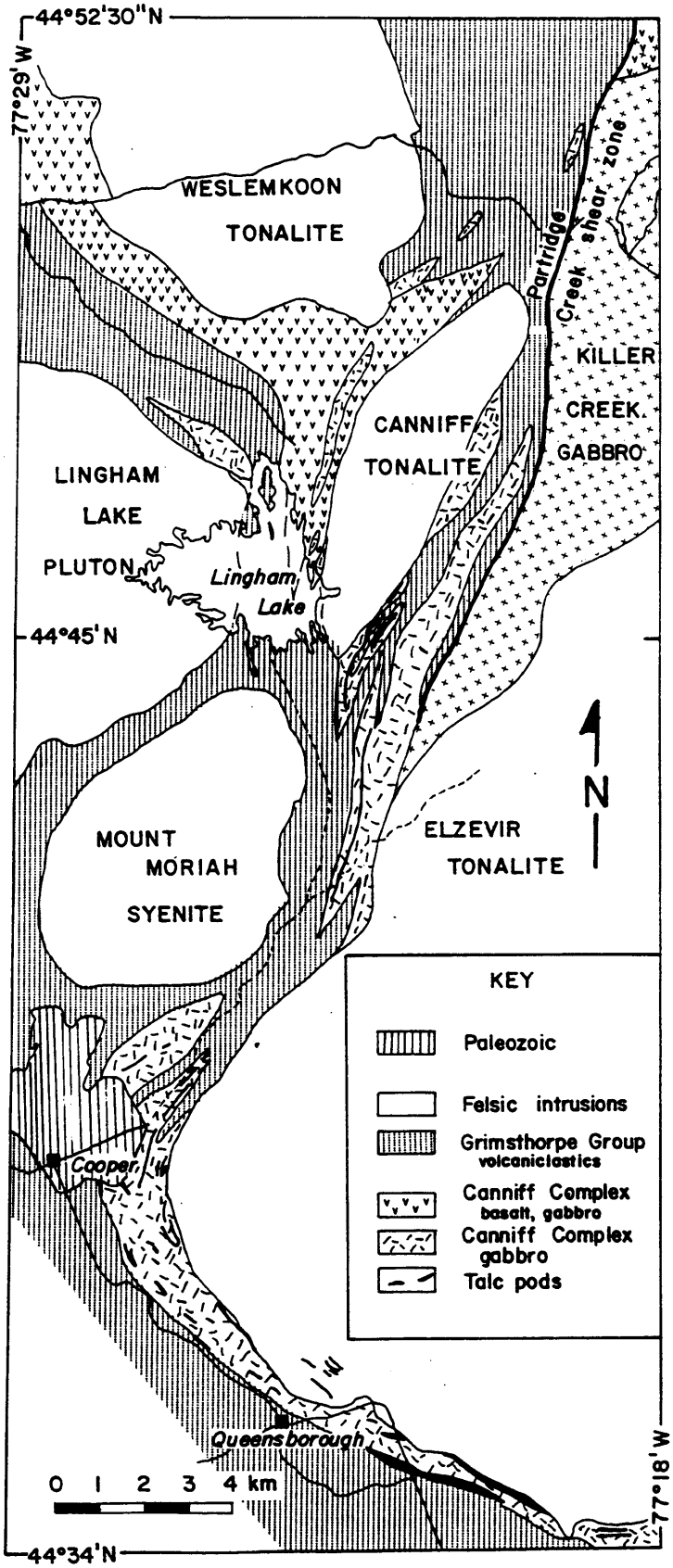
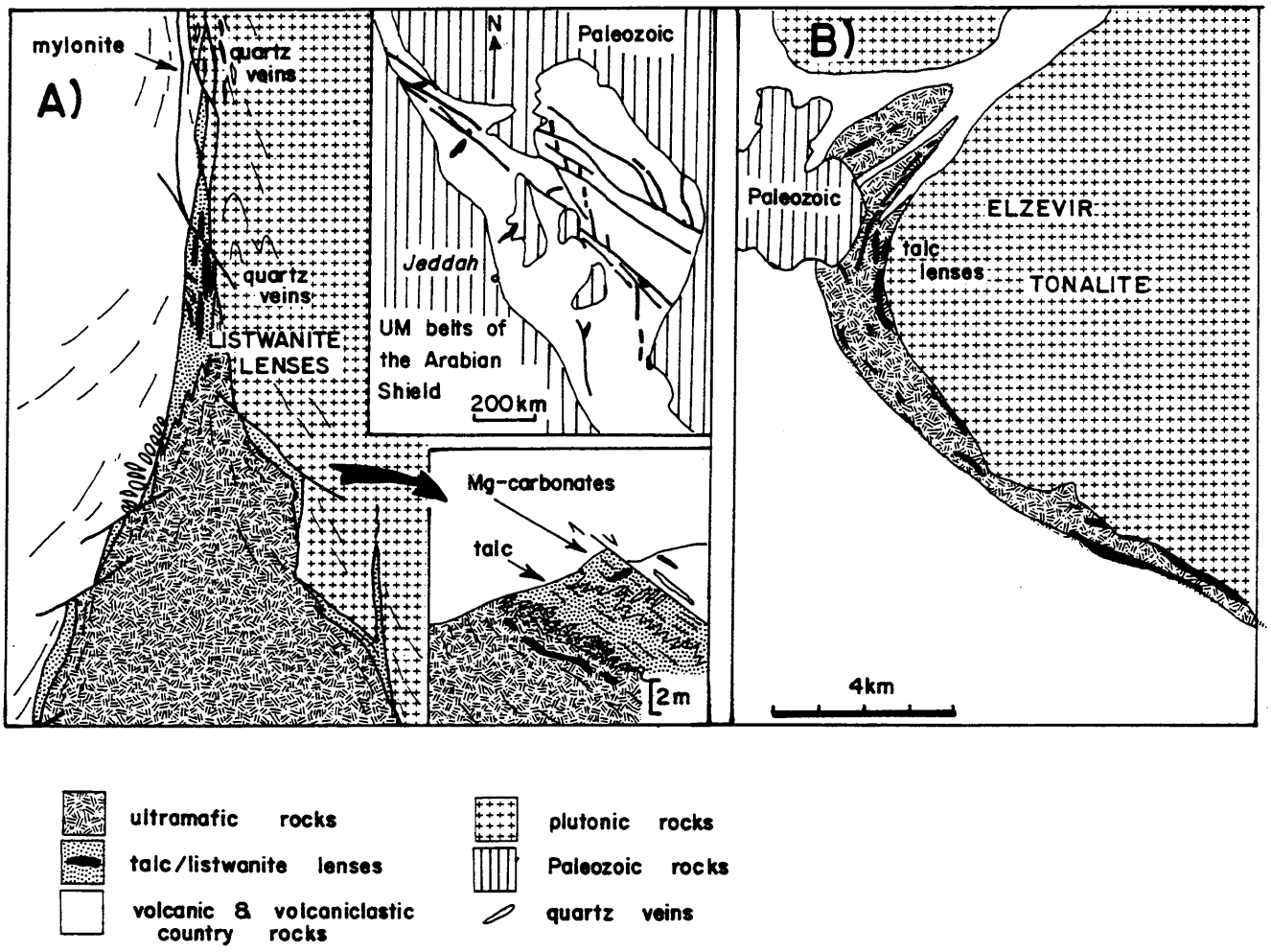


Figure 21: Sketch illustrating listwanite model for gold occurrence. Compare figures a and b.
A) Sketch showing the distribution of listwanites in the Arabian Shield (after Buisson and Leblanc 1986).
B) Sketch showing distribution of talc bodies, Canniff Complex rocks, and gold occurrences in the Elzevir area (after LeBaron and van Haaften 1990, Malzak et al. 1985).



GRENVILLE SUPERGROUP
METASEDIMENTARY ROCKS
GRIMSTHORPE GROUP (units 3-4)

Introduction

The bulk of the supracrustal rocks in the Grimsthorpe Domain consist of mafic volcaniclastic metasediments, rusty-weathering schists, with subordinate, interbedded mafic, commonly pillowed, flows, and minor pelite and metawacke. This supracrustal sequence is termed herein the Grimsthorpe Group (*see also* Easton 1992a), with type areas as indicated in Table 3.

Metaconglomerates in the lower part of the section contain mafic volcanic fragments and gabbro clasts similar to the Canniff Complex. The Grimsthorpe Group is in probable unconformable contact with the Canniff Complex and is roughly correlative with the Tudor Formation, Basal Group, Grenville Supergroup (Easton 1992a). Important characteristics of the Grimsthorpe Group are its dominantly mafic (basaltic) composition and the lack of carbonate metasedimentary rocks which are typical of the Grenville Supergroup outside of the Grimsthorpe domain.

Clastic Metasedimentary Rocks of Dominantly Volcanic Provenance (unit 3)

Volcaniclastic rocks of unit 3 are well exposed along the Skootamatta road and on the shores of Lingham Lake. A crude stratigraphic sequence seems to be present, which, in the Lingham Lake area, forms an apparently homoclinal succession (Figure 22). This succession consists, from east to west, of gabbro-clast tuffaceous conglomerates which grade upward into conglomerates consisting of basaltic volcanic detritus. These conglomerates are locally intercalated with a few rare pillowed flows, in turn, overlain by basaltic composition tuffaceous sandstones and pebble conglomerates, overlain by basaltic composition mudstones with some tuffaceous conglomerate and volcaniclastic sandstone lenses, which then grade into more aluminous siltstones and mudstones, and metawackes and metarenites. Graded bedding in the tuffaceous sandstones and the conglomerates provide top indications throughout the sequence. Rusty schists with associated gossan zones are common in all of the above rock types, but primarily in the tuffaceous mudstones and conglomerates. In addition, there seems to be a fining of the sedimentary sequence with distance from the tonalite plutons in the area, *i.e.* to the northwest in the Lingham Lake area, and to the north and northeast in the Skootamatta Road/Partridge Creek area. The top of the section is truncated by the Lingham Lake pluton. The base of the section consists of protomylonitic gabbros of unit 2 described in greater detail above. This homoclinal sequence can be traced to the north, but the amount of volcaniclastic sediment decreases, and a thick sequence of massive and layered amphibolite (possibly metaflows) are found near the base of the homoclinal sequence adjacent to the Weslemkoon Tonalite (Figure 4). The amphibolites are more deformed and metamorphosed than the volcaniclastic sediments and they do not retain primary textures. This greater degree of deformation and metamorphism is in part related to the emplacement of the tonalite bodies, but it may also reflect a relative

age difference between the flow rocks and the volcaniclastic sediments, as is the case for the protomylonitic gabbros which shed clasts into the lower part of the volcaniclastic sequence.

The coarsest volcaniclastic units consist of polymictic, matrix-supported tuffaceous conglomerate, with a mafic matrix (unit 3f) (Photo 6). A wide-range in rounding of clasts is exhibited, ranging from angular clasts (Photo 7) to well-rounded cobbles (Photo 6). No discernable pattern in degree of rounding could be established throughout the area. Conglomeratic rocks consistute roughly 35%-50% of the volcaniclastic succession in the map area. The amount of conglomerate may be underestimated, as in small bush outcrops, it is commonly difficult to distinguish unit 1a from tuffaceous sandstones (unit 3d) and conglomerate (unit 3f). A distinctive variety of conglomerate (unit 3g) is distinguished on the map face, and has already been noted in previous sections. Unit 3g consists of dark green, heterolitihic, matrix-supported, conglomerate with a mafic matrix and abundant gabbro (mainly unit 2a) and mafic metavolcanic clasts (Photo 5). It is generally found only in close proximity to outcrop areas of unit 2a.

Sand-sized tuffaceous metasediments consist of volcanic wackes and tuffaceous sandstones (unit 3d), black, green and dark grey weathering, biotite-hornblende-quartz-plagioclase gneiss (unit 3b) probably representing mafic tuffaceous arenites and wackes (Photo 8). These units are medium-bedded, show graded bedding, and were probably deposited as turbidites (Photo 8a, 8b). Tuffaceous mudstones and tuffs are also common, consisting of dark green to green weathering, thinly bedded, hornblende-plagioclase schists (unit 3c) (Photo 8c). These rocks are similar to units 1e and 1f, except that they are intercalated with tuffaceous metasedimentary, not metavolcanic, rocks. North of Grimsthorpe Lake, tuffaceous mudstones contain relict porphyroblasts (unit 3n), however, the original porphyoblastic mineral is no longer recognizable in hand sample or thin-section. In the same area, minor calc-silicate gneisses (unit 3k) are also present. Rusty schists (unit 3r) are common within the volcaniclastic sequence, and consist of either sulphide-bearing tuffaceous mudstones or sulphide-bearing zones in unit 3f. Rusty schists also occur near the contacts of some gabbroic dikes (unit 5). No attempt was made on OFM 168 (back pocket) to distinguish these various types of rusty schists (unit 3r).

In the Pringle Lake area adjacent to the northeast corner of the map area, and in Bon Echo Provincial Park, is a unit of distinctive, grey to dark grey, massive, biotite-hornblende-quartz-plagioclase gneiss, commonly containing magnetite, and locally garnet, porphyroblasts (unit 6h). No primary textures are preserved in this unit, and it is unclear if the unit is even bedded. If bedded, bedding is on the scale of 3-10 m. This unit probably represents a metawacke, and based on its homogeneous nature and map distribution, it is likely of volcanic provenance. It is uncertain whether this unit is correlative with the Grimsthorpe Group, hence its inclusion within unit 6 *(see subsequent section).*

The volcaniclastic rocks are little deformed, with well rounded volcanic, and where present, protomylonitic gabbro, cobbles, that show no vertical or horizontal stretching (Photos 5, 6, 7). Individual conglomerate units can be traced along strike for up to a kilometre in areas of good exposure, however, good top indicators are generally only seen along roads or lakeshores, and repetition of the section through folding is probable. There is no structural evidence that the supracrustal rocks are preserved in synclinal troughs between the tonalite plutons. In the Lingham Lake area units consistently face to the west, and in the Killer Creek area units face east.

In thin section, sedimentary textures are typically preserved, particularly in the coarser-grained metasediments where rock-fragments and volcanic clasts are easily distinguished, despite metamorphic recrystallization. In both the coarser and finer grained sediments, hornblende-quartz-plagioclase (typically oligioclase) assemblages dominate, with minor epidote, carbonate and opaque minerals. Grains are euhedral, and mafic minerals are commonly elongated, parallel to bedding, and define a strong foliation in the rock. In some samples, a later, secondary cleavage is also visible, defined by oriented opaque minerals or quartz lenticles. As noted in the previous description of the Canniff Complex, metasediments of both units 3 and 4 of the Grimsthorpe Group typically have euhedral grains, with well-defined grain boundaries, with hornblende being the dominant mafic mineral. In contrast, Canniff Complex rocks, including clasts present in units 3f and 3g, typically have diffuse grain boundaries, with actinolite as the dominant mafic mineral.

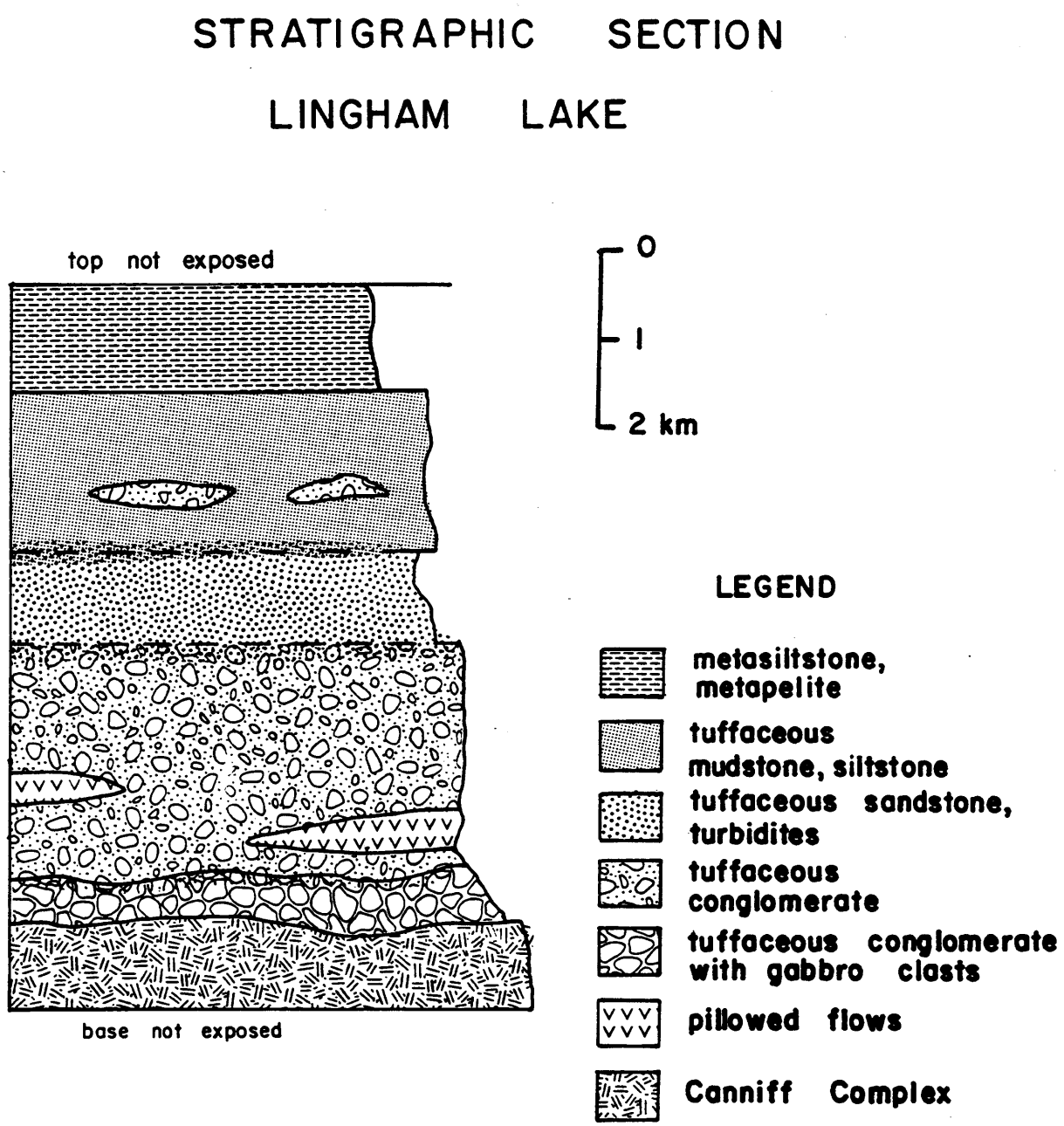
Siliceous Clastic Metasedimentary Rocks (unit 4)

Along the northeastern margin of the Lingham Lake pluton, locally on islands in Lingham Lake, and along the forest access road to Lingham Lake, more silicic and aluminous metasedimentary rocks occur. These include meta-arenite (unit 4a), metawacke (unit 4b), metasilstone and metapelite (unit 4c), and rusty schists, possibly representing black shales (unit 4r). The metapelites are the most abundant lithology, and are locally porphyroblastic, although the original metamorphic mineralogy is no longer recognizable in hand specimen.

In thin section, rocks of unit 4 differ from rocks of unit 3 in having significantly higher quartz contents, as well as either green, or more commonly red-brown, biotite. Several samples of rusty schist (unit 4c-4r) contain fine-grained garnet porphyroblasts not readily observed in hand specimen. In some instances, the garnets are oriented along the secondary cleavage present in the rock, whereas, amphiboles and mica define the primary, bedding-parallel fabric in the samples. In the north-central part of the map area southeast of Killer Lake, intercalated beds of unit 3 and 4 contain abundant epidote and carbonate, as well as poorly preserved porphyroblasts. These beds are much more calc-silicate rich than other rocks within the map area. It is possible that the relict porphyroblasts in these rocks were originally amphibole (hornblende?), but they have

now been retrograded to fine-grained actinolite-epidote-albite aggregates.

Figure 22: Sketch showing composite stratigraphic section within the Grimsthorpe Group (units 3 and 4) in the Lingham Lake area.



Geochemistry of the Grimsthorpe Group

Figures 9, 16, 23, 24 and 25 and Table 8 present geochemical data on volcaniclastic and metasedimentary rocks of units 3 and 4 the Grimsthorpe Group. The dataset utilized includes samples collected by the authors and samples collected by G. Di Prisco from the Elzevir area due south of the Grimsthorpe area. Most samples from unit 3 classify as tholeiitic basalts, and no geochemical distinction can be made between mafic metavolcanic rocks of the Canniff Complex and volcaniclastic rocks of the Grimsthorpe Group (Figure 9, 24). This result is not surprising, given the field evidence suggesting a considerable volcanic provenance to these rocks, and the presence of gabbroic cobbles in many unit 3 tuffaceous conglomerates.

As shown in Figure 16, a conglomerate containing gabbroic clasts (unit 3g) is nearly identical in its pattern to a Canniff Complex metagabbro sample, consistent with the field evidence that the conglomerate was derived in part from the Canniff Complex metagabbro. Both silica and sodium are effective discriminants between rocks of unit 3 and unit 4 (Figure 24). The epiclastic rocks of unit 4 have higher silica values, and lower sodium values (<2.5% NaO) than their volcaniclastic counterparts in unit 3 (Figure 24, Table 8).

Chondrite-normalized REE plots for Grimsthorpe Group metasedimentary rocks are shown in Figure 25. Figure 25a illustrates the patterns for samples of volcanic wackes and tuffaceous sandstones (unit 3d) and rusty schists (unit 3r). There is a tight clustering of data, and no, or only a slight, Eu anomaly. Proterozoic and Phanerozoic metasediments derived from mixed source terranes typically have prominent Eu anomalies (*cf.* Taylor and McLennan 1985). Thus, the lack of a Eu anomaly in the Grimsthorpe Group rocks is consistent with their derivation from a little weathered, mafic volcanic source terrane.

Figure 25b illustrates the REE patterns for samples of volcanic conglomerates. Again, there is a tight clustering of data, with no, or a slight positive or a slight negative Eu anomaly, and minor LREE enrichment. These flat, 10 times chondrite enriched patterns are consistent with derivation from a tholeiitic volcanic or gabbroic source. Sample 90RME-0031 (Figure 25b) contains gabbroic clasts (unit 3g), and shows no significant differences from the other samples. The pattern for sample 90RME-0019 (Figure 25b) is similar to the pattern found in the metawackes and rusty schists, and may indicate that this conglomerate was derived from slightly more reworked or weathered source than the other conglomerates. The only anomalous pattern seen in Figure 25b is sample 90RME-0017 which was obtained from a silicified conglomerate from the United Reef Petroleums Limited gold property. This silicified conglomerate is illustrated in Photo 3b.

Figure 23: A) AFM plot of Grimsthorpe Group metasedimentary rocks (units 3 and 4) compared to the field of Grimsthorpe Domain metabasalts (unit 1). Note general overlap between the two groups. More aluminous samples (unit 4) plot toward the Na_2O/K_2O apex. B) Jensen plot of Grimsthorpe Group metasedimentary rocks (Units 3 and 4) compared to the field of Grimsthorpe Domain metabasalts. Note general overlap between the two groups. More aluminous samples (unit 4) plot toward the Na_2O/K_2O apex.

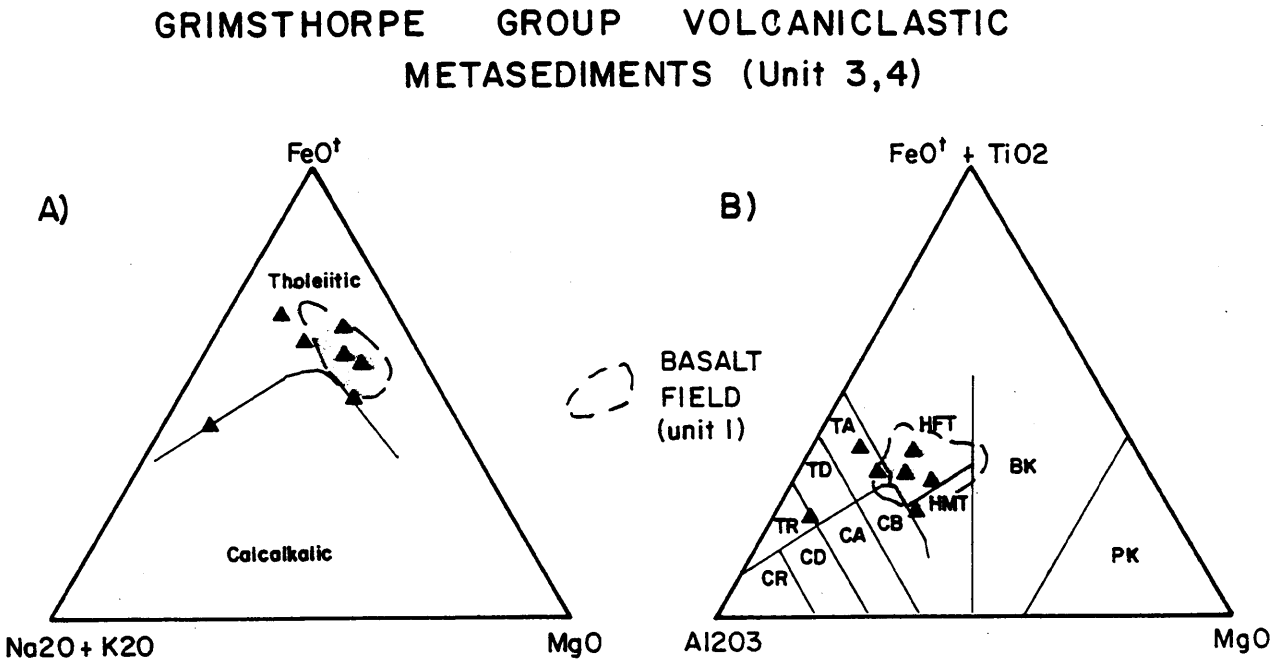


Figure 24: Plot of SiO_2 versus Na_2O for metasedimentary rocks of the Grimsthorpe Group. Unit 3 samples include mainly volcaniclastic rocks, whereas unit 4 samples include pelitic and epiclastic metasedimentary rocks. Field of Grimsthorpe Domain metabasalts shown for comparison.

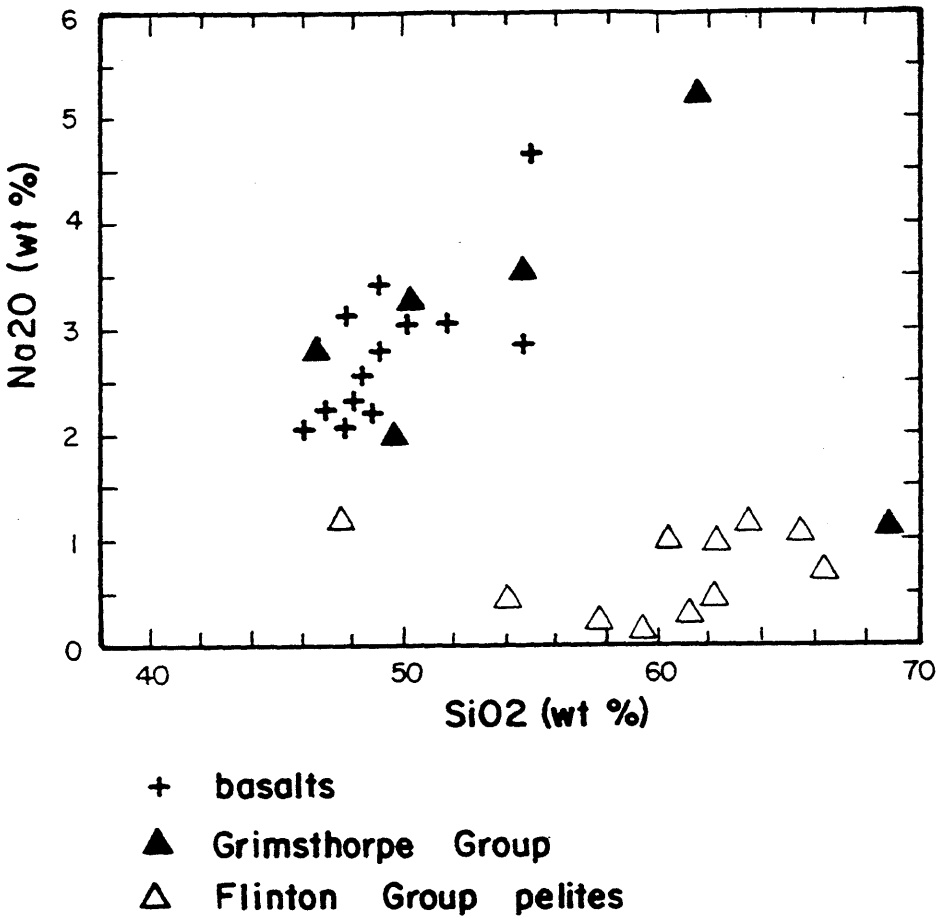


Figure 25: Chondrite-normalized REE plot for Grimsthorpe Group volcaniclastic metasedimentary rocks.
A) Samples of volcanic wackes, tuffaceous sandstones and rusty schists. Sample 90RME-0003 is a volcanic wacke, samples 90RME-0041, -0049, -0085 are rusty schists.
B) Samples of volcanic conglomerates. Sample 90RME-0017 is a silicified conglomerate associated with a gold occurrence in the map area. Sample 90RME-0019 is slightly silicified hence its slightly anomalous pattern. Sample 90RME-0031 is a volcanic conglomerate containing gabbro clasts (unit 3g). Samples 90RME-0075, -0103, -0105, -0108, and -0109 are volcanic conglomerates (unit 3f).

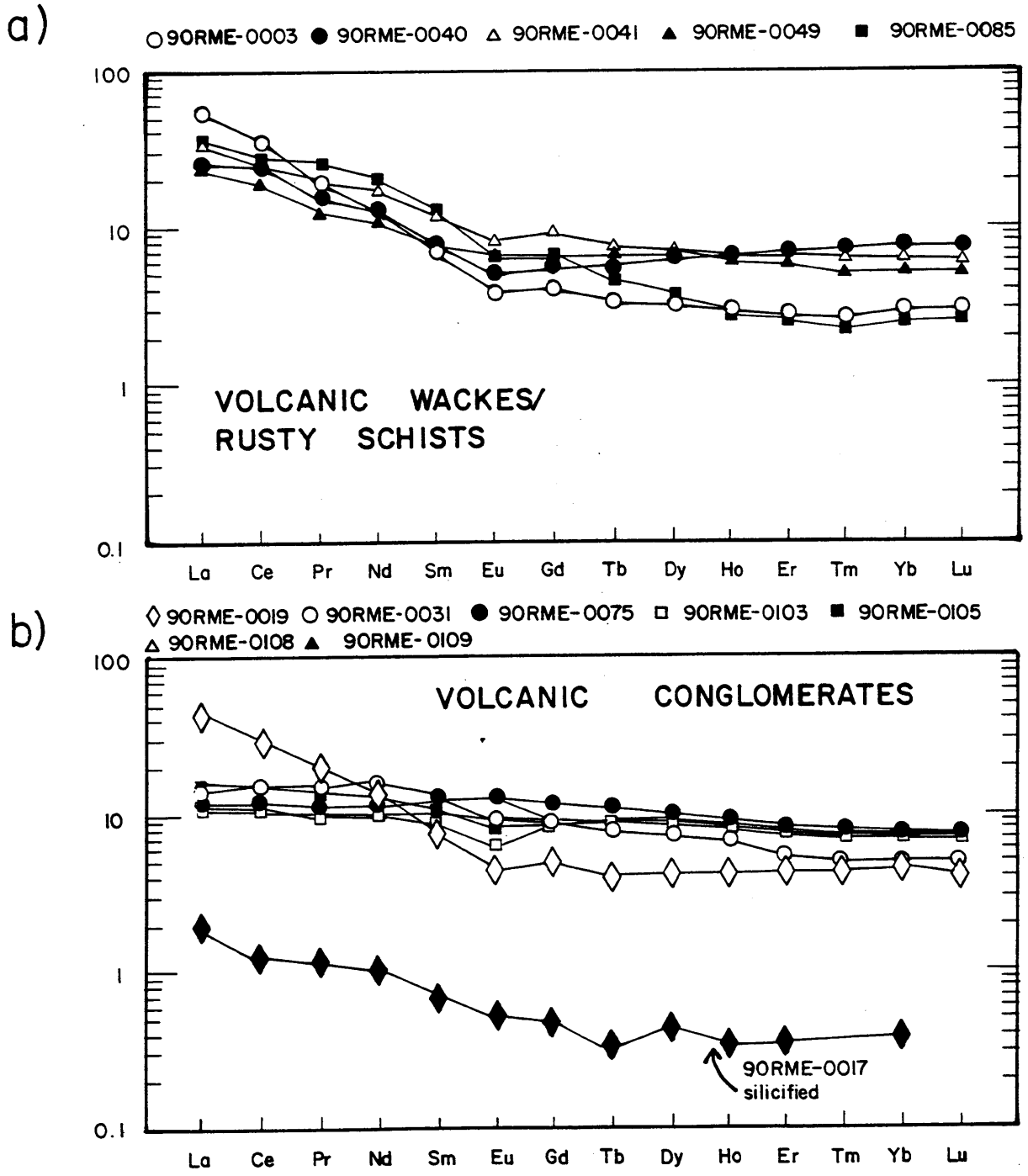


TABLE 8: Chemical analyses of volcaniclastic metasedimentary rocks (units 3 and 4) from the Grimsthorpe and Elzevir areas.

wt%.	1	2	3	4	5	6	7
SiO_2	46.09	49.97	48.08	68.86	49.57	54.50	61.40
TiO_2	2.80	0.40	1.39	0.66	3.07	0.99	0.87
Al_2O_3	16.40	16.23	14.17	10.96	13.98	15.10	16.30
Fe_2O_3	3.36	2.21	2.75	3.73	2.18	0.80	0.73
FeO	10.12	8.64	10.24	6.91	11.91	11.60	5.81
MgO	5.80	7.23	6.94	1.59	5.00	3.50	1.29
MnO	0.19	0.20	0.24	0.27	0.18	0.21	0.14
CaO	9.64	7.76	10.61	1.67	8.54	7.07	3.74
Na_2O	2.79	3.26	2.38	1.17	2.04	3.63	5.29
K_2O	0.39	0.47	0.28	2.16	0.36	0.37	1.90
P_2O_5	0.32	0.04	0.12	0.27	0.30	0.13	0.23
CO_2	0.04	0.06	0.96	0.04	1.04	0.37	0.16
S	0.30	0.01	0.04	0.00	0.02	0.18	0.03
H_2O^+	1.17	1.90	1.47	0.74	ND	1.02	0.68
H_2O-	0.07	0.05	0.08	0.09	ND	0.13	0.08
LOI	0.50	1.30	1.40	0.30	0.70	0.70	0.60
Total	99.48	98.43	99.75	99.12	98.19	99.60	98.70
Mg#	44.02	54.80	49.31	21.23	39.11	33.61	26.22
Density	2.71	2.64	2.70	2.46	2.70	2.62	2.46
Ba	84	113	107	248	44	ND	ND
Be	<1	<1	<1	3	2	<1	<1
Co	45	40	47	15	28	35	8
Cu	64	19	29	8	14	60	11
Mo	<10	<10	<10	ND	<10	<10	<10
Nb	5	3	3	10	4	<3	15
Ni	49	37	47	26	54	6	7
Rb	6	17	5	107	6	13	39
Sc	29	46	50	12	44	38	11
Sr	424	210	174	118	155	140	241
Th	<10	<10	<10	15	<10	<10	<10
V	258	266	362	76	467	374	38
Y	29	11	34	29	59	26	56
Zn	97	66	107	101	130	122	112
Zr	184	24	85	159	289	64	907

ND = not determined, bd = below detection limits

Sample No.	Sample Location	Rock Type	Unit	Reference
1) 90RME-0031	306520E 4964300N	conglomerate	3g	this study
2) 90RME-0036	303845E 4967225N	volcanic wacke	3b	this study
3) 90RME-0037	303975E 4966760N	basalt	1c	this study
4) 90RME-0042	304080E 4966360N	siltstone	4c	this study
5) 90RME-0265	302160E 4977780N	mudstone	1f	this study
6) 89GDP-0682	309900E 4945760N	wacke	3b	Di Prisco 1989
7) 89GDP-3152	314980E 4934050N	wacke	3b	Di Prisco 1989

TABLE 8 (continued):

wt%.	8	9	10	11	12	13	14
SiO_2	48.53	58.93	49.61	64.83	75.80	54.70	58.93
TiO_2	0.87	0.83	2.71	0.65	0.05	1.37	0.83
Al_2O_3	10.42	11.73	15.87	12.50	13.93	13.28	12.73
Fe_2O_3	19.67	14.30	14.24	9.35	0.61	12.22	12.91
FeO	ND	ND	ND	ND	ND	ND	ND
MgO	2.74	3.17	5.55	2.61	0.10	5.13	3.04
MnO	0.05	0.06	0.17	0.11	0.01	0.44	0.05
CaO	1.38	1.89	9.55	3.35	0.25	5.22	1.55
Na_2O	2.00	2.16	2.92	2.44	4.38	1.33	2.89
K_2O	2.41	1.44	0.35	1.50	3.92	2.95	1.20
P_2O_5	0.21	0.20	0.29	0.13	0.01	0.21	0.21
CO_2	1.95	0.66	0.18	0.71	0.14	2.23	0.37
S	bd	bd	0.31	0.34	0.01	0.21	ND
H_2O^+	4.62	2.78	0.97	1.35	0.45	1.42	2.62
H_2O-	1.32	0.87	0.05	0.40	0.02	0.20	0.71
LOI	11.40	5.21	0.83	2.06	0.52	2.40	5.15
Total	99.68	99.92	99.09	99.53	99.58	99.25	99.49
Mg#	21.62	30.51	43.56	35.60	24.51	45.40	31.80
Density	2.49	2.45	2.59	2.42	2.30	2.56	2.44
Ba	349	162	50	420	203	380	170
Be	1	<1	1	1	1	1	2
Co	8	19	45	9	5	32	21
Cu	79	164	85	65	5	44	109
Mo	<10	<10	<10	<10	<10	<10	<10
Nb	10	10	8	<5	10	5	6
Ni	8	26	43	14	<5	82	51
Rb	61	59	5	49	117	119	40
Sc	17	17	26	16	4	26	17
Sr	119	147	368	245	84	104	154
Th	<10	<10	<10	<10	<10	<10	<10
V	171	158	217	118	<5	228	173
Y	11	19	25	27	8	28	25
Zn	68	33	80	95	11	131	79
Zr	132	168	159	172	65	142	162

ND = not determined, bd = below detection limits

Sample No.	Sample Location	Rock Type	Unit	Reference
8) 90RME-0003	313190E 4968420N	wacke	3b	this study
9) 90RME-0019	314795E 4968500N	rusty conglomerate	3f	this study
10) 90RME-0040	304020E 4966410N	rusty schist	3r to 4r	this study
11) 90RME-0110	313850E 4967660N	albitite-felsite	1z	this study
12) 90RME-0041	304000E 4966410N	rusty schist	3r to 4r	this study
13) 90RME-0049	305660E 4964960N	rusty schist	3r to 4r	this study
14) 90RME-0085	310200E 4961600N	rusty schist	3r to 4r	this study

TABLE 8 (continued):

wt%.	15	16	17	18	19	20	21
SiO_2	59.16	46.82	51.99	53.19	51.03	51.97	50.21
TiO_2	1.04	1.36	1.43	1.60	1.45	1.59	1.21
Al_2O_3	11.01	14.24	13.74	13.46	13.68	13.63	14.04
Fe_2O_3	12.19	13.11	11.21	13.19	13.64	13.54	13.08
FeO	ND	ND	ND	ND	ND	ND	ND
MgO	1.52	6.46	7.21	5.80	6.22	6.69	8.35
MnO	0.02	0.14	0.13	0.12	0.18	0.17	0.19
CaO	0.93	8.00	8.80	6.00	8.64	7.57	8.54
Na_2O	3.92	3.77	3.74	3.23	2.96	2.83	3.43
K_2O	0.76	0.61	0.35	1.19	0.60	0.75	0.17
P_2O_5	0.16	0.14	0.16	0.19	0.14	0.16	0.17
CO_2	8.61	2.13	0.30	0.15	0.31	0.14	0.20
S	bd	bd	0.48	0.28	0.40	0.45	0.01
H_2O^+	1.21	1.67	1.11	1.47	1.26	0.45	1.23
H_2O-	0.84	0.18	0.12	0.41	0.21	0.02	0.07
LOI	8.28	4.44	1.13	1.72	1.23	0.80	0.67
Total	98.99	99.09	99.89	99.69	99.77	99.70	100.06
Mg#	19.80	49.39	56.02	46.55	47.45	49.46	55.84
Density	2.42	2.56	2.55	2.52	2.56	2.55	2.57
Ba	176	109	45	155	853	91	40
Be	<1	1	<1	<1	<1	<1	<1
Co	29	34	33	52	40	39	43
Cu	202	103	1365	128	93	64	6
Mo	<10	<10	<10	<10	<10	<10	<10
Nb	13	5	5	5	5	5	5
Ni	150	58	64	68	57	72	74
Rb	19	10	9	39	14	5	5
Sc	17	39	39	37	38	41	43
Sr	60	341	282	167	212	206	121
Th	<10	11	<10	<10	<10	<10	<10
V	387	337	272	270	279	298	257
Y	11	38	32	33	31	33	26
Zn	64	61	42	39	64	105	133
Zr	141	808	109	79	99	118	75

ND = not determined, bd = below detection limits

Sample No.	Sample Location	Rock Type	Unit	Reference
15) 90RME-0075	303880E 4967720N	schist	3	this study
16) 90RME-0103	313310E 4968040N	conglomerate	3f	this study
17) 90RME-0105	313300E 4979600N	conglomerate	3f	this study
18) 90RME-0108	313270E 4967880N	conglomerate	3f	this study
19) 90RME-0109	313360E 4967730N	conglomerate	3f	this study
20) 90RME-0111	313870E 4967610N	wacke	3b	this study

Depositional Environment of the Canniff Complex and the Grimsthorpe Group

The relationship between the Canniff Complex and the Grimsthorpe Group is illustrated in Figure 26. The Canniff Complex most likely represents a basement complex to the Grimsthorpe Group. Whether that basement represents Proterozoic oceanic crust, or simply an older basaltic shield volcano complex, is equivocal at present. The Grimsthorpe Group represents a volcaniclastic apron related to a series of shallow-water, locally emergent, basaltic shield volcanoes. Several volcanic centres were probably present in the Grimsthorpe area, as illustrated in Figure 27, however, the volcanic centres themselves were partly to completely obliterated by later gabbro and tonalitic intrusions (Figure 27). As a consequence, only the deposits in the proximal-distal to distal facies regime of these volcanoes are still preserved.

The Early Proterozoic Amisk Lake volcano in the Flin Flon greenstone belt (Ayres *et al.* 1991) serves as a possible model for the relationships seen within the Grimsthorpe area. Ayres *et al.* (1991) suggest that the volcano was an oceanic island that differs from modern oceanic volcanoes in having a larger volume of pyroclastic rocks and a higher rate of subsidence (and corresponding thicker stratigraphic sequence). As the Amisk Lake volcano developed, eruptive conditions fluctuated over time from subaqueous to subaerial, back to subaqueous, and back again to subaerial. These flucuations were caused by rapid subsidence due to crustal loading and variable rates of upward construction of the volcano. The Amisk Lake basaltic sequence consists of about 50% volcaniclastic rocks which occur as intercalations between subaqueous lava flows and thick sequences of subaqueous turbidites and subaerial air-fall tuffs. Although some of these deposits have been reworked and transported, all were initially produced by a combination of phreatomagmatic and magmatic explosions generated by magma rising into water-saturated, basaltic sequences near ancient shorelines of the island. Although the Amisk Lake volcano had a shield morphology typical of modern basaltic volcanoes, in terms of products it more closely resembles a composite volcano.

We feel that the Amisk Lake volcano is an excellent analogue for the Grimsthorpe Group. Differences between the two are the fact that in the Grimsthorpe area, we do not see the proximal regime that is preserved at the Amisk Lake volcano. Further, in the Grimsthorpe area, as all preserved products are subaqueous, it is difficult to judge the degree to which the volcanic island was emergent, however, the abundance of tuffaceous conglomerates, locally with subrounded to rounded cobbles, suggests that the Grimsthorpe area volcanoes were indeed emergent. Finally, one consequence of the Amisk Lake model proposed by Ayres *et al.* (1991) is that peperites are likely to occur.

Figure 26: Paleogeographic reconstruction showing the relationships between and the depositional environments of the Canniff Complex and the Grimsthorpe Group.

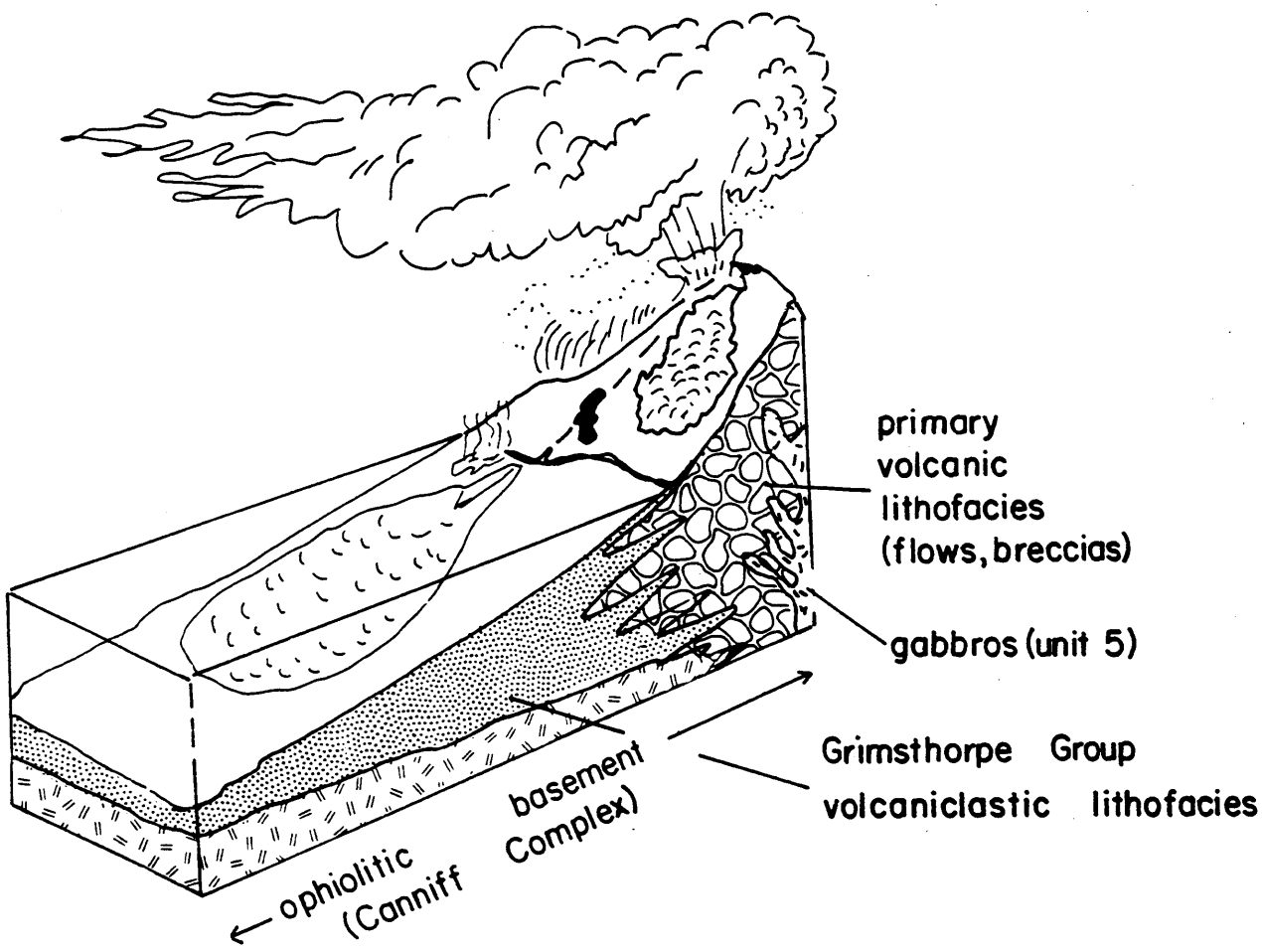
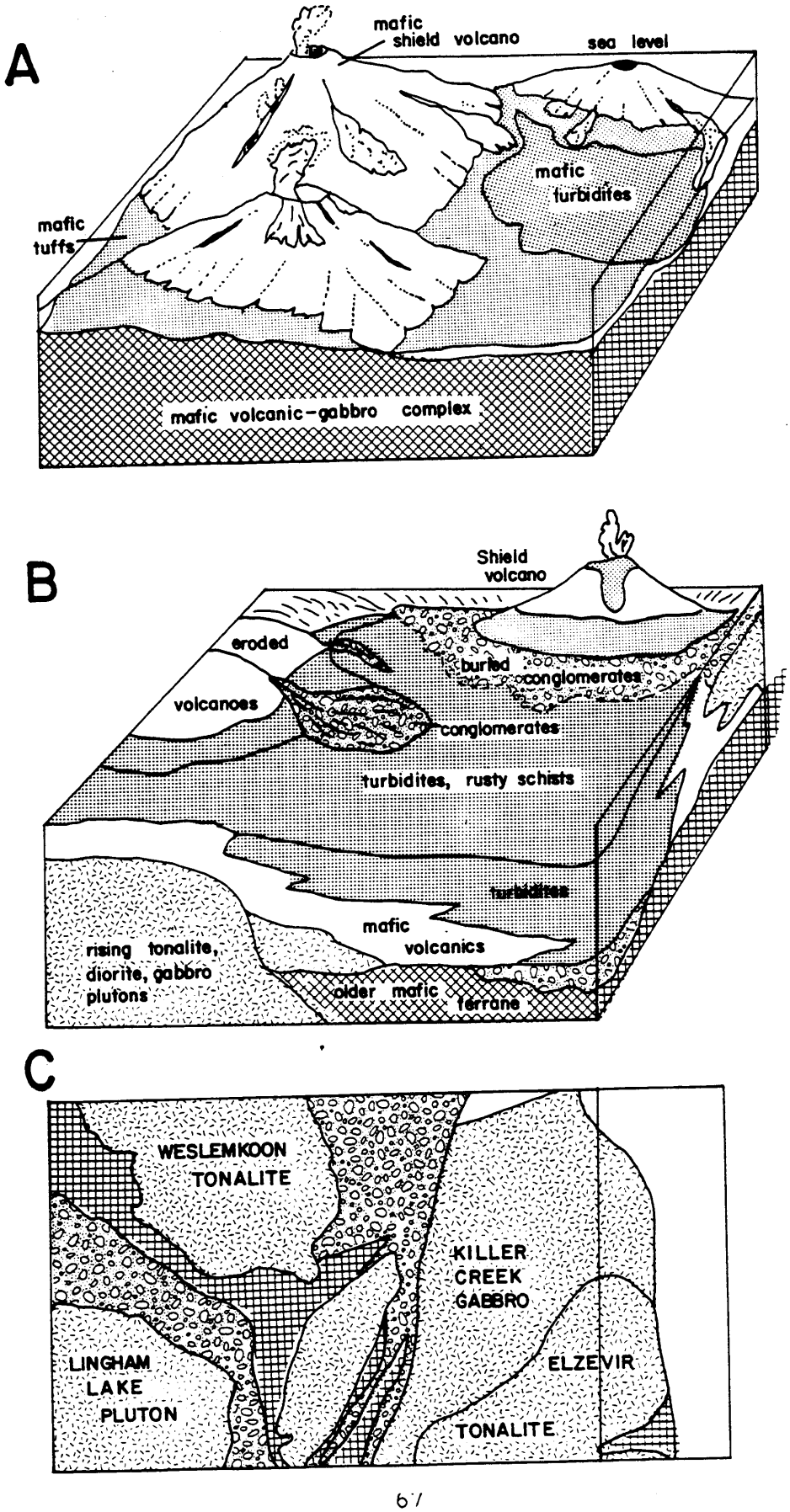


Figure 27 (next page): Inferred development of the Grimsthorpe area between 1300 and 1100 Ma.
A) Canniff Complex mafic volcanics and gabbros are deposited in an oceanic environment at circa 1300 Ma.
B) Canniff Complex is uplifted and eroded, eroded volcanoes form bulk of detritus of Grimstorpe Group, with minor volcanism during during deposition of the Grimsthorpe Group. Diorite, gabbro, and tonalite plutons rise from depth and engulf lower portions of the eroded volcanic pile at circa 1275 Ma.
B) Present-situation in the Grimsthorpe area (Skootamatta Syenite not shown for clarity showing relationship of main lithologic packages illustrated in A and B.


A
mafic
shield volcano
sea level
mafic
turbidites
mafic
tuffs
mafic volcanic-gabbro complex
B
Shield
volcano
eroded
volcanoes
buried
conglomerates
conglomerates
turbidites, rusty schists
turbidites
mafic
volcanics
rising tonalite,
diorite, gabbro
plutons
older mafic terrane
C
WESLEMKOON
TONALITE
KILLER
CREEK
GABBRO
LINGHAM
LAKE
PLUTON
ELZEVIR
TONALITE

MAFIC INTRUSIVE ROCKS (unit 5)
GABBROIC TO DIORITIC DIKES AND PLUTONS

Unit 5 consists of gabbroic sills, plutons and stocks (Photo 9a, 9b) and basaltic and gabbroic dikes (Photo 9c, 9d) intrusive into both the Canniff Complex and the Grimsthorpe Group. Unit 5 also comprises gabbroic and dioritic dikes that cross-cut the Elzevir Tonalite, but which have been metamorphosed.

A variety of ages of dikes are likely present in the map area, based on cross-cutting relationships, rock type, and degree of preservation. Fine-grained basaltic to gabbroic dikes cutting the Canniff Complex may have served as feeders to mafic flows within the Grimsthorpe Group. Larger gabbroic masses intrude rocks of the Grimsthorpe Group and may be subvolcanic intrusions. Dikes cutting the tonalite plutons in the area are among the youngest rocks in the area, however, in the field it proved difficult to assign relative ages to the dikes, or to even recognize distinctive dike swarms in all but a few instances. As a consequence, unit 5 consists of a variety of rock units of different ages and petrogenesis, but of similar bulk rock composition.

Larger, fine-to medium-grained, gabbroic masses intrude the Grimsthorpe Group north of Skootamatta Lake and 1-2 km north of the northern boundary of the map area in Effingham Township. The latter body is well exposed on the hydro-transmission corridor in that area. Gabbro plutons of unit 5 also occur in the Grimsthorpe Group northeast of Lingham Lake. Large gabbro sills and small stocks are also present along the forest access road to Lingham Lake. Gossan zones are locally found along the contacts of these bodies, particularly the sills, where the intrude tuffaceous conglomerates and mudstones of the Grimsthorpe Group. Unit 5 gabbro bodies are overall finer grained, and generally more melanocratic, than either the Canniff Complex or the Killer Creek metagabbros (compare Photos 4a, 9a and 10a). North of Skootamatta Lake, in the Rainy Lake area north of the map area, and in the vicinity of Lingham Lake, intrusion breccias occur in the gabbroic rocks, with veinlets of anorthositic gabbro to tonalite form the matrix to the brecciated gabbro fragments (unit 5x) (Photo 9b). These intrusion breccias appear to be the result of migrating interstitial fluids that formed during the differentiation of the gabbro bodies, as little movement between gabbro blocks has occurred, the thin nature of crosscutting veinlets, and the absence of larger accumulations of the intersitial liquid. In contrast, intrusion breccias associated with emplacement of the Elzevir Suite tonalites (Photo 11c) are angular, show a mixing of fragment types, and in general, matrix is equal to, or more abundant than, the gabbroic blocks. Much of the gabbroic phase of the Lingham Lake pluton consists of melanocratic gabbros of unit 5. The most abundant rock type in these gabbroic bodies is melanocratic, fine- to medium-grained gabbro (unit 5b) (Photo 9a, 9b) and mesocratic, fine- to medium grained gabbro (unit 5a). Minor phases, found only in the largest gabbroic bodies, are anorthosite and anorthositic gabbro (unit 5c), coarse-grained gabbro (unit 5d), and feldspar porphyritic fine- or medium-grained gabbros (unit 5f, 5g).

Unit 5 dikes consist dominantly of fine- to medium-grained gabbro (unit 5a), feldspar porphyritic gabbro (unit 5f), and fine-grained gabbro to basalt (unit 5e). Dikes range from a few centimetres to 10 metres in width, most are 30 to 100 cm wide. Many small dikes (<1 m across) are not distinquished on the map face because of scale. Most dikes are vertical to sub-vertical, and have sharp contacts with country rocks. A variety of trends are present, however, 060^{o} is the dominant dike trend in the area, regardless of dike composition and texture. This may reflect the regional stress-field at the time of dike emplacement, and may suggests that many of the dikes were emplaced in a short time-interval. The dike trend does not parallel and regional structural trends, and it is unlikely that it reflects any pre-existing structure.

In thin section, most dikes consist of euhedral hornblende and plagioclase grains, in near equal amounts. Oxide minerals and epidoite are common accessory minerals. Ophitic texture is preserved in some dike rocks. Most dike rocks are better preserved in thin section than Cannif Complex rocks, but are not as well preserved as the surrounding host plutonic rocks, even where the dikes can be observed cross-cutting the host rocks.

A particularly distinctive dike rock that has no obvious counterpart in the main phases within the map area are grey-weathering, fine-grained gabbro dikes with well-developed cooling joints oriented perpendicular to the dike margins (Photo 9c). These dikes are vertical to sub-vertical, trend 060^{o}, cross-cut foliation within the Grimsthorpe Group rocks, and show no noticeable internal structural fabrics. In thin section, euhedral hornblende and plagioclase crystals define a pseudo-ophitic texture, with abundant late formed titanite and oxide minerals also being present. These dikes are particularly abundant in the Grimsthorpe Group adjacent to the Lingham Lake pluton, and may be related to the intrusion of the late phases of that body.

TABLE 9: Chemical analyses of dike rocks from the Grimsthorpe area.

wt%.	1	2	3
SiO_2	62.23	48.40	56.58
TiO_2	0.87	1.81	1.81
Al_2O_3	16.16	13.82	15.98
Fe_2O_3	1.60	4.03	3.67
FeO	5.26	9.69	5.03
MgO	2.54	6.39	2.49
MnO	0.06	0.22	0.21
CaO	4.07	10.69	5.47
Na_2O	3.83	2.13	4.26
K_2O	1.58	0.47	1.65
P_2O_5	0.31	0.22	0.76
CO_2	0.06	0.39	0.25
S	0.01	0.28	0.09
H_2O^+	0.98	1.34	0.94
H_2O-	0.16	0.18	0.19
LOI	0.80	1.00	1.00
Total	99.72	100.06	99.38
Mg#	40.32	46.1	34.75
Density	2.47	2.7	2.51
Ba	206	107	314
Be	<1	<1	<1
Co	11	41	9
Cu	20	39	14
Mo	<10	<10	<10
Nb	4	5	6
Ni	20	32	<5
Rb	49	15	45
Sc	12	45	18
Sr	288	167	485
Th	<10	<10	<10
V	99	363	71
Y	20	50	52
Zn	58	118	121
Zr	233	136	221

Sample No.	Sample Location	Rock Type	Unit	Reference
1) 90RME-001	8314840E 4967640N	lamprophyre dike	9d	this study
2) 90RME-002	6316690E 4967240N	mafic dike	10?	this study
3) 90RME-100	1312550E 4968820N	mafic dike	10?	this study

FELSITES AND MYLONITES (unit 6)

Felsic to Intermediate Gneisses

Unit 6 consists of recrystallized mylonitic rocks that represent the westward extension of two extensive shear zones documented by Easton and Ford (1991b) in the adjacent Mazinaw area. Unit 6 rocks occur mainly near Pringle Lake, immediately adjacent to the northeast corner of the map area and within Bon Echo Provincial Park. Consequently, these rocks are a minor component within the map area and are only briefly described herein. Easton and Ford (in prep.) provide a more exhaustive description of these rocks.

Rivers (1976) interpreted these rocks as mylonites because the layering in the rocks is much finer (<2 mm) in scale than typically observed in metamorphosed supracrustal rocks in the area, the grain size of calcite in calc-silicate and marble units varied by an order of magnitude between layers (0.2-200 mm) and the rock types displaying the layering varied along strike. These observations are similar to our own. In addition, quartzofeldspathic gneiss locally containing porphyroclasts of plagioclase are present, indicating that grain size reduction did occur. These gneisses also contain intercalated garnet and magnetite porphyroblasts bearing units (unit 6h) which probably developed during the second regional metamorpohic event to affect the Mazinaw Terrane (but which had little or no effect in the Grimsthorpe Domain). Rivers (1976) suggested that the protoliths were either fine-grained when mylonitization occurred, or mylonitization was very intense. Both suggestions probably apply.

Three main lithologic types are present within the shear zones. (1) Finely-laminated, pink, buff, or grey weathering, quartzofeldspathic gneisses ("felsites"), locally containing garnet, plagioclase or magnetite porphyroclasts (unit 6a). (2) Finely-laminated, green to dark green biotite-hornblende-plagioclase mafic gneisses (unit 6b). The mafic gneisses are commonly intercalated on a 5 to 30 m scale with the quartzofeldspathic gneisses. (3) Foliated, grey weathering, hornblende-biotite-plagioclase gneisses which contain randonmly oriented garnet+/-magnetite+/-hornblende porphyroblasts (unit 6h). These gneisses are sugary-textured, and resemble metawackes, although they shown no obvious bedding features, and form thick, homogeneous units. They may represent a mylonitized dioritic protolith, or a mylonitized sequence of compositionally homogeneous volcanic-derived metawackes. In addition to these units, protomylonites derived from granitic, gabbroic and supracrustal rocks (marbles, metawackes) are found locally within the shear zones.

Ayer (1979), who mapped the Pringle Lake area and the southern part of Bon Echo Provincial Park, interpreted many of these fine-grained rocks as metavolcanics of andesitic and dacitic composition. Primary textures indicative of a volcanic origin are absent in these rocks. It should be noted that when Ayer (1979) conducted his mapping, ductile mylonite zones had been little studied, and were poorly documented from the Grenville Province. Hence, interpretation of these fine-grained rocks as metavolcanic

rocks was reasonable at that time. In summary, although some of the rocks present in the Pringle Lake area may at one time have been intermediate to felsic volcanics or volcaniclastic sediments, intense mylonization in this area has destroyed primary textures in these rocks making protolith identification problematical.

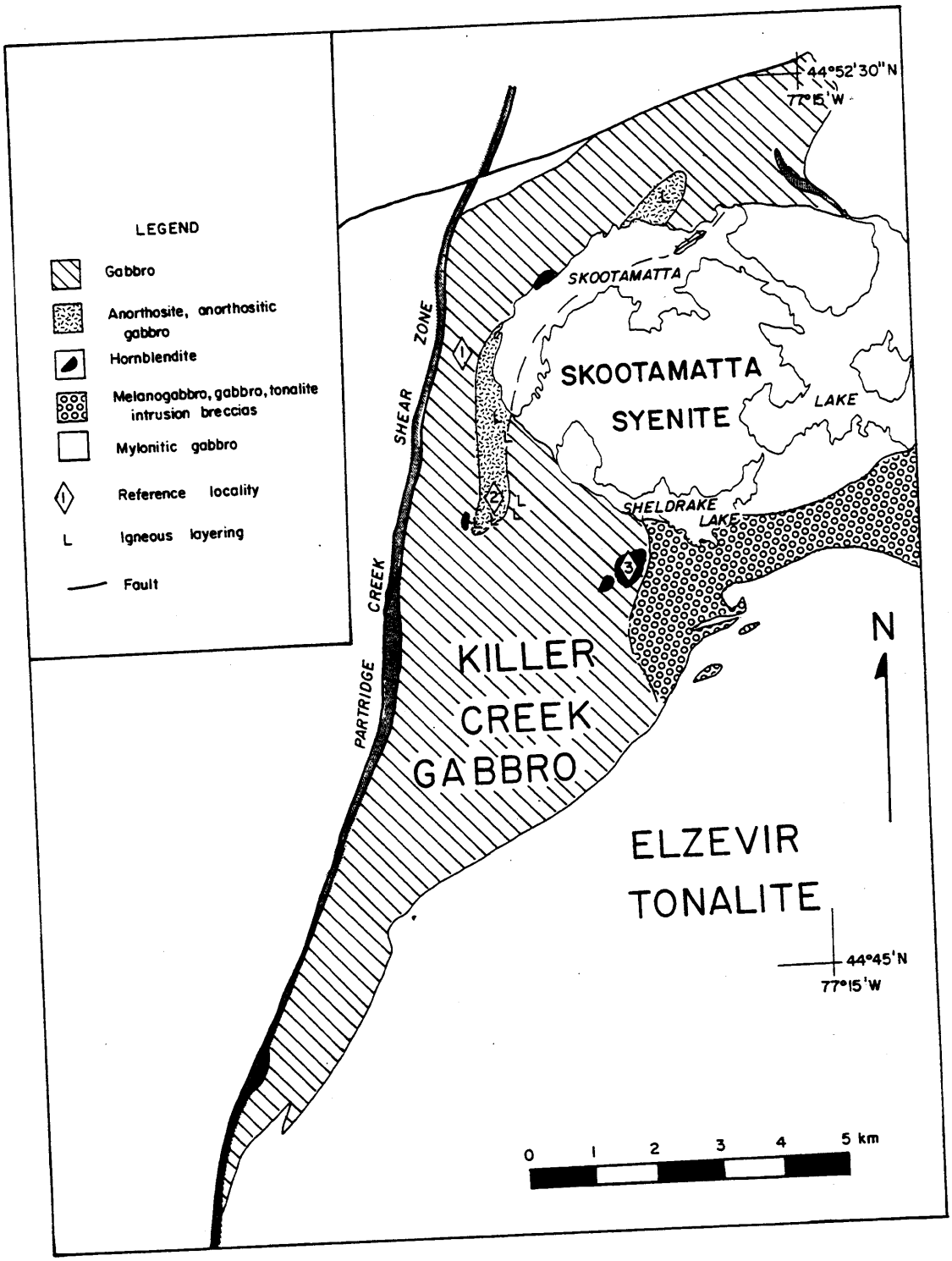
KILLER CREEK GABBRO (unit 7)

The Killer Creek Gabbro has been previously termed the Skootamatta complex (*e.g.* Di Prisco 1989) or the northwestern gabbro (Connelly 1986). We recommend that the term Skootamatta complex be abandonded for two reasons. First, to eliminate confusion with the better known and more established term the Skootamatta Syenite. Second, the Killer Creek Gabbro is intruded by the *ca.* 1270 Ma Elzevir Tonalite, which is itself roughly 180-200 Ma older than the Skootamatta Syenite. Thus, the Killer Creek body is clearly a unique intrusion, perhaps one of the oldest in the Central Metasedimentary Belt, and thus deserving of a distinctive name.

The body is named for Killer Creek, along which it is well exposed, particularly in roadcuts on the Skootamatta road. Reference sections are labelled in Figure 4 and 28 and include a 1 km stretch of the Skootamatta road along Killer Creek west of Skootamatta Lake which exposes gabbroic and anorthositic rocks; a section along a logging road 2 km south of the Skootamatta road which exposes gabbroic and anorthositic rocks and numerous outcrops of igneous layered rocks, and an area 1 km south of Sheldrake Lake which exposes hornblendites and melanocratic gabbros of the Killer Creek Gabbro. The term Suite is used in this report to refer to bodies of similar and composition and age present elsewhere in the map area that are geographically separate from the main Killer Creek Gabbro. The age of the body is not precisely known, although it is older than the *ca.* 1267 Ma Elzevir Tonalite (L.M. Heaman, geochronologist, Royal Ontario Museum, personal communication, 1990).

Composition of the Killer Creek Gabbro ranges from ultramafic to anorthositic, and igneous layering is preserved throughout the intrusion. The most abundant rock type consists of holocrystalline, medium-grained, hornblende gabbro with a colour index of 35-40 (unit 7a) (Photo 10a). Other varieties of gabbro include medium-grained melanocratic gabbro (colour index 40-60, unit 7b), generally found in association with hornblendite pods; coarse-grained gabbro (unit 7d), feldspar porphyritic gabbros with fine- to medium-grained matrices (unit 7f, 7g). Also present are several pod-like masses of hornblendite (unit 7h), commonly magnetite-bearing, that are several hundred metres in diameter. Hornblendite is found throughout the intrusion, generally in the core region. Anorthositic gabbros, gabbroic anorthosite and anorthosite (unit 7c) occur in the northwest corner of the Killer Creek Gabbro, and also preserve igneous layering (Photo 10b, 10c). Mylonitized equivalents of Killer Creek Gabbro (unit 7m) occur both in the Partridge Creek and Mooroton shear zones. Figure 28 is a sketch showing the distribution of major phases within the Killer Creek Gabbro.

Figure 28: Distribution of major phases within the Killer Creek Gabbro.



In thin section, the Killer Creek gabbros consist of interlocking hornblende and plagioclase laths. Plagioclase is well-formed, although locally some laths are distorted, due either to intital crystallization or subsequent deformation. Plagioclase typically has a dusty appearance due to scattered hematite grains and a slight reddish tinge. This dusty appearance and colouration is not present in any other plutonic rocks within the map area, with the exception of the Skootamatta Syenite. Plagioclase is typically labradorite in composition. Unlike the Canniff Complex and unit 5 gabbros, Killer Creek gabbro samples are fresher and do not show the grain size recrystallization due to metamorphism.

The only unit within the Killer Creek Grabbro that shows significant alteration and recrystallization are the hornblendites (unit 7h). Original hornblende is now pseudomorphed by actinolite aggregates, and plagioclase has been recrystallized to form fine-grained crystals f oligioclase composition. Severely altered samples also contain late, red biotite crystals, epidote and carbonate. Oxide minerals are also recrystallized and are finely dispersed throughout the hornblendite samples.

Within 1 km of the Skootamatta Syenite, secondary, red-brown biotite, formed from amphibole breakdown, is common within samples of the Killer Creek body. Also, within this zone, hornblende is typically recrystallized, and locally actinolite is present.

Geochemistry of the Killer Creek Gabbro

Samples of the Killer Creek Gabbro collected by the authors, Di Prisco (1989), Ayer (1979) and Chappell (1978) are listed in Table 5. Chemical variation within the suite is portrayed in Figures 11-17. As noted under the discussion of the geochemistry of the Canniff Complex metagabbros, the Killer Creek Gabbro shows two differentiation trends (Figure 11a) and has higher TiO_2 and P_2O_5 values than Canniff Complex metagabbros (Figure 17). This may indicate derivation of the Killer Creek Gabbro within a calcalkalic tectonic setting, possibly an arc, and is consistent with subsequent intrusion by the arc-derived tonalite magmas of the Elzevir Suite. In contrast, the Canniff Complex metagabbros formed in an extensional environment.

ELZEVIR TONALITE SUITE (unit 8)

Tonalitic to granodioritic rocks of the Elzevir Tonalite underlie most of the domain, and include the Elzevir, Canniff and Weslemkoon tonalites and the Lingham Lake pluton. Supracrustal rocks are preserved in narrow bands between the plutons, and it is likely that the plutons are continuous at depth. Gravity modelling suggests the plutons extend to a depth of 3-5 km (Real and Thomas 1987).

The Elzevir Tonalite may be a composite pluton, based on changes in grain size and textures between the northern and central parts of the body and the distribution of xenoliths (Easton and Ford 1990a, 1990b). The Lingham Lake pluton (Lingham Lake Complex of Lumbers 1969) consists mainly of medium-grained quartz diorite (Photo

11a) with numerous schileren-rich and mafic xenolith-rich zones (Photo 11b) that has intruded an older gabbroic body similar to the synvolcanic unit 5 gabbro present in the domain, which for mapping purposes is included as part of the pluton. It is probable that the Lingham Lake pluton represents a high-level cross-section through one of the tonalitic plutons, with the slightly more mafic composition the result of incorporation of mafic host rocks (Figure 25b).

Lingham Lake pluton

The Lingham Lake pluton (Lingham Lake Complex of Lumbers 1969, the term pluton is preferred over complex since in the 1983 Stratigraphic Code, the term complex applies to bodies containing rocks of several classes) is the most geological complex of the Elzevir Suite plutons within the map area. It consists of two main phases, an older gabbroic phase (unit 5), locally with large inclusions or roof pendants of metavolcanic rocks (unit 1), and a younger diorite, quartz diorite and melanodiorite (units 8e, 8j) (Photos 11a, 11b). Contact relationships between the two phases are sharp, however contact relationships within the phases (*e.g.* between diorite and quartz diorite) are diffuse and gradational. Schileren-rich and xenolith-rich zones (Photo 11b) are common throughout the Lingham Lake pluton, particularly along the eastern margin of the pluton in Lingham Lake.

In thin section, the Lingham Lake diorites are hydiomorphic granular rocks consisting mainly of oligioclase and green biotite, with minor quartz and orthoclase. Green biotite is typical of the Elzevir Suite within the map area. In addition, late, fine grained, disseminated white mica is ubiquitious in all diorite samples. This secondary white mica is also characteristic of the Elzevir Suite within the map area. Red-brown biotite occurs in some samples near the margin of the pluton. It is not known if this change in biotite colouration reflects differences in oxidation state between core (oxidized) and margin (reduced) of the pluton, or secondary metamorphic effects due to differential fluid flow along the pluton margin.

Canniff Tonalite

The Canniff Tonalite consists of roughly equal proportions of granodiorite and tonalite, with granodioritic phases being most common along the western and southwestern margin of the pluton. It is relatively homogeneous, and no inclusion-rich or intrusion breccias zones were observed within the body. Grain size is also relatively constant throughout the intrusion. The elongated form of the body contrasts with the oblate forms typical of the other Elzevir Suite plutons, and reflects the regional tectonic fabbric. The tonalite is flanked on both sides by Canniff Complex metagabbros, and the elongated form of the intrusion may reflect pre-existing structure in the host rocks.

Elzevir Tonalite

The Elzevir Tonalite (unit 8) consists of two main plutonic masses in the map area. The more northeasterly mass consists of roughly equal proportions of coarse-grained

tonalite and granodiorite both containing large quartz clots. This mass intrudes the Killer Creek Gabbro and as the contact with the tonalite is approached, diking becomes more abundant in the gabbroic rocks, and a sharp contact between the two bodies is difficult to define. This is especially true south of Sheldrake and Skootamatta lakes where a complex intrusion breccia zone is found between the Elzevir Tonalite and the Killer Creek Gabbro. The hornblendites and melanocratic gabbros of the Killer Creek Gabbro Suite are particularly abundant in this intrusion breccia zone.

The southerly and southwesterly mass, which extends south into the Elzevir area, is a medium-grained tonalite, with only very locallized granodioritic patches, and which lacks the distinctive quartz clots of the northerly mass. The southerly mass has a sharp contact with the gabbros, and diking into the gabbros and gabbro xenoliths are much less abundant along the tonalite-gabbro contact in this part of the area.

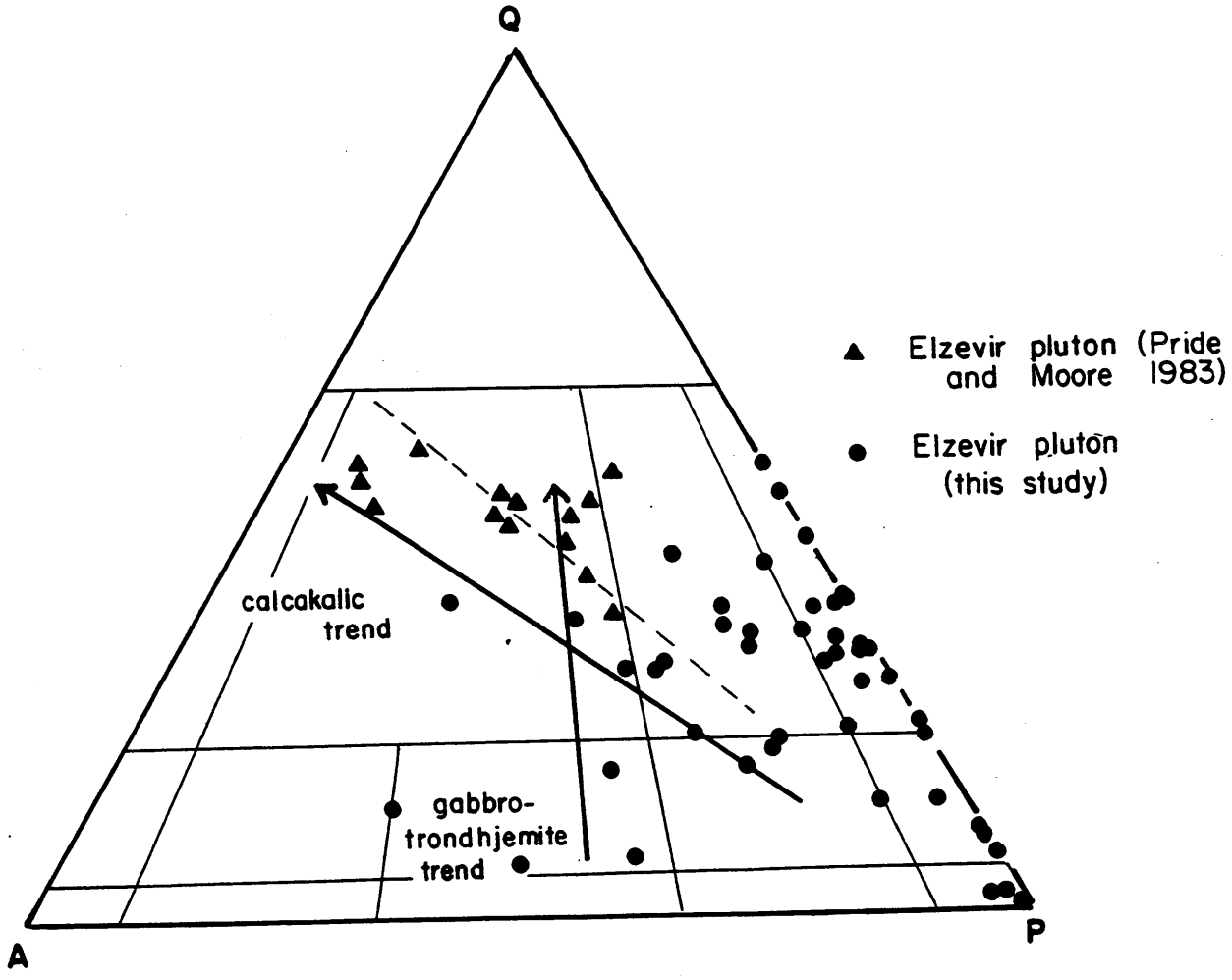
Fine-grained tonalite and plagioclase porphyritic dikes of tonalite composition cut gabbroic and tonalitic rocks in the eastern block and volcaniclastic sediments of the western block (unit 8f). These dikes also cut tonalites of the Elzevir pluton (Photo 11d). Several of these younger dikes are found in the vicinity of the United Reef Petroleums Limited gold property (Figure 4) and may in part be related to the gold mineralization. In addition, Moore and Morton (1986) reported "dacite" dikes from the Marble Lake area which are similar to these dikes that cut tonalites in the eastern block. Connelly *et al.* (1987) dated fine-grained tonalite dikes adjacent to the Elzevir Tonalite at 1229 +11/-4 Ma. This age is roughly 40 Ma younger than the age of the Elzevir Tonalite (1267 Ma, L. Heaman, geochronologist, Royal Ontario Museum, Toronto, Ontario, personal communication 1989). These younger tonalite dikes in the Grimsthorpe area may be equivalent of the dikes dated by Connelly *et al.* (1987). If so, then they represent an event common to the eastern and western blocks and the Marble Lake area.

In thin section, the Elzevir Suite tonalites are hypidiomorphic granular rocks consisting mainly of quartz, oligioclase and green biotite, with minor orthoclase. Quartz commonly occurs in clots, a texture also noted in the field in hand specimens. Green biotite is typical of the Elzevir Suite within the map area, and unlike the LIngham Lake pluton, no red-brown biotite was observed in any tonalite samples.

Late, disseminated, fine euhedral grains of white mica are ubiquitious in all tonalite samples and probably indicates a late, low-grade metamorphic event in the area after pluton emplacement. This secondary white mica event is widespread in the adjacent Mazinaw area, where it occurs in all rock units (Easton and Ford, in press). Whether the two late, white mica-forming events in the two areas can be directly related is open to speculation. Hanes *et al.* (1988) report Ar-Ar ages of *ca.* 900 Ma from muscovite samples from the Elzevir Tonalite south of the map area. These ages provide a minimum age on the timing of the late white mica event in the area.

Figure 29 is a QAP plot summarizing the modal composition of of the Elzevir Tonalite, and incorporates data mainly from the southern mass. Figure 29 also includes data collected by Di Prisco (1989) south of the Grimsthorpe area. Tonalite and granodiorite are the major phases of the pluton. The modal data presented here contrasts with data from Pride and Moore (1983) which shows more granodioritic to monzogranitic composition. In part this may be due to the fact that the data of Pride and Moore (1983) is normative, rather than modal; in part it may be an artifact of their sampling.

Figure 29: QAP plot showing composition variation within the Elzevir Tonalite. Note data from this study is modal, data from Pride and Moore is based on normative calculations. Consequently, data from this study should be considered more reliable.



Weslemkoon Tonalite

The Weslemkoon Tonalite covers an area of over 512 km^2 and can be divided into a northern and a southern lobe (Lumbers 1968, Figure 30). Only the southern lobe is located within the map area. The body is made up dominantly of leucotonalite to tonalite, however several large areas of granodiorite are present, as well as intrusion breccia zones containing abundant gabbro (unit 5) and metavolcanic (units 1 and 3) xenoliths.

Figure 30 shows the distribution of the main rock types within the Weslemkoon Tonalite. Of all the tonalite bodies within the map area, the Weslemkoon shows the widest variation in rock types and textures, particularly within the northern lobe. Intrusion breccias (Photo 11c) are particularly abundant near the "node" where the two lobes of the pluton join, and along the southeastern margin of the northern lobe. In addition, north of Rainy Lake, 1 km north of the northern boundary of the Grimsthorpe area, tonalite intrusion breccias occur roughly 2 km distant from the main mass of the Weslemkoon Tonalite, and may represent the presence of a larger tonalite mass at depth.

Geochemistry of the Elzevir Tonalite Suite

Analyses of various plutons of the suite collected from the Grimsthorpe and immediately adjacent areas by the authors are tabulated in Table 10. Geochemical trends are shown in Figure 31 which, in addition to the samples listed in Table 10, includes samples collected by Di Prisco (1989), Chappell (1978) and Ayer (1979) immediately adjacent to the map area.

On an AFM plot (Figure 31), the diorites and tonalites appear to define a suite, with minor overlap in composition between tonalite and dioritic phases. The diorites show little overlap with Killer Creek Gabbro or hornblende diorite phases of the Kaladar Complex (data of Chappell 1978).

The geochemistry of the Elzevir Tonalite has been studied by Pride and Moore (1983) who classified it as a high-alumina tonalite that probably formed in an island arc environment. They also suggested a genetic link between Mazinaw Group dacites and Elzevir Suite tonalites, with both being derived from the melting of lower crustal material.

Wu *et al.* (1991) describe the geochemistry of the Weslemkoon Tonalite, and compared the chemistry of lower and higher metamorphic grade parts of the body. These results are described more fully in the section on *Metamorphism*.

Figure 30: Sketch map showing the generalized structural and lithologic features of the Weslemkoon Tonalite. Modified after Lumbers (1968) with the addition of additional data in the Grimsthorpe and Effingham township areas.

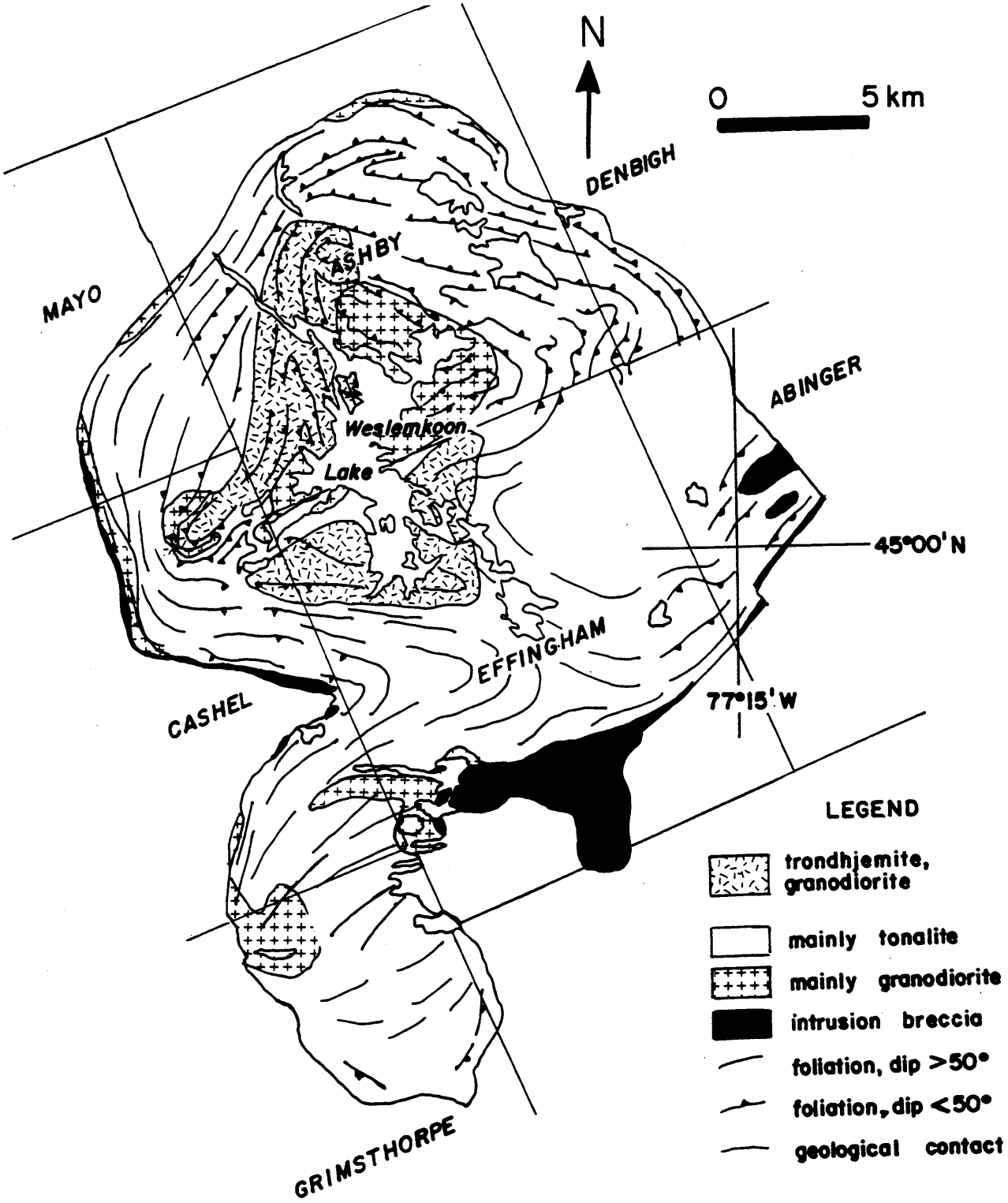


Figure 31: AFM plot showing chemical variation within the Elzevir Tonalite Suite. Diorite samples are from the Lingham Lake pluton and the Kaladar Complex area (Chappell 1978). Tonalite and granodiorite samples are from the Elzevir and Weslemkoon Tonalites. Field of Killer Creek Gabbro shown for comparison.

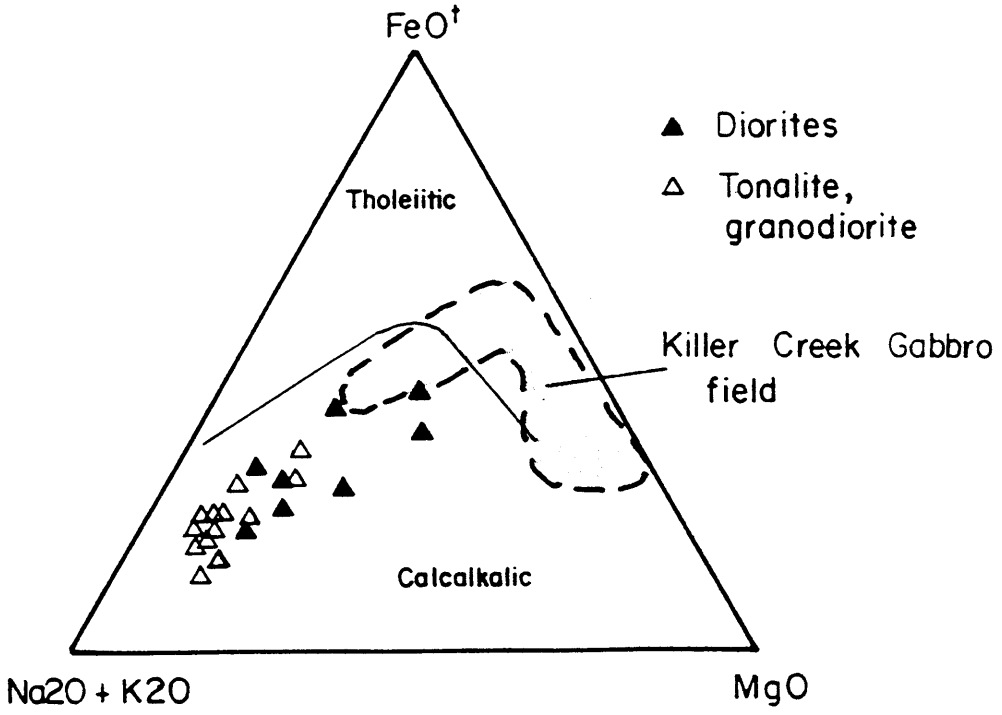


TABLE 10: Chemical analyses of Elzevir Suite diorites, granodiorites and tonalites (unit 8) from the Grimsthorpe and Elzevir areas.

wt%.	1	2	3	4	5	6	7
SiO_2	69.01	68.58	68.77	70.10	54.30	67.10	69.80
TiO_2	0.36	0.31	0.32	0.26	1.83	0.34	0.44
Al_2O_3	15.91	15.89	16.14	16.50	17.30	17.50	14.70
Fe_2O_3	0.45	0.61	0.52	0.01	0.74	0.19	0.09
FeO	1.97	1.34	1.55	1.78	5.60	2.09	2.40
MgO	0.75	0.88	0.91	0.90	2.97	1.43	0.92
MnO	0.04	0.04	0.03	0.03	0.10	0.04	0.04
CaO	2.47	2.37	2.94	2.19	5.01	3.43	1.99
Na_2O	4.56	4.10	4.04	5.09	4.34	4.70	3.43
K_2O	2.39	3.51	2.63	1.50	4.84	1.70	3.67
P_2O_5	0.10	0.09	0.09	0.07	0.94	0.06	0.09
CO_2	0.90	0.22	0.18	0.11	0.41	0.22	0.85
S	0.00	0.00	0.01	0.01	0.02	0.01	0.01
H_2O^+	0.66	0.49	0.46	0.57	0.37	0.67	0.54
H_2O-	0.09	0.06	0.05	0.07	0.12	0.08	0.08
LOI	1.70	0.80	0.50	0.80	0.40	0.90	1.00
Total	99.66	98.49	98.64	99.20	98.90	99.50	99.10
Mg#	36.01	45.36	44.56	47.27	45.79	52.99	39.79
Density	2.37	2.36	2.37	2.67	2.79	2.70	2.67
Ba	358	388	351	ND	ND	ND	ND
Be	1	3	2	1	1	<1	2
Co	5	5	6	<5	11	7	<5
Cr	ND	ND	ND	ND	ND	ND	ND
Cu	<5	7	13	7	8	<5	13
Mo	<10	<10	<10	<10	<10	<10	<10
Nb	3	5	3	5	<3	4	9
Ni	<5	8	10	<5	14	9	11
Rb	48	97	77	43	76	36	113
Sc	4	4	5	2	11	5	4
Sr	185	274	312	393	2265	449	251
Th	<10	<10	<10	<10	<10	<10	<10
V	33	20	25	13	108	28	23
Y	5	6	5	<5	30	<5	12
Zn	13	42	45	51	81	52	51
Zr	141	152	131	166	176	197	133

ND = not determined, bd = below detection limits

Sample No.	Sample Location	Rock Type	Unit	Reference
Weslemkoon and Elzevir tonalites				
1) 90RME-0020	314940E 4967775N	tonalite dike	8t	this study
2) 90RME-0112	311910E 4968970N	granodiorite	8b	this study
3) 90RME-0113	308340E 4968260N	tonalite	8a	this study
4) 89GDP-0353	312895E 4948156N	tonalite	8a	Di Prisco 1989
5) 89GDP-0708	307100E 4956000N	melanodiorite	8e	Di Prisco 1989
6) 90RME-0889	321325E 4936160N	tonalite	8a	Di Prisco 1989
7) 90RME-3410	315870E 4939055N	tonalite	8a	Di Prisco 1989

TABLE 10: (continued).

wt%.	8	9	10	11	12	13	14
SiO_2	70.68	72.87	67.58	60.27	59.90	55.48	66.90
TiO_2	0.30	0.28	0.57	0.92	0.90	0.77	0.49
Al_2O_3	15.81	14.54	15.37	17.21	16.80	17.44	15.68
Fe_2O_3	0.41	0.55	0.88	1.75	1.94	1.27	1.08
FeO	1.28	1.73	2.77	4.23	4.83	5.96	2.79
MgO	1.36	0.67	2.18	2.61	0.00	4.72	1.39
MnO	0.03	0.04	0.06	0.10	0.11	0.14	0.06
CaO	2.39	1.83	3.84	4.91	5.14	7.69	3.08
Na_2O	5.85	4.85	4.84	3.45	3.83	2.80	3.50
K_2O	1.74	2.53	1.67	2.35	2.12	1.63	3.46
P_2O_5	0.12	0.11	0.23	0.25	0.25	0.13	0.14
CO_2	ND	ND	ND	0.53	0.29	0.41	0.34
S	0.04	0.00	0.02	0.01	0.01	0.02	0.01
H_2O^+	ND	ND	ND	ND	ND	ND	ND
H_2O-	ND	ND	ND	ND	ND	ND	ND
LOI	ND	ND	ND	1.40	0.80	1.10	0.80
Total	100.01	100.00	100.01	98.59	96.12	98.46	98.92
Mg#	59.51	34.92	52.17	44.48	ND	54.22	39.70
Density	2.36	2.35	2.41	2.47	2.46	2.55	2.40
Ba	212	296	269	379	290	222	386
Be	ND	ND	ND	2	2	2	2
Co	ND	ND	ND	13	15	24	8
Cr	15	16	34	ND	ND	ND	ND
Cu	17	4	4	14	24	44	8
Mo	ND	ND	ND	<10	<10	<10	<10
Nb	7	15	11	12	12	5	13
Ni	13	6	31	19	24	45	14
Rb	39	59	40	76	69	49	83
Sc	ND	ND	ND	13	11	20	6
Sr	185	274	312	393	2265	449	251
Th	ND	ND	ND	<10	<10	<10	<10
V	ND	ND	ND	91	80	148	36
Y	5	5	13	15	15	16	14
Zn	30	58	61	80	82	80	54
Zr	142	214	150	154	152	81	174

ND = not determined, bd = below detection limits

Sample No.	Sample Location	Rock Type	Unit	Reference
Weslemkoon and Elzevir tonalites				
8) C74-145		granodiorite	8b	Chappell 1978
9) C74-242		granodiorite	8b	Chappell 1978
10) GR-136		granodiorite	8b	Chappell 1978
Lingham Lake pluton				
11) 90RME-0151	307670E 4959240N	diorite	8j	this study
12) 90RME-0153	308040E 4959420N	diorite	8j	this study
13) 90RME-0159	307800E 4958150N	melanodiorite	8e	this study
14) 90RME-0160	306890E 4959210N	diorite	8j	this study

SKOOTAMATTA SYENITE (unit 9)

The contact of the Skootamatta Syenite (unit 9) roughly follows the shape of Skootamatta and Sheldrake lakes, and is coincident with the 1500 gamma contour on the regional aeromagnetic map (GSC 1952). The body has a well-defined aeromagnetic signature distinct from other plutons in the Grimsthorpe area, but similar to the nearby Mount Moriah and Gawley Creek syenites which also occur within the Elzevir Terrane (Figure 3). Two main phases are present in the Skootamatta Syenite; a grey, medium-grained to coarse-grained biotite-hornblende-monzodiorite to monzonite phase (unit 9d) that is found locally throughout the body which appears to be cut by a pink, medium-grained to coarse-grained biotite syenite phase (unit 9a, 9c) that makes up the bulk of the intrusion. Fine-grained syenite dikes (unit 9b) also occur throughout the intrusion. Ultrapotassic lamprophyric dikes (unit 9d) are locally present along the margin of the body, but are less abundant then in the nearby Mount Moriah Syenite (Easton, unpublished data).

Figure 32 shows the extent of the Skootamatta Syenite and the distribution of major rock types within the body. As far as could be determined, there was no systematic variation in rock types between the core and margin of the intrusions. Contacts with the country rocks are sharp, and syenite dikes were not found more than a kilometre from the contact. Xenoliths of the country rocks are rare. Some metasomatism may have occurred along the contact, as gabbroic rocks of the Killer Creek Gabbro locally become biotite-bearing adjacent to the contact (unit 7n), and secondary feldspar and felspathoid growth occurs in some gabbros (unit 7n) near the contact with the syenite. In terms of rock types and textures, the Skootamatta Syenite most closely resembles the Gawley Creek Syenite. The Skootamatta, Mount Moriah and Gawley Creek syenites are part of a suite of roughly 1090-1075 Ma old potassic and ultrapotassic plutons that are found in the Central Metasedimentary Belt in Ontario and Quebec, termed the Skootamatta Suite by Easton (1992a).

The Skootamatta Syenite was first mapped in 1869 by H.G. Vennor (Vennor 1870) of the Geological Survey of Canada as a suite of diorites and syenites. Meen (1944) distinguished the syenites on his map, but in his report he only discusses the Mount Moriah syenite. In these and subsequent works, it was thought that the gabbros, diorites and syenites in the area were genetically related, and this suite was referred to as the Skootamatta Complex. Connelly (1985) established that the gabbros were older than the Elzevir Tonalite (consistent with our observations), and introduced the term Skootamatta Stock for the resultant monzodiorites and syenites. Easton and Ford (1990a) suggested that the body be formally named the Skootamatta Syenite, with type areas as located on Figure 32, in accordance with the North American Stratigraphic Code.

Harris (1991) studied the petrography of the Skootamatta Syenite in detail, and his data augments the observations made by the authors. Petrographically, three main rock

types are present in the Skootamatta Syenite; monzodiorite, monzonite, and syenite. Of these rock types, syenite comprises over 50% of the exposed surface area of the pluton. Harris (1991) reports one sample of quartz monzonite, however it lies on the mozonite-quartz monzonite boundary and was not distinquished as such in the field. Figure 32 illustrates the distribution of the three rock types in the pluton. No systematic variation is noted. In addition, the three rock types can be further subdivided on the basis of mafic minerals into a hornblende-pyroxene-bearing suite and a biotite-bearing-suite. Generally, hornblende-pyroxene-biotite-bearing monzodiorites, monzonites and syenites are silica-poor in comparison to their biotite-only-bearing counterparts. Table 11, adapted from Harris (1991) summarizes the petrography of samples from the Skootamatta Syenite. It should be noted that a variety of fine-grained syenite and lamprophyre dikes cut the coarse-grained rocks of the pluton, suggesting a complex emplacement history.

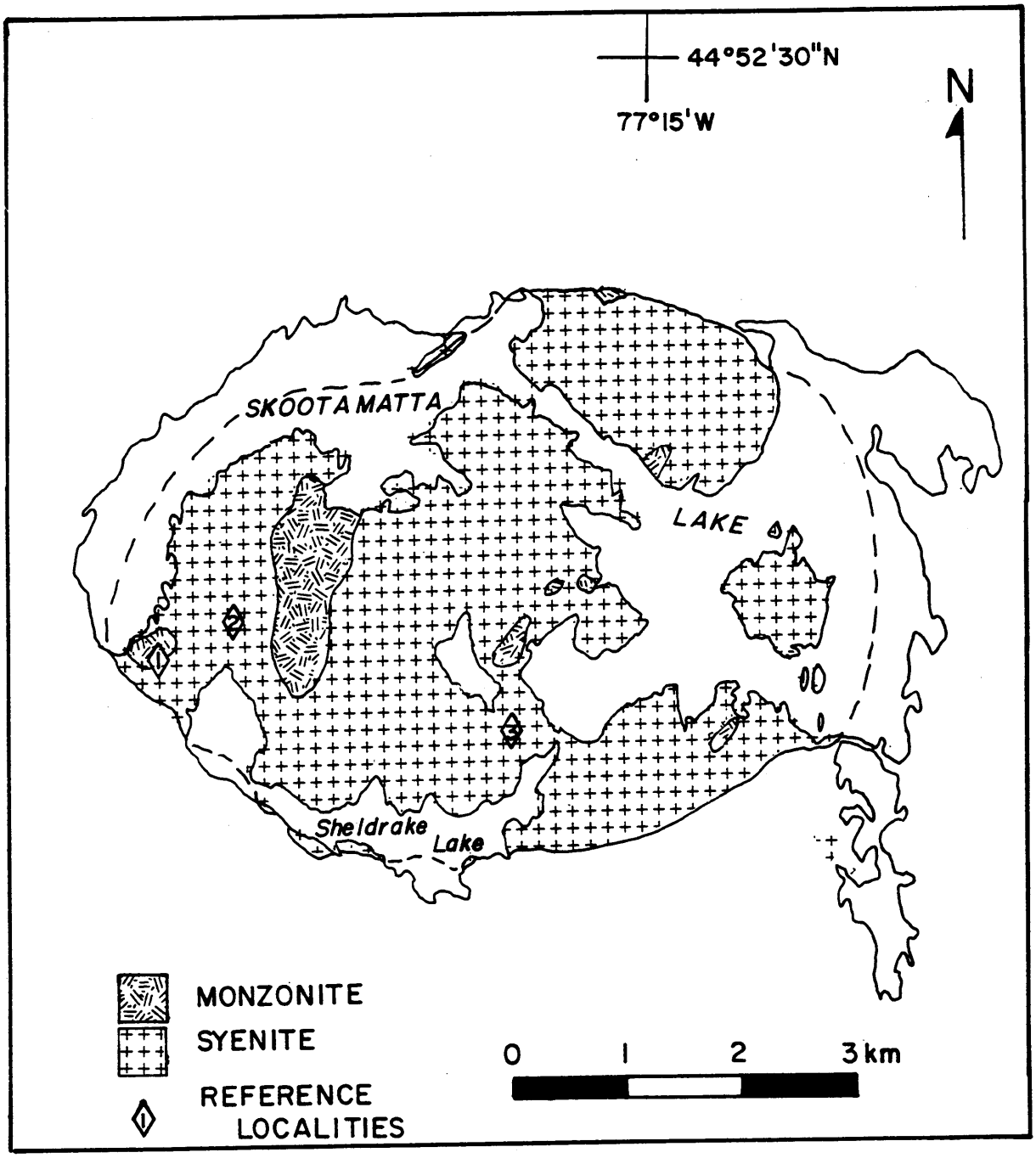
Trachytic texture is present in the Mount Moriah Syenite (Easton, unpublished data) and defines a flow foliation in the margin of the pluton. Trachytic texture was not observed within the Skootamatta Syenite. A weak foliation defined by biotite chains occurs sporadically in the biotite-syenite phase of the Skootamatta Syenite. Corriveau (1989) regarded similar textures in the Kensington Syenite as a flow foliation which could be mapped out. This texture was too weak and sporadic within the Skootamatta Syenite to allow it to be mapped systematically.

Table 11: Average modal mineralogy values for samples of the Skootamatta Syenite studied by Harris (1991). Values are in weight percent.

Modal Minerals	Monzodiorite	Monzonite	Quartz Monzonite	Syenite
Microcline	8.0	35.0	35.0	57.0
Orthoclase	6.5	4.8	5.0	3.6
Plagioclase	40.0	31.3	35.0	19.0
Biotite	22.5	14.4	10.0	8.6
Amph/Pyroxene*	3.0	3.8	0.0	1.1
Quartz*	0.0	tr	5.0	0.4
Apatite	7.0	3.4	3.0	1.7
Titanite	3.5	0.5	2.0	1.3
Opaques	6.5	2.4	3.0	1.7
Zircon	tr	tr	tr	tr
Colour Index	32.0	20.5	13.0	11.0
An%	22-27	15-19	11-17	9-17

* mineral not present in all samples

Figure 32: Sketch map showing the distribution of major rock types in the Skootamatta Syenite.



Monzodiorites

Monzodiorites are mesocratic (colour index 25-40), homogeneous in composition, holocrystalline, medium- to fine-grained rocks, containing microcline, orthoclase, plagioclase, biotite. Amphibole and pyroxene are also common, but not essential, consitutents. Mesoperthite and antiperthite commonly contain replacement or patchy textures, are fine-grained (<1 mm), anhedral, and typically contain sericite as an alteration product (Harris 1991). Plagioclase and microcline occur as anhedral, irregular-shaped crystals, either 1.5-3 mm or <0.5 mm in size. Albite and pericline twinning may be present in plagioclase. Sericite occurs in both minerals as an alteration product, but secondary calcite occurs only in plagioclase cyrstals. Where pyroxene is present, it is green, weakly pleochroic, and is always rimmed by a strongly pleochroic amphibole, and it is likely the amphibole is a reaction product of the pyroxene (Harris 1991). Biotite is fine-grained (<1 mm), but has a "chain-like" habit, with lengths up to 15 mm. Bent or fractured crystals are common, and chlorite alteration is locally present. Both red-brown and green biotite occurs. Accessory minerals include apatite, titanite, and zircon. Harris (1991) notes the presence of both magnetite and ilmenite as opaques.

Monzonites

Monzonites are leuco- to mesocratic (colour index 10-35), homogeneous in composition, blue-grey to smokey-grey, holocrystalline, massive to slightly foliated medium- to coarse-grained rocks containing microcline, orthoclase, plagioclase and biotite. Amphibole and pyroxene are also common, but not essential, consitutents. Braided or replacement type mesoperthite is present as medium- to fine-grained (<4 mm) anhedral crystals (Harris 1991). Most mesoperthites are strained and zoned. Plagioclase and microcline occur as coarse- to fine-grained (<6.0 mm) anhedral crystals, with plagioclase being highly sericitized and microcline rarely altered (Harris 1991). Amphibole and pyroxene occur as separate, anhedral crystals. In the one quartz monzonite sample, quartz is fine-grained (< 1 mm), and occus as anhedral, patchy crystals adjacent to biotite. Biotite flakes are generally <6 mm in size, and commonly bent or fractured. Biotite "chains" up to 40 mm long are present in some samples, giving the rock a pyramidal cleavage (Harris 1991). Both green and red-brown biotite occurs. Accessories are similar to those present in the monzodiorites.

Syenites

Syenites are leucocratic (colour index 7-20), homogeneous in composition, pink to reddish-pink, holocrystalline, massive, fine- to coarse-grained rocks containing microcline, orthoclase, plagioclase and biotite. Amphibole and pyroxene are also common, but not essential, consitutents. Interlocking, braided and replacement type mesoperthite is present as medium- to fine-grained (<4 mm) anhedral crystals (Harris 1991). Plagioclase and microcline occur as medium- to fine-grained (<3.0 mm) anhedral crystals, and may show well-developed twinning. Where quartz is present, it is fine-grained and anhedral, generally occurring adjacent to biotite. Amphibole and pyroxene

occur as separate, anhedral crystals. Biotite flakes are generally <5 mm in size, and commonly bent or fractured, and always red-brown in colour. Chlorite alteration is prominent. Accessories are similar to those present in the monzodiorites.

Geochemistry

Twenty samples of the Skootamatta Syenite were analyzed for major and trace elements by the Geoscience Laboratories of the Ontario Geological Survey. Results are presented in Tables 12 and 13. Three main chemical groups are present, which generally correspond with the three main rock groupings of the body (Table 12). There does not appear to be any significant geochemical distinction between amphibole-pyroxene-biotite-bearing and biotite-only-bearing samples, although Harris (1991) suggests that the amphibole-pyroxene-biotite suite is metaluminous, whereas the biotite-bearing suite is peraluminous to metaluminous. All samples are alkalic, and show ultrapotassic to shoshonitic affinities (Figure 33).

TABLE 12: Key chemical differences between monzodiorites, monzonites, and syenites within the Skootamatta Syenite.

Consitutent	Mafic	Monzonites	Syenites
SiO_2	<51.5	51.5-56	>56.0
Al_2O_3	<16.1	16.1-18.9	>16.3<20.5
Fe_2O_3	>10	5.8-10	<5.8
MgO	>3.1	1.9-3.1	<1.9
CaO	>5	3-5	<3
P_2O_5	>1.3	0.7-1.3	<1.3

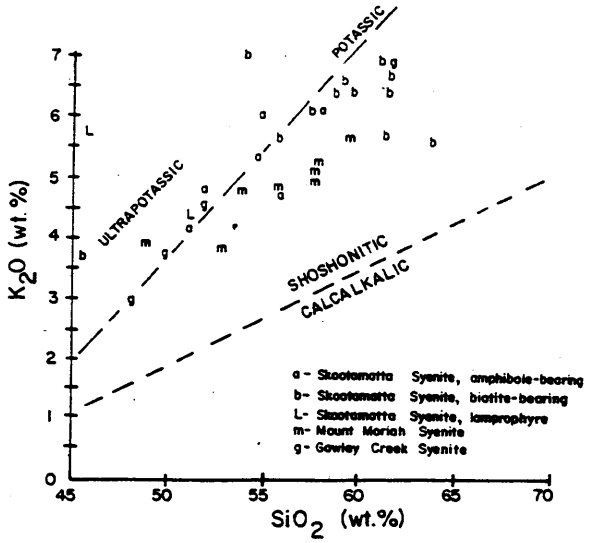


Figure 33: K_2O versus SiO_2 plot showing the ultrapotassic to shosonitic character of the Skootamatta Syenite (fields after Foley et al. 1987) All samples plot as alkalic using the classification of Irvine and Baragar 1971). Samples from the Mount Moriah and Gawley Creek syenites are shown for comparison.

TABLE 13: Chemical analyses of Skootammata Suite rocks (unit 9) from the Grimsthorpe area.

wt%.	1	2	3	4	5	6	7	8	9
SiO_2	47.67	57.90	54.59	55.79	51.02	70.43	55.95	61.56	51.88
TiO_2	1.66	0.60	1.19	0.94	1.59	0.15	1.09	0.78	1.55
Al_2O_3	16.69	20.29	17.61	18.87	15.18	14.37	19.20	17.98	18.04
Fe_2O_3	5.44	1.72	8.03	5.88	9.74	2.38	6.24	4.40	8.21
FeO	6.32	2.26	ND	ND	ND	ND	ND	ND	ND
MgO	6.38	1.32	2.37	2.05	4.31	0.18	1.95	1.04	2.82
MnO	0.14	0.07	0.12	0.09	0.16	0.01	0.08	0.08	0.11
CaO	7.92	2.62	4.16	3.62	6.77	1.08	4.34	1.28	4.92
Na_2O	2.99	4.84	4.47	4.56	3.96	4.17	5.01	5.10	4.18
K_2O	1.63	5.53	5.24	5.55	4.14	5.33	4.67	6.61	4.75
P_2O_5	0.85	0.45	0.96	0.69	1.38	0.07	0.73	0.25	1.22
CO_2	0.12	0.09	0.09	0.56	0.21	0.63	0.08	0.05	0.91
S	0.33	0.01	0.06	0.02	0.03	0.14	0.01	0.01	0.03
H_2O^+	1.06	0.50	ND	ND	ND	ND	ND	ND	ND
H_2O-	0.24	0.14	ND	ND	ND	ND	ND	ND	ND
LOI	1.00	0.80	0.40	1.00	0.60	0.80	0.30	0.50	0.90
Total	99.44	98.34	99.14	98.99	98.85	98.97	99.56	99.58	98.58
Mg#	50.34	38.19	36.89	40.84	46.70	13.03	38.23	31.88	40.48
Density	2.62	2.41	2.44	2.42	2.50	2.32	2.43	2.37	2.46
Ba	1479	3272	ND	ND	ND	ND	ND	ND	ND
Be	1	1	2.3	0.5	2	4	1	3	1.5
Co	45	8	15	6	23	4	10	2	10
Cu	69	<5	26	10	8	25	17	5	10
Mo	<10	<10	<10	<10	<10	<10	<10	<10	<10
Nb	3	3	13	3	11	14	5	16	11
Ni	147	5	12	3	49	4	6	2	4
Rb	29	66	112	71	96	193	86	147	89
Sc	18	5	7	6	12	1	5	6	8
Sr	2399	2163	2354	2218	2258	600	2960	401	2497
Th	<10	<10	16	<10	13	51	11	17	6
V	238	33	102	52	141	18	76	25	92
Y	15	12	41	22	47	22	27	31	35
Zn	171	72	118	95	163	16	107	63	124
Zr	118	96	272	128	204	228	197	220	229

ND = not determined, bd = below detection limits

Sample No.	Sample Location	Rock Type	Unit	Reference
1) 90RME-0118	317818E 4966275N	monzonite	9c	this study
2) 90RME-0119	318560E 49966300N	syenite	9a	this study
3) 90RME-2004	321000E 4965550N	monzonite	9c	this study
4) 90RME-2005	320100E 4966850N	monzonite	9c	this study
5) 90RME-2006	320980E 4966250N	monzonite	9c	this study
6) 90RME-2014	319400E 4967450N	felsite dike		this study
7) 90RME-2019	322200E 4967950N	syenite	9a	this study
8) 90RME-2022	322300E 4969200N	syenite	9a	this study
9) 90RME-2023	321300E 4968900N	monzonite	9c	this study

TABLE 13 (continued):

wt%.	10	11	12	13	14	15	16	17	18
SiO_2	74.88	45.79	63.69	61.05	53.96	58.85	61.28	51.17	61.45
TiO_2	0.02	1.58	0.52	0.58	1.32	0.64	0.83	1.41	0.62
Al_2O_3	13.28	16.06	17.04	18.88	18.36	18.63	16.34	15.78	17.96
Fe_2O_3	1.08	10.74	4.09	3.94	6.95	4.76	5.44	10.07	4.18
FeO	ND	ND	ND	ND	ND	ND	ND	ND	ND
MgO	0.07	5.03	0.92	1.21	2.38	1.42	1.48	3.14	1.19
MnO	0.00	0.16	0.05	0.05	0.10	0.05	0.06	0.15	0.06
CaO	0.35	5.91	1.41	1.47	3.10	2.27	2.37	5.13	1.94
Na_2O	3.35	3.03	5.35	5.13	3.71	4.99	4.31	4.69	4.75
K_2O	6.16	5.37	5.47	6.82	6.94	6.31	5.60	4.08	6.33
P_2O_5	0.01	2.24	0.26	0.35	0.80	0.45	0.48	1.78	0.25
CO_2	0.08	1.55	0.07	0.07	0.07	0.45	0.10	0.13	0.88
S	0.00	0.02	0.01	0.01	0.02	0.05	0.03	0.01	0.06
H_2O^+	ND	ND	ND	ND	ND	ND	ND	ND	ND
H_2O-	ND	ND	ND	ND	ND	ND	ND	ND	ND
LOI	0.10	3.60	0.40	0.50	1.40	0.50	0.50	1.80	0.70
Total	99.30	99.51	99.20	99.98	99.04	98.87	98.69	99.20	99.43
Mg#	11.38	48.12	30.82	37.82	40.41	37.14	35.01	38.18	36.05
Density	2.30	2.51	2.36	2.37	2.42	2.38	2.38	2.47	2.37
Ba	ND	ND	ND	ND	ND	ND	ND	ND	ND
Be	3	4	3.5	1	1	1	2	3.6	2.7
Co	1	21	5	3	4	5	10	15	2
Cu	3	4	5	4	15	10	6	7	5
Mo	<10	<10	<10	<10	<10	<10	<10	<10	<10
Nb	17	19	26	5	5	7	18	29	15
Ni	3	28	4	2	3	4	7	8	3
Rb	329	214	143	89	101	154	161	105	111
Sc	1	9	2	4	9	4	4	8	4
Sr	135	1295	991	755	1856	1193	1300	2498	660
Th	21	13	30	3	2	9	26	20	14
V	1	159	36	17	54	29	68	115	25
Y	17	46	33	13	22	24	29	58	20
Zn	10	140	51	58	102	57	69	140	57
Zr	85	377	394	87	115	179	354	485	113

ND = not determined, bd = below detection limits

Sample No.	Sample Location	Rock Type	Unit	Reference
10) 90RME-2024	321300E 4968900N	felsite		this study
11) 90RME-2025	321650E 4969250N	lamprophyre	9d	this study
12) 90RME-2032	319600E 4965200N	syenite	9a	this study
13) 90RME-2033	319600E 4965200N	syenite	9a	this study
14) 90RME-2054	317820E 4966260N	monzonite	9c	this study
15) 90RME-2055	317980E 4966330N	syenite	9a	this study
16) 90RME-2056	317980E 4966330N	syenite	9a	this study
17) 90RME-2057	318690E 4966900N	lamprophyre	9d	this study
18) 90RME-2074	323680E 4965360N	syenite	9a	this study

TABLE 13 (continued):

wt%.	19	20	21	22	23	24	25	26	
SiO_2	68.56	73.31	54.85	58.03	59.66	59.28	57.51	45.61	
TiO_2	0.27	0.13	1.18	0.78	0.28	0.66	0.90	2.27	
Al_2O_3	16.10	13.90	17.67	18.65	20.15	18.84	18.37	14.86	
Fe_2O_3	2.65	1.87	7.62	5.11	2.40	5.05	5.45	15.05	
FeO	ND	ND	ND	ND	ND	ND	ND	ND	
MgO	1.35	0.20	2.29	1.59	0.59	1.52	1.51	4.59	
MnO	0.04	0.00	0.12	0.10	0.02	0.08	0.06	0.13	
CaO	2.83	0.33	3.45	2.85	2.18	1.96	2.94	6.05	
Na_2O	4.60	3.60	4.74	5.10	5.46	4.90	4.79	3.43	
K_2O	2.88	5.54	5.98	6.03	6.35	6.51	6.03	3.68	
P_2O_5	0.05	0.02	0.79	0.48	0.23	0.44	0.48	2.11	
CO_2	0.23	0.16	0.08	0.08	0.76	0.05	0.46	0.85	
S	0.03	0.01	0.00	0.03	0.03	0.01	0.01	0.08	
H_2O^+	ND	ND	ND	ND	ND	ND	ND	ND	ND
H_2O-	ND	ND	ND	ND	ND	ND	ND	ND	ND
LOI	0.60	0.30	1.00	0.40	1.60	0.7	0.90	2.20	
Total	99.93	99.20	99.69	99.12	98.92	99.94	98.94	99.98	
Mg#	50.22	17.48	37.31	38.13	32.74	37.35	35.43	37.66	
Density	2.36	2.31	2.43	2.40	2.36	2.38	2.40	2.54	
Ba	ND	ND	ND	ND	ND	ND	ND	ND	
Be	2	4	3	1	2	1	1	2	
Co	6	2	10	7	6	5	7	32	
Cu	4	5	10	14	28	5	7	39	
Mo	<10	<10	<10	<10	<10	<10	<10	<10	
Nb	11	17	28	8	7	9	8	14	
Ni	16	3	3	4	3	3	4	15	
Rb	84	222	123	93	100	99	79	84	
Sc	5	1	9	6	1	4	5	12	
Sr	343	264	1921	1814	2132	1047	1571	1563	
Th	7	65	13	6	12	3	1	3	
V	21	5	72	46	23	34	48	198	
Y	10	19	51	27	10	23	23	43	
Zn	47	17	127	98	38	78	82	175	
Zr	120	180	531	277	256	137	721	254	

ND = not determined, bd = below detection limits

Sample No.	Sample Location	Rock Type	Unit	Reference
19) 90RME-2077	322300E 4969240N	felsite dike		this study
20) 90RME-2078	322300E 4969240N	felsite dike		this study
21) 90RME-2079	323080E 4968580N	syenite	9a	this study
22) 90RME-2098	323060E 4967900N	monzonite	9c	this study
23) 90RME-2104	322540E 4967680N	syenite	9a	this study
24) 90RME-2156	321500E 4967500N	monzonite	9c	this study
25) 90RME-2157	321600E 4967500N	lamprophyre	9d	this study
26) 90RME-2161	320500E 4968000N	monzonite	9c	this study

Harris (1991) notes that trace element patterns of the Skootamatta Syenite show a negative Nb anomaly, a small negative Ti anomaly, and a negative Th anomaly in biotite-bearing monzonites when compared to N-MORB, all characteristic features of igneous rocks occurring at convergrent plate boundaries (Perfit *et al.* 1980). Harris (1991) plotted the normative mineralogy in the NaAlSiO4-SiO2-KAlSiO4 system, and concluded that the pluton was emplaced in an shallow environment of near 5 kbars water pressure. He also concluded that fractional crystallization was not the sole process involved in forming the compositional spread present in the pluton, and that some other process or contamination had occurred.

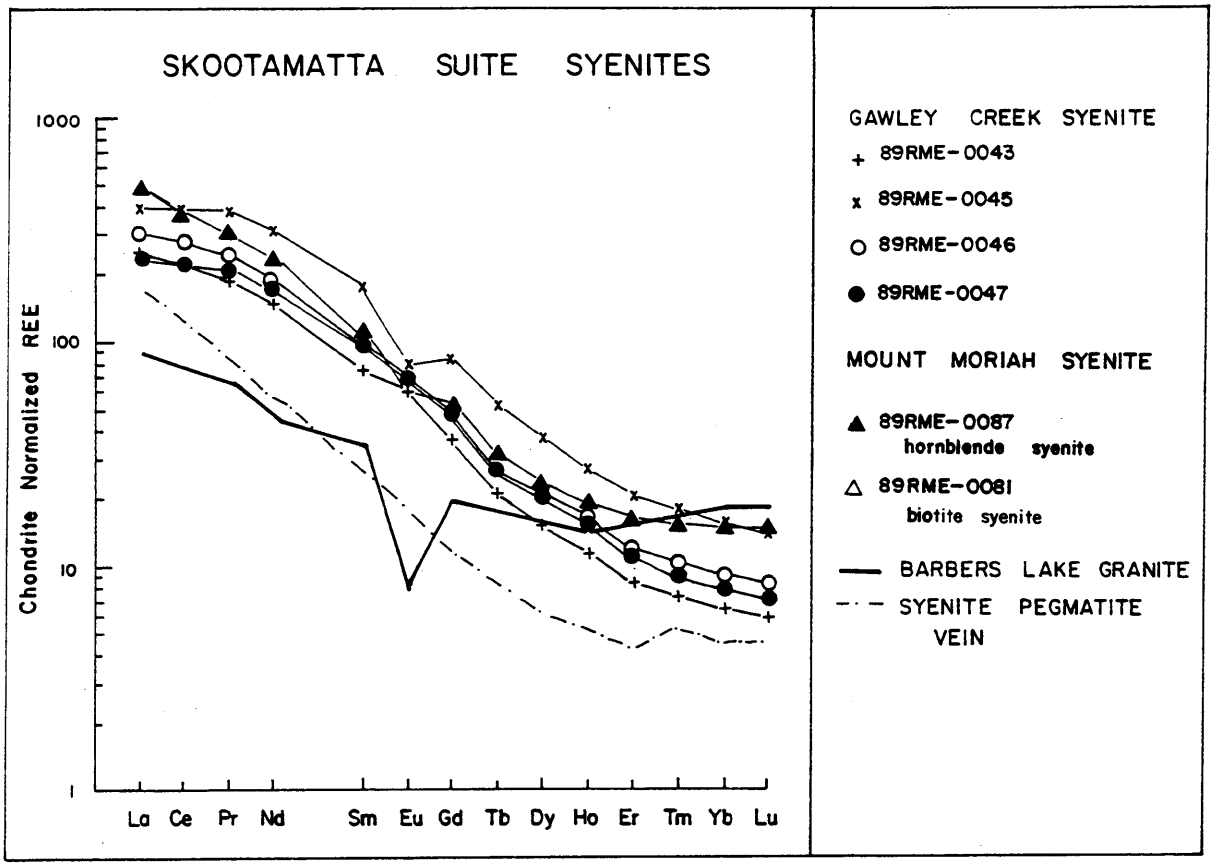
Corriveau (1989), in a study of Skootamatta Suite plutons in western Quebec recognized a silica-saturated suite of shoshonitic affinity, consisting mainly of hornblende syenite and quartz-syenite occurring as marginal phases to larger plutons, and a silica-undersaturated suite of potassic (leucitic) affinities. As shown in Figure 31, both silica-saturated and silica-undersaturated rocks are represented by the Elzevir Terrane plutons. Most of the Gawley Creek pluton and the amphibole-pyroxene-biotite syenites of the Skootamatta pluton are silica-undersaturated, whereas most Mount Moriah samples and the biotite-syenites from the Skootamatta pluton are shoshonitic. Both types can occur in the same pluton, as noted by Corriveau (1989).

Ultrapotassic rocks can be divided into three end-member groups (Foley *et al.* 1987) on the basis of geochemistry, and the classification is applicable to volcanic and plutonic phases. Each group occurs in a specific tectonic setting: Group I ultrapotassic rocks occur in stable continental areas, Group II in rift zones, and Group III in island arcs. Corriveau (1989) demonstrated that the Skootamatta suite rocks belong to Group III, and the geochemical data presented herein is consistent with this classification. High Ca, Si, Al, and low K/Al are characteristic geochemical features of Group III rocks. Modern examples are the Italian Roman Province and the Sunda Arc in Indonesia. Corriveau (1989) suggested derivation of the parental magmas from a widespread, relatively homogeneous mantle source due to subduction. She also suggested that fractonal crystallization, crustal assimilation, and *in situ* metasomatism were insignificant processes in evolving the magmas of the suite, although they may have played a role in differentiation within individual plutons once the magma was emplaced. This is consistent with the conclusions of Harris (1991).

Figure 34 is a plot of rare earth element data for Skootamatta Syenite Suite rocks in Ontario. Data from the Skootamatta Syenite was not available at the time of writing. Patterns for the Gawley Creek and Mount Moriah syenites are nearly identical, and it is likely that the Skootamatta Syenite is little different. For comparison, a sample of the Barbers Lake alaskitic granite of the *ca.* 1240 Ma Methuen Suite (Easton 1992a) and a late syenite-pegmatite vein from Silver Lake, Ontario are shown in Figure 34. The high REE abundances of the syenites is typical of alkalic rock suites. In the Mount Moriah Syenite, hornblende-bearing syenites have a slight Eu anomaly, higher HREE, and

slightly higher total REE abundances. The difference in pattern between the hornblende- and biotite-bearing syenites is probably simply the result of crystal fractination involving hornblende. This is in general agreement with field relations which suggest that the biotite-syenites are, for the most part, slightly younger than the hornblende-bearing syenites.

Figure 34: Chondrite-normalized REE plot for Skootamatta Suite syenites from the Elzevir Terrane. The Barbers Lake alaskitic granite is part of the Methuen Suite (Easton 1992a). The syenite pegmatite vein was collected near Silver Lake, Ontario. These latter two samples are located in the Sharbot Lake domain, Elzevir Terrane.



MIDDLE TO LATE PROTEROZOIC

MAFIC DIKES (unit 10)

Fine-grained, weakly metamorphosed, shallow-dipping to subvertical, east-northeasterly trending, diabase dikes of unit 10 cross-cut the Weslemkoon Tonalite, the Lingham Lake pluton (Photo 12, and the Mazinaw Granite located northeast of the map area. These are fine-grained, greenish weathering dikes with chill margins and sharp contacts. They are generally slightly recessive weathering. In the field, they are greener and fine-grained than unit 5 dikes. In thin section, these dikes consist of fine-grained aggregates of hornblende and plagioclase, weakly foliated, and preserving no original igneous textures. These dikes are tentatively correlated with the Kingston (Frontenac) dike swarm which has a minimum age of 900 Ma and which occurs throughout southeastern Ontario having similar trends.

FELSIC INTRUSIVE ROCKS

Undeformed, coarse-grained to pegmatitic, biotite-magnetite-quartz-orthoclase dikes and veins occur in a few localities in the map area within the northern lobe of the Weslemkoon Tonalite within, and north of the map area. These bodies are too small to show on the map face, and thus are not given a map unit designation. These bodies occur in areas subjected to amphibolite facies metamorphism, and consist of veins and dikes up to 50 m wide exhibiting a variety of trends. Probably the most significant feature of this unit is its general absence throughout the map area, in contrast to the relative abundance of pegmatites north and east of the Grimsthorpe Domain in the Bancroft and Mazinaw Terranes (Figure 3).

PALEOZOIC

ORDOVICIAN

Fault Gouge and Hematitic Sandstones (unit 11)

Along the Skootamatta Road, just west of the western margin of the Weslemkoon Tonalite, the road intersects an east-trending fault near UTM 304770E 4967810N. Both fault gouge and sandstone of probable Ordovician age is exposed. Fault gouge consists of penetratively fractured amphibolites, locally invaded by ferroan dolomite and calcite veins. The amphibolite has been extensively chloritized, and the rocks are green in colour and have a greasy feel. Hematite is common on fracture surfaces. At this locality, a shallow-dipping ($<5^{o}$) unit of hematitized litharenite (unit 11) rests atop fault gouge. This rock is unmetamorphosed and resembles Paleozoic clastic rocks commonly observed at the Paleozoic/Precambrian unconformity. Along strike to the east, where the fault crosses the Weslemkoon Tonalite, the tonalite becomes hematite-stained (unit 8h). Quartz veins are also common in the tonalite adjacent to this fault. This fault follows the trend of Ottawa-Bonnechere graben structures in the area, and the occurrence of sandstone of probable Paleozoic-age along this fault is consistent with the time of development of the Ottawa-Bonnechere graben (Easton 1992a).

CENOZOIC
QUATERNARY

Most Cenozoic sediments in the map area were deposited during the Pleistocene epoch, and consist of till, and glaciofluvial deposits located along major drainages in the area. Henderson (1972) provides a brief summary of the surficial geology of the Kingston area, including the Grimsthorpe area. Overburden (till and soil) cover is moderate (1-2 m) over most of the map area, increasing slightly in thickness to the north. Areas underlain by moderate to thick overburden cover are well-forested, and include most of the areas underlain by the Grimsthorpe Group and the Weslemkoon Tonalite. Glaciofluvial deposits consist mainly of sand and gravel deposits located along the Black River and Partridge Creek, and appear to be small fan-deltas related to drainage of now abandoned streams into once much larger drainage systems that occupied the Black River and Partridge Creek. Aggregate resources in the area are described in detail in MNR (1987a, 1987b) and have locally been exploited for construction of the Skootamatta Road and other forest access roads in the area.

The Recent deposits in the map area are composed of organic swamp and alluvial deposits. Most swamps are located in lineaments which parallel major geologic contacts and fault zones. The Recent alluvial deposits are associated with the Black River and Partridge Creek drainages, and include minor stream sediments, and reworked glaciofluvial sands and gravels.

METAMORPHISM

Most of the map area has been subjected to greenschist facies metamorphism, with local occurrences of amphibolite facies metamorphism near the north-central boundary of the map area (Figure 5). The increase of metamorphic grade in the north reflects a regional metamorphic pattern within the Grimsthorpe domain which increases from south to north from greenschist facies to lower amphibolite facies. Rocks within the map area do not develop any visible diagnositic mineral assemblages that can be traced as isograds. Some metasiltstone and metapelites of the Grimsthorpe Group contain visible knots representing relict porphyroblasts, but original mineralogy is no longer preserved, making determination of metamorphic conditions problematic. Garnet and hornblende were the only preserved porphyroblasts observed in thin section, with hornblende being most common in recrystallized mylonitic rocks and mafic, volcaniclastic metasediments, and with garnet being most common in more aluminous metasediments (unit 4c), typically in conjunction with biotite. Retrograded porphyroblasts have forms indicative of either garnet or hornblende, but confirmation of the original porphyroblast mineralogy could not be determined in thin section.

Lumbers (1968) suggested that a contact metamorphic aureole, reaching medium-grade hornfels conditions, was developed along the margin of the Weslemkoon (and other tonalite intrusions). On the basis of our studies, this suggestion can neither be confirmed or denied. Most of the rocks found in the "contact aureole" consist of

protomylonitic gabbros or mafic metavolcanic rocks of the Canniff Complex. These rocks were deformed, and probably metamorphosed, prior to deposition of the Grimsthorpe Group. As a consequence, it is difficult to establish on the basis of our preliminary survey whether or not the locally higher metamorphic grade conditions observed in Canniff Complex rocks is the result of contact metamorphism by the Weslemkoon and Canniff tonalites or is a relict of an earlier metamorphic event not preserved in younger supracrustal rocks within the map area. Chappell (1978), in his study of the Kaladar Complex (*i.e.* Canniff Complex and Killer Creek Gabbro) south of the map area, also suggested that the hornfelsic character of the metavolcanic rocks adjacent to the tonalites might be a relict feature, and not a contact metamorphic effect of the tonalite intrusions.

As previously noted, in thin section, Canniff Complex rocks are texturally and mineralogically distinct from Grimsthorpe Group rocks (radiating, fine-grained actinolite-plagioclase aggregates with diffuse grain boundaries *versus* euhedral, hornblende-plagioclase aggregates). This textural distinction persists even in Canniff Complex clasts present within Grimsthorpe Group metaconglomerates (unit 3f). This textural distinction suggests that the Canniff Complex metamorphic episode may have been distinct from the Grimsthorpe Group metamorphism, however, considerably more metamorphic petrology needs to be conducted within the map area to confirm this suggestion.

The significance of the characteristic green colouration of biotite in most Elzevir Suite rocks within the map area is open to speculation. Lalonde (1992), in summarizing biotite colouration, suggests that green colour is indicative of high Fe^{3+} contents, *i.e.* oxidation. Consequently, the biotite colouration may reflect oxidation conditions during pluton emplacement that survived regional metamorphism.

Secondary, red-brown biotite occurs in association with the Partridge Creek alteration zone, a series of gold occurrences 1 km east of the Partridge Creek alteration zone, and in gabbroic rocks adjacent to the Skootamatta Syenite. In all these cases, the colouration appears to be related to late stage-fluid movement, and possibly reducing conditions. In summary, detailed study of biotite colouration in the Grimsthorpe domain may be a useful tool in identifying late-stage alteration within the area and economic mineralization.

As noted previously, Elzevir Suite plutonic rocks, plus the Skootamatta Syenite, all exhibit development of late, disseminated, white mica grains. This mica-forming event is only observed in these intermediate to felsic metaplutonic rocks and may reflect regional cooling after regional uplift following the Grenville Orogeny.

Although rocks of the Caniff Complex may have been subjected to a pre-1250 Ma period of medium-grade metamorphism, probably occurring soon after emplacement.

The bulk of the rocks in the domain, including all the metaigneous rocks, except the Skootamatta and Mount Moriah syenites, have been subjected to a regional metamorphic event of unknown age. This event could have occurred at one of three different times, *ca.* 1230 Ma (Elzevirian Orogeny?), *ca.* 1180-1165 Ma (same age as Frontenac Terrane metamorphism as suggested by Lumbers *et al.* 1990), or at *ca.* 1100-1070, coincident with deformation in the Central Gneiss Belt and titanite ages in the Belmont domain (Davis and Bartlett 1988, Lumbers *et al.* 1990). K-Ar hornblende and muscovite ages indicate cooling below blocking temperatures of these two respective minerals at *ca.* 1020 Ma and *ca.* 900 Ma respectively (Hanes *et al.* 1988, Cosca 1989). It is possible that the late mica-forming event is coincident with the *ca.* 900 Ma muscovite age reported by Hanes *et al.* (1988).

The Grimsthorpe Domain differs from the adjacent Mazinaw Terrane to the east in being subjected to only one major episode of regional metamorphism, the timing of which is still undetermined (*see above*). In contrast, the Mazinaw Terrane was subjected to a high-grade metamorphism (M1) accompanied by regional deformation prior to Flinton Group deposition (*ca.* 1180-1165 Ma or earlier) and a medium- to high-grade post-Flinton metamorphism (M2) (*ca.* 1150-1080 Ma) that was accompanied by only local deformation.

Rocks younger than the Canniff Complex are little deformed for the most part, and primary textures, be they sedimentary or igneous are well-preserved. Exceptions to this rule are the intense but localized deformation associated with the Partridge Creek and Mooroton shear zones. In the case of the Mooroton shear zone, the presence of straight gneisses in the shear zone suggest that the shear zone developed during or prior to peak metamorphic conditions. These straight gneisses could have formed coincident with either M1 or M2 within the Mazinaw Terrane, as the Moorton shear zone marks the Grimsthorpe Domain/Mazinaw Terrane boundary and Mazinaw Terrane metamorphic effects may have affected the boundary. In the case of the Partridge Creek shear zones, the shear zone has been rerystallized, suggesting that it too formed during peak-metamorphism within the Grimsthorpe Domain. This event, may not necessarily be coincident with either M1 or M2 within the Mazinaw Terrane. Chappell (1978) also suggests that little deformation accompanied metamorphism within rocks lying within the Grimsthorpe Domain. In his examination of the Kaladar Complex (*i.e.* Killer Creek Gabbro), Chappell (1978) also noted the deformation only occurred sporadically in shear zones, and that such zones contained chlorite-actinolite assemblages indicating a lower temperature regime than the hornblende-plagioclase assemblage typical of the gabbro. Chappell (1978) attributed the preserved textures in the gabbros as indicative of post-intrusion deuteric aleteration, not regional metamorphism. Chappell (1978) also noted an increase in metamorphic grade toward the contact with the Flinton Group (*i.e.* the southward extension of the Moorton shear zone), in agreement with our observations that the Grimsthorpe Domain and the Mazinaw Terrane have had different metamorphic histories.

Wu *et al.* (1991) compared the chemistry of the low and high grade parts of the Weslemkoon Tonalite within, and to the north of the map area. Rb, Sr and Ba showed greater dispersion in the high grade rocks, suggesting local remobilization. Total REE contents were lower in the high grade rocks (though the patterns remained unchanged), an effect Wu *et al.* (1991) attributed to titanite breakdown.

STRUCTURAL GEOLOGY

The structural history of the Grimsthorp Domain in the map area is relatively simple. Few if any regional fold structures have been identified, and most rocks in the domain are little strained. Conglomerates preserve well-rounded cobbles and small-scale sedimentary textures, including dewatering textures. Way up features are locally widely distributed in metavolcanic and metasedimentary rocks in the domain. In contrast, the older mafic and ultramafic intrusive rocks and older mafic metavolcanics of the Caniff Group, show higher degrees of strain, and are locally protomylonitic, particularly the intrusive rocks. Bedding parallel foliation is developed in most supracrustal rock units, and in the west-central part of the domain, a second easterly-trending cleavage, and late shears, are present. Mafic dikes of several ages cut the supracrustal units and the Weslemkoon Tonalite. Most dikes are near vertical and trend 060^{o}.

A deformation zone, up to 100 m wide, the Partridge Creek Shear Zone, transects the central part of the domain, separates the Elzevir Tonalite and the Killer Creek Gabbro Suite in the east from the supracrustal and metaplutonic rocks of the western part of the domain. The eastern part of the domain may expose a slightly deeper level of exposure than the western part of the domain.

The Mooroton shear zone marks the eastern margin of the domain with the Mazinaw Terrane. South of Flinton, the zone is narrow where it separates a thin sliver of Flinton Group metasedimentary rocks, and minor mafic metavolcanic rocks and ultramafic pods from the Northbrook Tonalite of the Mazinaw Terrane. Along the Skootamatta River between Northbrook and Skootamata Lake, a westerly zone of straight gneisses, about 150 m in width, containing deformed pods of Killer Creek gabbroic rocks is present. East of the terrane boundary is a zone, up to 1 km wide, of chloritized, sheared mafic metavolcanic rocks, locally contaning gold-arsenopyrite mineralization disseminated in the metavolcanic rocks and in quartz vein systems (*e.g.* Addington Mine, O'Donnell occurrences (Wolff 1982, Dillon 1985, Moore and Morton 1986, Laing *et al.* 1987, Harnois and Moore 1988) Further north, the zone is ill-defined where it is truncated by north-northwest-trending faults (Easton and Ford 1991b).

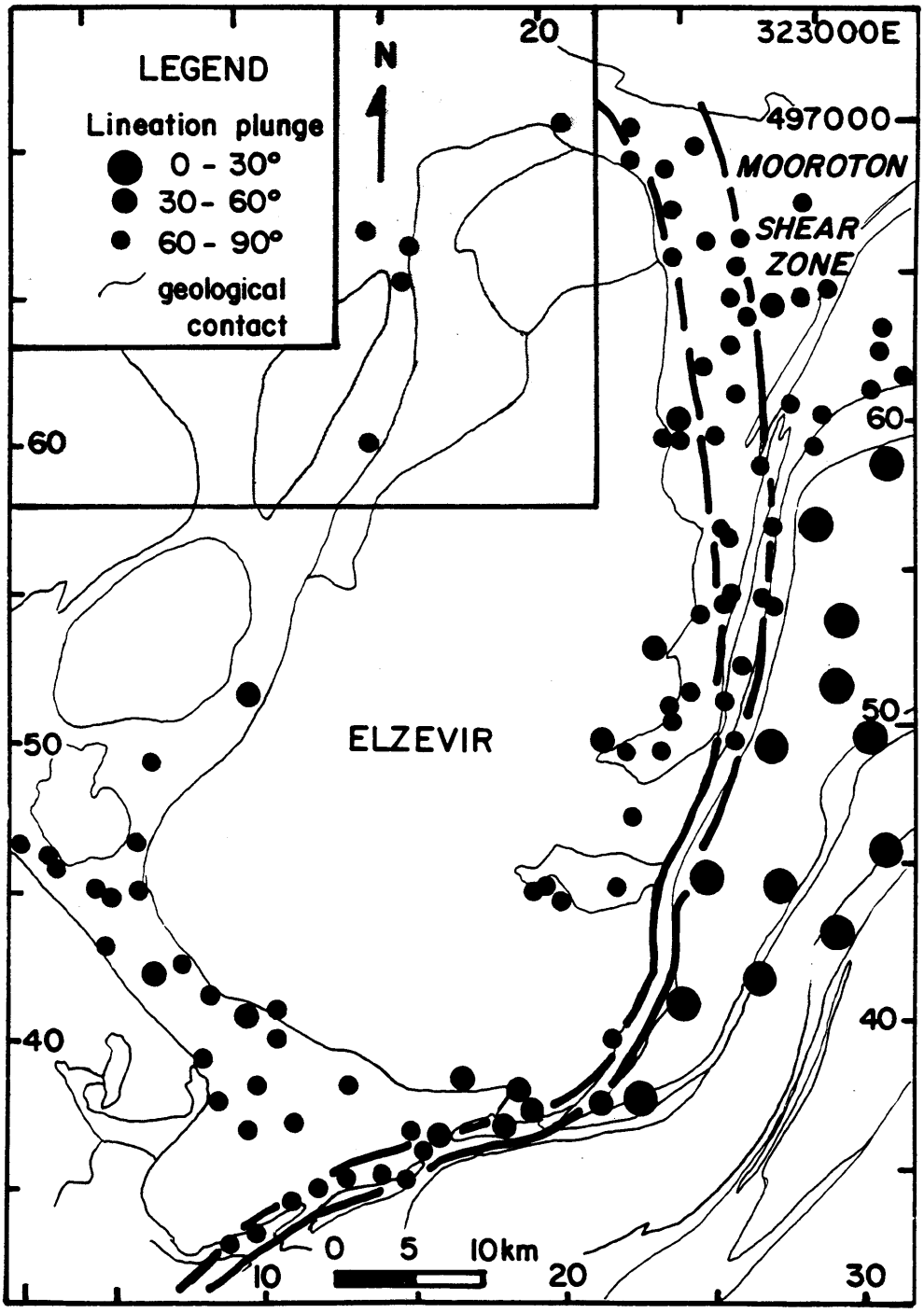
Meen (1944) suggested that the supracrustal rocks between the larger tonalite masses had the form of synclinal keels. Field party personnel found no evidence of regional synforms between the tonalite masses. Between the Lingham Lake pluton and the southern lobe of the Weslemkoon Tonalite, the structure appears to be homoclinal,

based on top indicators and the presence of a general fining-upward sequence in the supracrustal rocks. The same situation appears to occur between the Weslemkoon Tonalite and the Killer Creek Gabbro, although poorer exposure in this region makes mapping of regional structure problematic. If the cores of the plutons in the map area do indeed mark the site of former volcanic centres, than the preserved supracrustal rocks were deposited in small basins that developed between the centres (see Figure 27). Such basins would have a broad synformal form, however, stratigraphy might not be repeated across such basins and with subsequent deformation it would be difficult to determine if these sequences were synformal or homoclinal.

In the northwest corner of the map area, two foliations are present, a bedding-parallel, northwest-trending foliation, and a cross-cutting, east-trending foliation. The younger foliation is also associated with small (<5 cm wide) east-trending shear zones found in all lithologies. The younger foliation is best developed near the east-trending faults found in this part of the map area, and it is unclear if this spatial relationship is a genetic one, or if it simply reflects better outcrop exposure and access in the vicinity of the faults. Where observed, mineral lineations are steeply plunging (60°-90°). Lineations were most commonly observed in Canniff Complex rocks (units 1 and 2) and within the Partridge Creek and Mooroton shear zones.

Connelly (1985, 1986) conducted a detailed structural study of the margin of the Elzevir Tonalite. He noted a discordance in lineations between the Elzevir and Northbrook tonalites (Figure 35), and suggested it may represent a major tectonic break. This break corresponds to the southern extension of the Mooroton shear zone. Connelly (1985, 1986) suggested that the structural fabric in host rocks to the Elzevir Tonalite that parallels the Elzevir contact formed in response to lateral expansion of the intrusion during emplacement as a diapir. Connelly (1985, 1986) had difficulty resolving the structural history of the Elzevir Tonalite with fabrics present in Grenville Supergroup and Flinton Group rocks in the Harlowe area. We would argue that these two areas are in different lithotectonic terranes that have had different structural and metamorphic histories. Consequently, it cannot be assumed that fabrics in either terrane can be correlated.

Figure 35: Generalized map showing variation in plunge of lineations surrounding the Elzevir Tonalite. Note shallow character of lineations east of the Mooroton shear zone. After Connelly (1985).



GEOCHRONOLOGY

Relative and absolute age constraints on units within the map area are summarized in Table 2. Few rocks within the area have been dated. Rocks of the Elzevir and Weslemkoon Tonalites are dated at *ca.* 1267 Ma (L. Heaman, geochronologist, Royal Ontario Museum, Toronto, personnal communication 1989, Lumbers *et al.* 1990). Relative age relationships indicate that units 1 through 7 are older than the Elzevir Tonalite. Silver and Lumbers (1966) dated the Tudor Formation metavolcanics at 1286+/-15 Ma. It is not possible to determine if this age reflects the approximate age of deposition of the Grimsthorpe Group, or deposition of Canniff Complex metavolcanics. The first suggestion seems most likely, based on regional stratigraphic correlations (Easton 1992a). Fine-grained tonalite dikes adjacent to the Elzevir Tonalite, possibly equivalent to unit 8f, have been dated at 1229+11/-4 Ma (Connelly *et al.* 1987). Similar dikes occur in the Mazinaw Terrane, suggesting that the two terranes may have been continguous at that time. Skootamatta Suite plutons elsewhere in Ontario and Quebec have been dated using U-Pb zircon methods at *ca.* 1085-1075 Ma (Corriveau 1989), although none of the plutons within the Elzevir Terrane have been directly dated. Bell and Blenkinsop (1980) report an Rb-Sr whole rock age of 1020+/-50 Ma from the Skootamatta Syenite. This age nearly overlaps, within the error limits, the inferred U-Pb age of the body.

Hanes *et al.* (1988) present Ar-Ar ages on muscovites and feldspars from the Elzevir Tonalite, the Skootamata Syenite and the Killer Creek Gabbro. Muscovite ages from the Elzevir Tonalite cluster at around 900 Ma. Potassium feldspar ages from the Elzevir Tonalite and the Skootamatta Syenite range from 754-724 Ma. Plagioclase feldspar ages from the Killer Creek Gabbro and the Elzevir Tonalite range from 600 to 400 Ma. The 600 Ma age was from the Elzevir Tonalite, whereas the lowest ages of *ca.* 400 Ma were from the Killer Creek Gabbro adjacent to the contact with the Skootamatta Syenite, and may reflect recrystallization of the gabbro that increased subsequent Ar loss related to emplacement of the Skootamatta Syenite. Hanes *et al.* (1988) attributed the *ca.* 400 Ma ages to a hydrothermal alteration event related to Acadian-Caledonian events in the Appalachian orogen or activity on the Ottawa-Bonnechere graben. Lopez-Martinez and York (1983) obtained an age of *ca.* 450 Ma for a similar alteration event east of the map area. The presence of preserved Paleozoc sediments in the map area along east-trending, probable Ottawa-Bonnechere graben faults suggests the occurrence of local alteration and tectonic activity in the area during the Ordovician and the Devonian. This event may have also mobilized Rb and Sr in the body, resulting in the low Rb-Sr age of the body reported by Bell and Blenkinsop (1980).

GEOPHYSICS

Airborne Gamma-Ray Spectrometric Data

The abundance of mafic metavolcanics and metagabbroic rocks, as well as potassium-poor felsic plutonic rocks within the Grimsthorpe area gives the area a distinctive low signature on airborne gamma-ray spectrometric maps of the area (Ford

1992). The only exception are the syenite bodies of the Skootamatta Suite, which have distinctly higher potassium, thorium and uranium contents. The paucity of pegmatites in the area, the nature of the bedrock, and the lack of large anomalies on the airborne gamma-ray specrometric maps suggest that the area has little uranium potential.

Aeromagnetic Data

As seen on the detailed 1:50 000 scale aeromagnetic map (GSC 1952), and the 1:1 000 000 scale aeromagnetic maps of southern Ontario (Gupta *et al.* 1991a, 1991b), the Grimsthorpe Domain, including the map area, is characterized by relatively low magnetic relief, and represents a regional magnetic low. In this respect, the aeromagnetic and gamma-ray maps are roughly similar.

Detailed plots of the Grimsthorpe area where also made using the Ontario Single Master Aeromagnetic dataset of the Ontario Geological Survey. Plots made include both image and shadow presentations of the total magnetic grid and the vertical gradient of the total magnetic grid. These plots were not notably different from the published aeromagnetic map (GSC 1952), although the vertical gradient plot does highlight some of the more subtle magnetic features within the map area, as illustrated in Figure 36.

As illustrated on Figure 36, only three magnetic highs occur within the Grimsthorpe area: (i) an intense magnetic high over the Skootamatta Syenite (A on Figure 36), and other Skootamatta Suite plutons within the Grimsthorpe Domain; (ii) a narrow, north-trending magnetic anomaly that parallels Partridge Creek (B on Figure 36). This magnetic anomaly corresponds to a zone of alteration within metavolcanic and volcaniclastic metasedimentary rocks of the Grimsthorpe Group. This alteration zone is discussed in greater detail within the *Economic Geology section* of this report; and (iii) a magnetic anomaly associated with a melanocratic gabbro phase of the Lingham Lake pluton (C on Figure 36). The latter anomaly is an area that was recently logged and difficult to traverse. In addition, magnetic highs occur just east of the map area within, and east of the Moorton shear zone (D on Figure 36). Within the map area, there is considerable magnetic contrast across the Mooroton shear zone. Not shown on Figure 36 is a prominent magnetic high located northeast of Joeperry Lake in Bon Echo Provinicial Park which corresponds to hornblendite and melangabbro of the Killer Creek Suite. This is in marked contrast to the Killer Creek Gabbro within the Grimsthope area which is not distinct magnetically. Although magnetite and ilmenite are commonly found with hornblendites of the Killer Creek Gabbro within the Grimsthorpe area, most of these bodies are generally of insufficient size to register as anomalies on the 1:50 000 scale aeromagnetic map (GSC 1952). It is likely that a detailed aeromagnetic survey would pinpoint these hornblendite pods.

Less apparent on the total magnetic field map (GSC 1952), but more obvious on the vertical gradient plot, is a pattern of moderate magnetic relief associated with rocks of the Canniff Complex (E on Figure 36). The cause of this pattern is not known, but may

be associated with the Canniff Complex gabbros, as the arteas of most intense relief correspond to exposed gabbro bodies. Elzevir Suite plutons within the map area are characterized by very low magnetic relief and intensity (F on Figure 36).

Gravity Data

Real and Thomas (1987) conducted a detailed gravity survey over part of the Central Metasedimentary Belt, covering mostly the Grimsthorpe Domain and the Mazinaw Terrane. As illustrated in Figure 37, profiles 1 and 6 lie immediately north and south, respectively, of the map area and provide an indication of the regional crustal structure beneath the Grimsthorpe Domain. Two points should be noted. First, gravity modelling of plutons within the Grimsthorpe Domain indicate depth extents of roughly 4-5 km. This suggests that the supracrustal sequence in the area may be thin, and that the tonalite plutons coalesce at depth. This is consistent wth the aeromagnetic pattern over the domain. Second, crustal structure changes east of the Mooroton shear zone. Plutons in the Mazinaw Terane are modelled as thin sheets of roughly 1 km thickness. This is consistent with the field evidence reported here and in Easton and Ford (1990a, 1991b) indicating that the Mooroton shear zone is a major geologic structure.

Figure 36: Sketch showing vertical gradient of the total magnetic field over the Grimsthorpe area. Area shown is roughly similar to that shown in Figure 4. Letters refer to anomalies discussed in the text. Sketch is simplified from a plot made from the Ontario Geological Survey Single Master Aeromagnetic dataset.

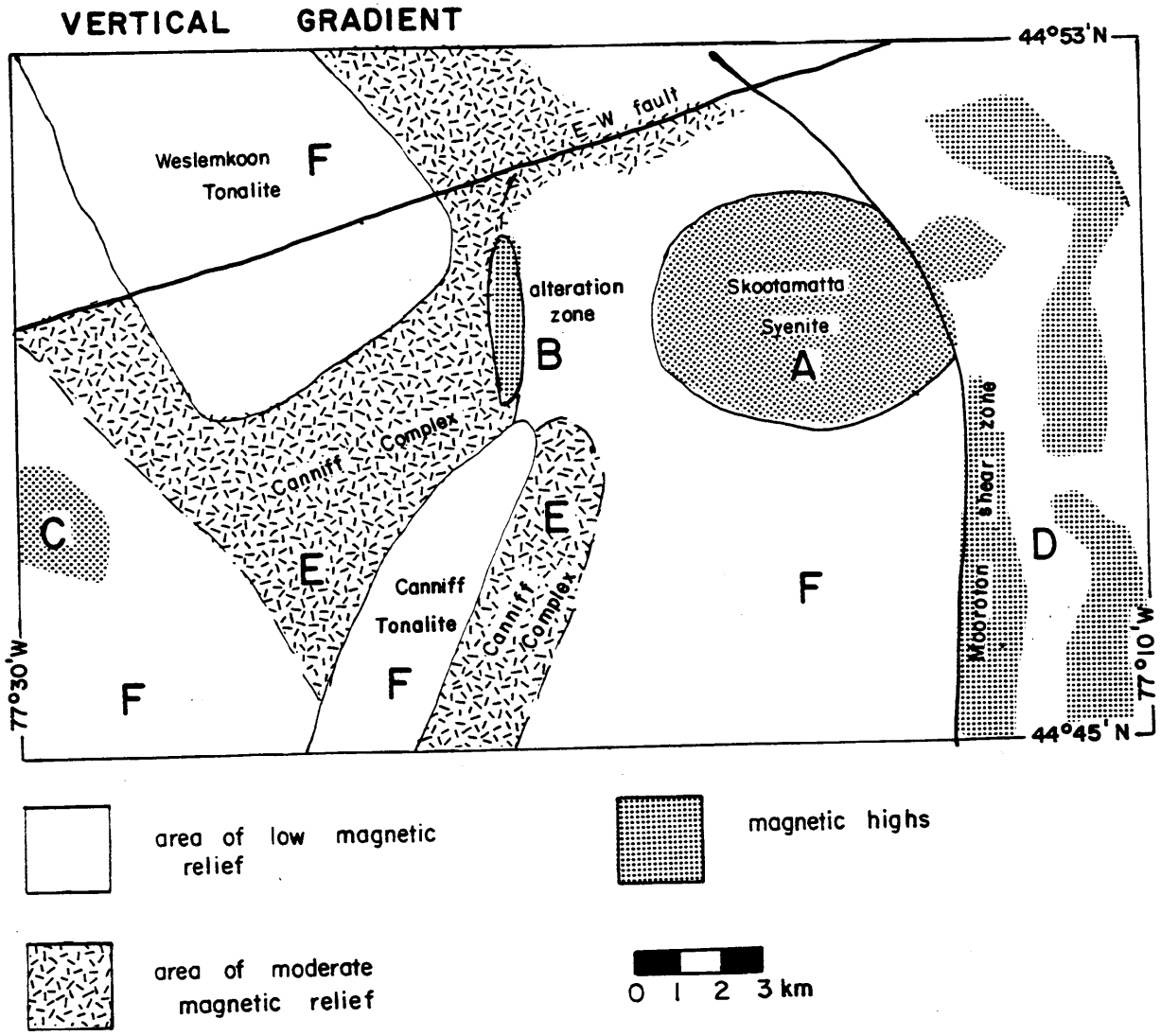
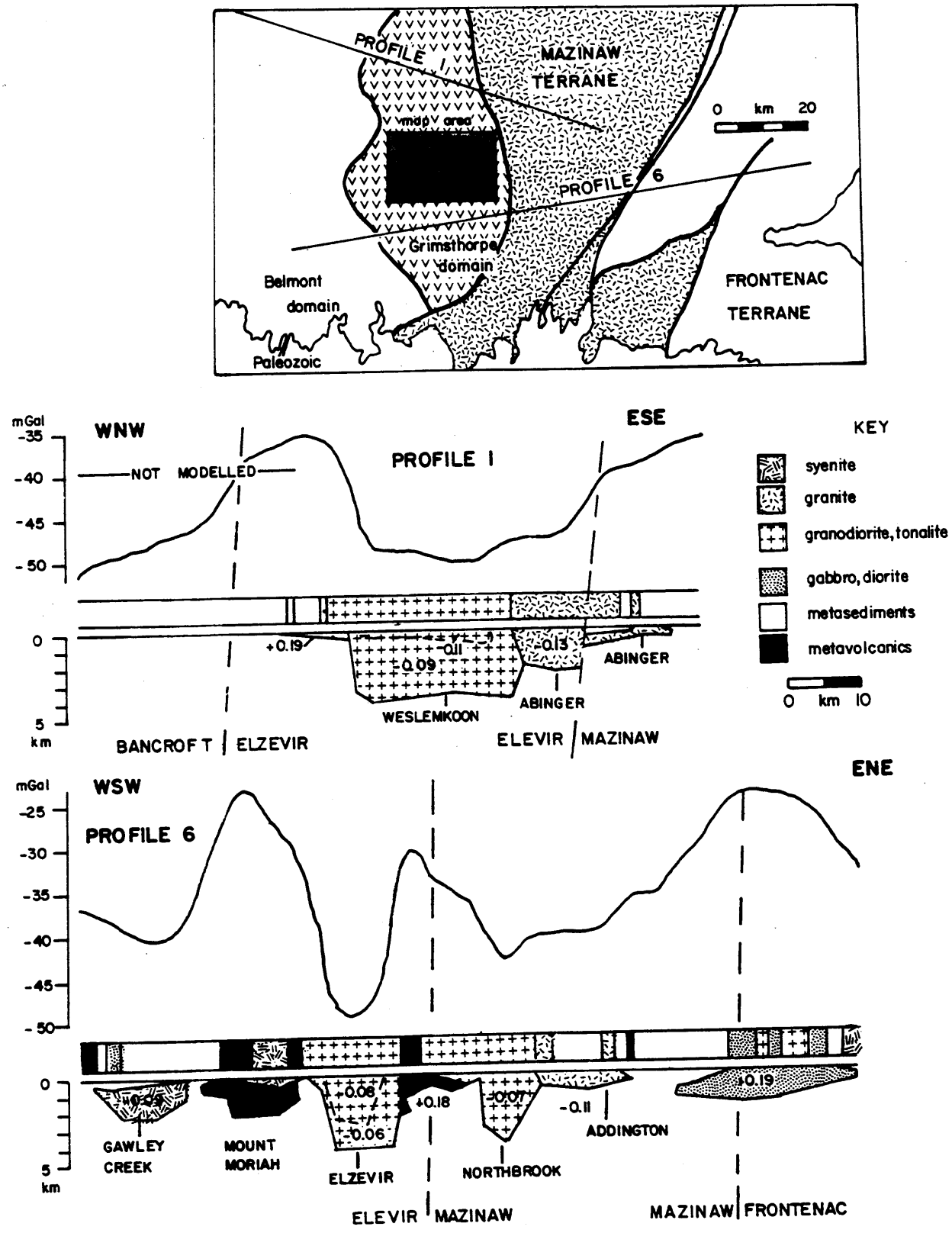


Figure 37: Gravity profile, surface geology, and gravity models for profile 6 across the Grimsthorpe domain. Model matches observed profile within +/- 1 mGal. Inset shows location of the profile with respect to the map area. After Real and Thomas (1987).



ECONOMIC GEOLOGY

Mineral Exploration Activity

There is no record of mineral production within the map area, and mineral exploration in the area has been minimal (*c.f.* Meen 1944, Assessment Files Research Office (AFRO), Ontario Geological Survey, Toronto). Geological Data Inventory Folios (GDIFs) are available for Anglesea (OGS 1984c), Cashel (OGS 1986), Effingham (OGS 1984a), and Grimsthorpe (OGS 1984b) townships and show only a few mineral occurrences in the area; these occurrences are shown on Figure 4. In contrast, similar rock types to the south of the map area have been subject to detailed exploration for both talc and gold mineralization (*e.g.* Di Prisco 1989, LeBaron and van Haaften 1989), and mafic metavolcanic rocks due east of the map area have been extensively explored for gold (Meen 1944, *Economic Geology section of* Moore and Morton 1986). Recent exploration activity has focussed on gold (*e.g.* LeBaron 1991). Active prospecting for gold was being undertaken in lots 24-29, concessions 12 and 13 of Anglesea Township and active staking was taking place in the vicinity of lots 15-17, concessions 5 and 6 of Grimsthorpe Township during the summer of 1990. Recent exploration work in the area is summarized in Table 14.

Assay Results

Field party personnel collected 91 samples for assay from a variety of rock units within the map area, and Table 15 presents the results of some of these assays. Data can be grouped into five main categories: assays from rusty schist units, assays from and adjacent to an east-west fault zone parallelling the Skootamatta road, assays from an alteration zone along the Skootamatta road, assays from known gold occurrences and quartz veins, and assays from gabbroic and ultramafic rocks, mainly of the Killer Creek Gabbro Suite.

Assays of rusty schists, which include gossaneous black schists (tuffaceous mudstones and black shales) as well as gossan zones within tuffaceous conglomerates and gossan zones in siltstones and tuffaceous sandstones adjacent to mafic dikes, locally show very minor enrichments in copper, nickel, or zinc (Table 15). Sample 90RME-0155 contains significant Zn and Pb contents. It was collected on Lingham Lake, near an area that is regularly used by fishermen as campsite. It is the authors' view that this anomaly is anthropogenic in origin (since Zn and Pb are common consistuents of dry cell batteries and no other elements are anomalous) and that it does not represent any significant mineralization. Only one sample (90RME-0011) was anomalous in gold. It is on strike with, but 500 m southeast of the gold-bearing United Reef Petroleums Limited property that showed the highest gold value of the samples listed in Table 15 (90RME-0017A). The highest gold values were obtained from a sample (90RME-0017A) collected in a trench in a silicified, rusty-weathering tuffaceous conglomerate outcrop (Photo 3b) on a property of United Reef Petroleums Limited located on lot 28, concession 14, Anglesea Township. Other samples from the same trench (90RME-0017B and 0017C) contained negligible gold. Samples 90RME-0019A

TABLE 14: Exploration work in the Grimsthorpe area.

Within Map Area

1) Killer Creek Project H. Dowhaluk 1989-90 Anglesea Twp., lots 25-28, conc. XII & XIII S1/2
- metavolcanics, Killer Creek Gabbro, till, rusty schists
- soil and stream geochemistry, rock assays, magnetometer and VLF-Em surveys. High assay of 0.674 oz/t (23 ppm) from quartz vein in gravel pit (potentially float)

2) Killer Group United Reef Petroleums 1987-88 Anglesea Twp., lots 27-28, conc. XIV
- Grimsthorpe Group volcaniclastic metasediments & metavolcanics, tonalite dikes, near edge of alteration zone
- mapping, stripping, trenching, magnetometer and VLF-EM surveys, high gold assay of 0.19 oz./ton (6660 ppb) from northeastern stripped area

3) Dempsey Option William Parks 1965 Anglesea Twp., lot 21S, conc. XI
- near Killer Creek Gabbro, Skootamatta syenite contact
- drilling, 2 holes (total 87 m), magnetite and pyrite reported, no assays given

4) Dempsey Option Conwest Exploration 1957-58 Anglesea Twp., lots 21-22, conc. X & XI
- near Killer Creek Gabbro, Skootamatta syenite contact
- magnetometer survey

Immediately Adjacent to Map Boundaries

5) Silva Lake area United Reef Petroleums 1988 Grimsthorpe Twp., lot 18 & 20, conc. XX
- Grimsthorpe Group volcaniclastic metasediments & metavolcanics, Canniff Complex metavolcanics?, Weslemkoon Tonalite
- mapping

6) United Reef Petroleums Limited 1987 Grimsthorpe Twp., lot 25-29, conc. XIII-XV
- Grimsthorpe Group volcaniclastic metasediments & metavolcanics, Canniff Complex metavolcanics?
- mapping, magnetometer and VLF-EM survey

7) gold-lead occurrence Lumbers 1968 Cashel Township, lot 20, conc. 1
- Grimsthorpe Group volcaniclastic metasediments & metavolcanics, Canniff Complex metavolcanics?, Weslemkoon Tonalite
- mapping, gold and silver reported in galena-bearing quartz vein. Could be related to E-W lineanent (Paleozoic fault) in area

TABLE 15: Assay results from Grimsthorpe area samples collected by field party personnel.

Sample Number	UTM Coordinates	Au(ppb)	Cu(ppm)	Ni(ppm)	Zn(ppm)
Rusty Schists					
90RME-0003	313190E 4968420N	11	74	<5	76
90RME-0009	314020E 4967770N	5	73	30	100
90RME-0010	314180E 4967680N	30	383	198	16
90RME-0011	314190E 4967630N	220	32	22	56
90RME-0014	314490E 4967460N	9	141	42	73
90RME-0016	314560E 4967820N	16	222	42	82
90RME-0021	314590E 4967370N	16	108	108	56
90RME-0031	306520E 4964300N	<2	103	46	94

TABLE 15: (continued).

Sample Number	UTM Coordinates	Au(ppb)	Cu(ppm)	Ni(ppm)	Zn(ppm)	
90RME-0032	306230E 4964440N	7	115	66	69	
90RME-0040	304020E 4966410N	21	71	14	99	
90RME-0041	304000E 4966410N	<2	47	84	146	
90RME-0042	304080E 4966360N	3	138	20	98	
90RME-0043	304350E 4966060N	2	77	10	100	
90RME-0049	305660E 4964960N	4	144	66	93	
90RME-0051	304150E 4965760N	12	372	30	103	
90RME-0054	305640E 4964060N	13	168	66	42	
90RME-0058	314680E 4966530N	6	37	12	33	
90RME-0059	314170E 4966280N	<2	10	48	123	
90RME-0060	313220E 4966200N	<2	<5	<5	25	
90RME-0061	313820E 4966290N	2	123	<5	186	
90RME-0064	315770E 4966460N	<2	225	30	135	
90RME-0067	315930E 4967300N	8	142	20	91	
90RME-0078	308760E 4963090N	3	57	20	180	
90RME-0084	308200E 4963840N	7	58	22	91	
90RME-0085	310200E 4961600N	32	245	142	62	
90RME-0092	314060E 4968170N	7	164	48	87	
90RME-0155	308830E 4959480N	4	161	34	3600	1200 ppm Pb
90RME-0166	308890E 4960050N	<2	34	26	143	
90RME-0176	312190E 4974530N	4	59	26	209	
90RME-0226	308820E 4957190N	4	58	54	98	
90RME-1038	305650E 4967570N	6	102	124	240	
90RME-1097	314920E 4976000N	3	37	<5	97	20 ppm Pb
90RME-1099	314430E 4974760N	3	203	62	104	
90RME-1100	314320E 4974650N	5	279	28	177	
90RME-2125	314230E 4974140N	3	163	12	165	
Alteration Zone						
90RME-0102	313310E 4968040N	<2	15	22	32	
90RME-0103	313310E 4968040N	<2	169	78	51	
90RME-0104	313300E 4979600N	<2	18	22	28	
90RME-0105	313300E 4979600N	<2	153	78	48	
90RME-0106	313270E 4967880N	<2	<5	10	<10	
90RME-0107	313270E 4967880N	<2	<5	<5	<10	
90RME-0108	313270E 4967880N	<2	100	54	72	
90RME-0109	313360E 4967730N	<2	68	78	115	
90RME-0110	313850E 4967660N	<2	<5	<5	<10	
90RME-0111	313870E 4967610N	<2	<5	82	148	
Fault Zone and Adjacent Rocks						
90RME-0069A	304770E 4967760N	<2	48	50	124	
90RME-0070A	304770E 4967810N	18	136	18	56	340 ppm Pb
90RME-0070C	304770E 4967810N	<2	8	50	95	
90RME-0071	304570E 4967700N	<2	34	58	102	
90RME-0072A	304510E 4967720N	6	6	22	32	
90RME-0072B	304510E 4967720N	<2	14	16	45	60 ppm Pb
90RME-0073	304380E 4967760N	<2	56	58	101	
90RME-0074	304150E 4967770N	<2	33	58	119	
90RME-0075	303880E 4967720N	4	60	58	72	
90RME-0076	302620E 4968300N	13	80	26	113	

TABLE 15: (continued).

Sample Number	UTM Coordinates	Au(ppb)	Cu(ppm)	Ni(ppm)	Zn(ppm)
Quartz Veins					
90RME-0012	314270E 4967570N	<2			
90RME-0019A	314795E 4968500N	<2			
90RME-0034	303660E 4967370N	<2			
90RME-1009	311460E 4968740N	<2			
90RME-1018	307760E 4969450N	4			
90RME-1021	306910E 4970670N	<2			
90RME-1023	307210E 4971230N	5			
90RME-1024	307290E 4971330N	<2			
90RME-1038B	305650E 4967570N	<2	10	12	53
90RME-2041	307800E 4968200N	<2			
90RME-2045	306100E 4967850N	22			
Gold Occurrences					
90RME-0017A	314530E 4968260N	880	400	30	14
90RME-0017B	314530E 4968260N	6	630	32	16
90RME-0017C	314530E 4968260N	<2	6	8	<10
90RME-0018A	314545E 4968350N	2	237	20	47
90RME-0019B	314795E 4968500N	4	157	28	42
Others					
90RME-0081	309180E 4962840N	<2	65	124	91
90RME-0095	318840E 4967120N	3	475	80	106
90RME-0261	309080E 4963805N	ND	233	72	101
90RME-0266	301995E 4978200N	ND	173	44	78
90RME-1004	311910E 4968970N	<2	31	148	91
90RME-1013A	308530E 4968460N	<2	84	250	79
90RME-1013B	308530E 4968460N	2	90	64	71

Gabbroic and Ultramafic Rocks

	Au(ppb)	Cu(ppm)	Ni(ppm)	Zn(ppm)	Cr(ppm)	Pt(ppb)	Pd(ppb)	
90RME-0117	317090E 4966730N	9	193	26	53	138	2	<1
90RME-0250	318460E 4963825N	ND	117	142	123	526	ND	ND
90RME-0269	000000E 0000000N	<2	117	69	138	ND	<1	1
90RME-1067	317580E 4967990N	7	336	86	144	358	3	3
90RME-1068	317800E 4968220N	<2	69	540	162	2040	5	6
90RME-1071	318060E 4968380N	<2	720	44	154	120	10	6
90RME-1072	319250E 4969180N	4	132	180	139	456	<1	2
90RME-1112	321260E 4969760N	4	69	250	143	ND	6	3
91RME-0060	318980 4976480N	<2	32	240	175	970	<1	<1
	V=725 ppm, hornblendite, Bon Echo Provincial Park							
91RME-0138	315199E 4973605N	39	26	ND	92	ND	ND	ND
	metagabbro, diss. sulphides, Rainy Lake							
91RME-0162	3249330E 4969770N	15	645	ND	57	ND	ND	ND
	disseminated sulphides, Pringle Lake area							
91RME-1141	318800E 4976340N	49	12	ND	155	1550	125	67
	V=327 ppm, fine-grained, mt-rich altered hornblendite, Bon Echo Prov. Park							

Detection limit for Au is 2 ppb, <5 ppm for Cu, Ni and Cr, and <10 ppm for Zn. Background levels in area are generally close to detection limits. ND = not determined

and B, collected from a nearby trench on lot 27, concession 14, Anglesea Township, also a United Reef Petroleums Limited property, showed no enrichment in gold. The sample population in Table 15 would seem to indicate that background levels for gold in the map area are about 10 ppb or less, thus sample 90RME-0017A is clearly anomalous from a regional perspective.

Samples 90RME-0102 through 90RME-0111 inclusive were collected from a north-trending zone of alteration and local silicification that also has a strong aeromagnetic expression (Figure 36). The most silicified samples are strongly depleted in copper, gold, nickel, and zinc. In addition, as shown in Table 16, this zone is also an area of Na-metasomatism, with significant addition of sodium to the country rock. The geochemistry of this alteration zone is discussed below in the next section.

TABLE 16: Sodium analyses of samples collected within the Partridge Creek alteration zone by field party personnel.

Sample No.	UTM location	Na (wt. %)	Comment
90RME-0102	313310E 4968040N	4.92	veined mafic rock
90RME-0103	313310E 4968040N	3.64	silicified conglomerate
90RME-0104	313300E 4979600N	4.48	veined mafic rock (photo 3a)
90RME-0105	313300E 4979600N	3.52	silicified conglomerate
90RME-0106	313270E 4967880N	5.63	veined mafic rock
90RME-0107	313270E 4967880N	5.66	massive white rock
90RME-0108	313270E 4967880N	2.92	rusty weathering conglomerate
90RME-0109	313360E 4967730N	2.93	slightly silicified conglomerate
90RME-0110	313850E 4967660N	4.59	felsite?
90RME-0111	313870E 4967610N	3.39	tuffaceous metasandstone
Range of unaltered tuffaceous conglomerates		3.00-3.7	
Sodium enrichment of at least 2-3% in most heavily viened and silicified mafic rocks			
Silicified conglomerate at United Reef Property		0.27	Sample 90RME-0017A, strongly depleted

See Table 15 for assay results from these samples.

Samples 90RME-0069 through 90RME-0072 inclusive were collected from fault gouge present along a Paleozoic-age fault that parallels the Skootamatta road in the northwest part of the map area. All samples listed in Table 15 were analysed for lead, but only samples 90RME-0070A and 90RME-0072B contained significant lead; all other samples contained lead below the 10 ppm detection limit. Barite-carbonate-lead veins are associated with Paleozoic faults elsewhere in the Central Metasedimentary Belt in Ontario and the anomalous values found in the two samples from the fault zone may indicate the presence of this type of mineralization along this fault.

Samples of quartz veins collected from throughout the map area were barren with respect to gold (Table 15). Quartz veins are more abundant in the Weslemkoon Tonalite

adjacent to the Paleozoic fault noted above, and may be related to it.

All gabbro and ultramafic samples listed in Table 15 are from the Killer Creek Gabbro Suite. Hornblendite samples from the Killer Creek Gabbro Suite show enrichments in both copper and chromium, and were also analyzed for platinum and palladium (Table 15). Samples 91-RME-0138, 91RME-0162 and 91RME-1141 contain between 15 and 50 ppb gold, much higher than the 5 ppb Au levels typically associated with ultramafic rocks (Buisson and Leblanc 1986).

Sample 90RME-1071 also contained 15%-20% magnetite. The presence of igneous layering within the Killer Creek body, as well as ilmenite and magnetite-rich layers, and the high chromium result from sample 90RME-1068 indicate that the body has potential for oxide and possibly platinum mineralization and warrants additional exploration. Easton and Ford (1991) reported enrichments in magnetite and chromite northeast of Joeperry Lake in Bon Echo Provincial Park, where a significant aeromagnetic high (GSC 1952) is underlain by a body of melanocratic metagabbro of the Killer Creek Gabbro Suite containing abundant hornblendite pods. Assay sample 91RME-060 (Table 15) is from one of these pods, and shows elevated concentrations of Cr and V. The high Ti contents of the Killer-type gabbros suggests the presence of ilmenite as well. The Joeperry Lake metagabbro has a fine-grained phase of chlorite-hornblende-magnetite around its margins, which may be the product of metamorphic reaction related to fluid interaction with surrounding rocks during regional metamorphism. This magnetite-rich rim may be largely responsible for the intense aeromagnetic signature of this body which is atypical of the suite elsewhere in the Grimsthorpe domain or the Mazinaw Terrane. This magnetite-bearing phase (Table 15, sample 91RME-1141) is enriched in both Cr (1550 ppm), and Pt (125 ppb) and Pallidium (67 ppb). Anomalous copper values are present from many samples of Killer Creek Gabbro (Table 15) and disseminated pyrite and chalcopyrite are common throughout the Killer Creek Gabbro. Consequently, the Killer Creek Gabbro Suite has potential for copper-sulphide mineralization. Assay results from other gabbro bodies in the area were unavailable at the time of report preparation.

Gold

The presence of known gold occurrences east and west of the Grimsthorpe area, the abundance of mafic volcanic rocks as indicated on regional scale maps, and the lack of much previous exploration have all made the Grimsthorpe area a target area for gold exploration over the past few years. The results of the current project necessitate a re-evaluation of the gold potential of the area.

Two factors to be accounted for in any future exploration are the significance of the Mooroton and Partridge Creek shear zones and the abundance of mafic volcaniclastic rocks in the area. The Mooroton shear zone is significant from the standpoint that it separates the Mazinaw Terrane (Figure 3), which contains mainly calcalkalic volcanic

sequences of basalt through rhyolite, extensive carbonate and siliceous clastic sedimentary sequences, and rocks of the Flinton Group, from the Elzevir Terrane which consists mainly of mafic volcanic rocks, gabbroic rocks, and tonalite plutons. Exploration philosophies derived for the Mazinaw Terrane may not necessarily be applicable to the Elzevir Terrane because of different lithologic sequences and likely different geologic histories between the two areas.

The Partridge Creek shear zone does not seem to juxtapose greatly different rock sequences, nevertheless, it is difficult to correlate across this zone. The shear zone does deform volcaniclastic and mafic plutonic rocks, and in itself may make an interesting exploration target for gold.

The abundance of volcaniclastic sediments in the area as opposed to mafic flow rocks may make the area less attractive for gold exploration. Gold occurrences previously reported in Cashel Township just north of the map area (Lumbers 1968) occur in the massive amphibolite units that may represent metaflows and not in volcaniclastic sediments. Gold properties east of the Mooroton shear zone are also hosted in deformed mafic metaflows. However, the United Reef Petroleums Limited properties are hosted in volcaniclastic rocks and have found some gold mineralization (Table 15).

As noted in the description of the Canniff Complex, the gold-bearing listwanite model of Buisson and Leblanc (1986) and Nixon and Hammack (1991) may be applicable to rocks of the Canniff Complex and the associated talc bodies. This model has not been previously applied in this area.

Tuffaceous conglomerates might make good host rocks for volcanogenic massive sulphide (VMS) deposits, particularly as the intercalated rusty schist horizons might locally serve as good cap rocks. The alteration zone east and north of Partridge Creek (Figure 4, 38) might be a promising target for VMS exploration.

Partridge Creek Alteration Zone

Upon discovery of sodium enrichment in some samples from the Partridge Creek alteration zone (see Table 16, 17, Figures 38, 39, 40, and 41), a follow-up geochemical survey of these rocks was performed in order to characterize the alteration in order to allow improved assessment of mineral potential within the alteration zone. Figures 39, 40 and 41 illustrate the geochemical characteristics of the alteration present within the zone.

Alteration within the zone is sporadic. As shown in Figures 38 and 39, samples 90RME-0102 through 90RME-0111 are all located within the alteration zone, however, only samples 90RME-0102, -0104, -0106, -0107, -0110 are visibly altered in hand specimen, and only these samples show striking geochemical anomalies. Samples within the alteration zone exhibit sodium and silica enrichments (Figure 39a), and

depletion in ferromagnesium elements, such as iron and titanium as illustrated in Figures 39b and 39c, respectively. Also shown in Figure 39 is the silicified conglomerate (90RME-0017, see Photo 3b) associated with gold mineralization on the United Reef Petroleums Limited property. This latter sample shows alteration characteritics distinct from those present within the Partridge Creek alteration zone (Figure 39, 40).

The most intensely altered samples within the Partridge Creek alteration zone also exhibit lower densities (Figure 40a, 40b) and lower volatile contents (Figure 40a) than do less altered counterparts. Rubidium (Figure 40d) and potassium (not shown) are notably depleted within the altered samples, however, thorium (Figure 40c) is locally enriched. Schandl *et al.* (1992), in their description of a sodium metasomatic event near Sudbury, also note thorium and uranium enrichment associated with sodium enrichment. However, Schandl *et al.* (1992) also report Zr-Y-REE enrichments in their samples. Such enrichmment does not occur within the Partiridge Creek alteration zone, in fact, as inidicated in Figure 40c and 40d, Zr is depleted within the most altered samples (as is Yb and Y).

As previously noted, late, red brown biotite is well developed in mafic metavolcanic rocks and volcaniclastic metasedimentary rocks within the Partridge Creek alteration zone and the zone of gold occurrences located due east of the alteration zone (Figure 38). The abundance of biotite within the zone is probably a reflection of the normal to high potassium and rubidium contents present within the alteration zone. In addition, it may indicate reducing conditions in the fluids associated with development of the alteration zone.

Chrondrite-normalized REE plots of the most intensely altered samples are shown in Figure 41. Samples 90RME-0107 and 90RME-0106 are the visibly most altered samples, and show the strongest depleteion in the REE. There is a progressive depletion in the REE from the least altered (Sample 90RME-0111) to the most altered (Sample 90RME-0107) sample. The depletion in REE is consistent with the observed depletion in Zr and Y previously noted.

Sodium enrichment has been reported in association with Archean volcanogenic massive sulphide deposits within the regional semiconformable alteration zone (Morton and Franklin 1987; Fyon *et al.* 1992) of the deposits (Figure 42). Fyon *et al.* (1992) note that the semiconformable alteration zone is better developed in fragmental than in effusive rocks. This alteration style can be developed up to 3 km below the paleo-sea floor on which the sulphides precipitated (Fyon *et al.* 1992). If the Partridge Creek alteration zone is related to a VMS deposit, then the deposit itself may be located several kilometres distant from the mapped zone of sodium enrichment.

An alternative explanation for the origin of the Partridge Creek alteration zone is that it may be related to movement of magmatic and hydrothermal fluids, or both, related to

emplacement of the nearbly Weslemkoon and Canniff tonalites. The Partridge Creek alteration zone lies about 1 km from the eastern margin of the Weslemkoon Tonalite and strikes parallel to the margin of the tonalite.

Sodium metasomatism in the Southern Province (Gates 1991; Schandl *et al.* 1992) is associated with gold mineralization. Although the geochemical character of the sodium metasomatism in the Partridge Creek alteration zone differs from that seen in the Southern Province (see discussion above, Schandl *et al.* 1992), it may be noteworthy the the United Reef Petroleum Limited gold occurrence is located only a few hundred metres east of the most intensely altered part of the Partridge Creek alteration zone (Figure 38).

Figure 38: Map showing the location of analyzed samples from the Partridge Creek alteration zone.

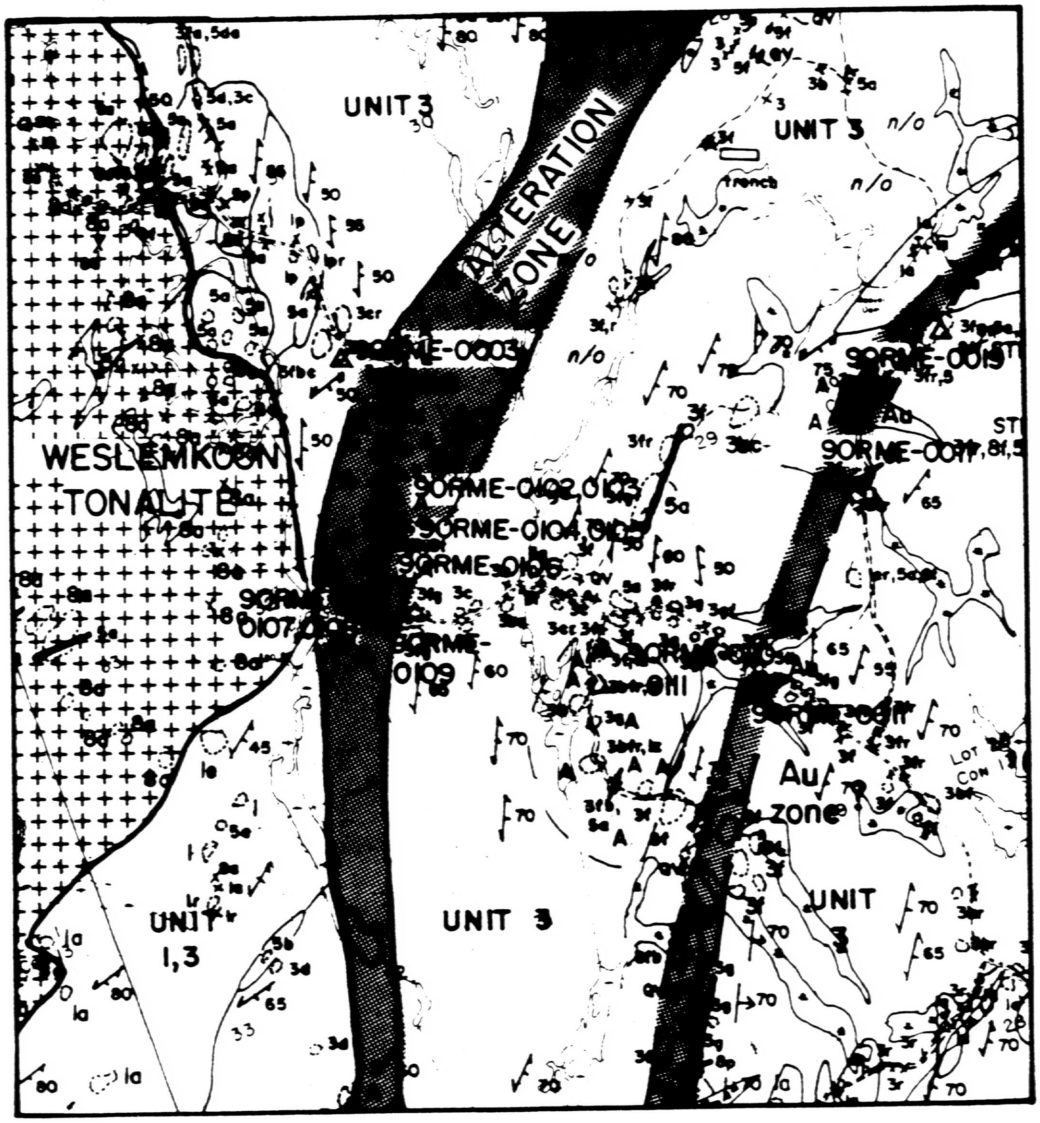


Figure 39: Geochemical features of the Partridge Creek alteration zone.
A) Plot of Na_2O versus SiO_2 showing Na and Si enrichment of samples in the alteration zone.
B) Plot of Fe_2O_3 (total iron) versus SiO_2 showing iron depletion within the alteration zone.
C) Plot of Na_2O versus TiO_2 showing TiO_2 depletion within the alteration zone.

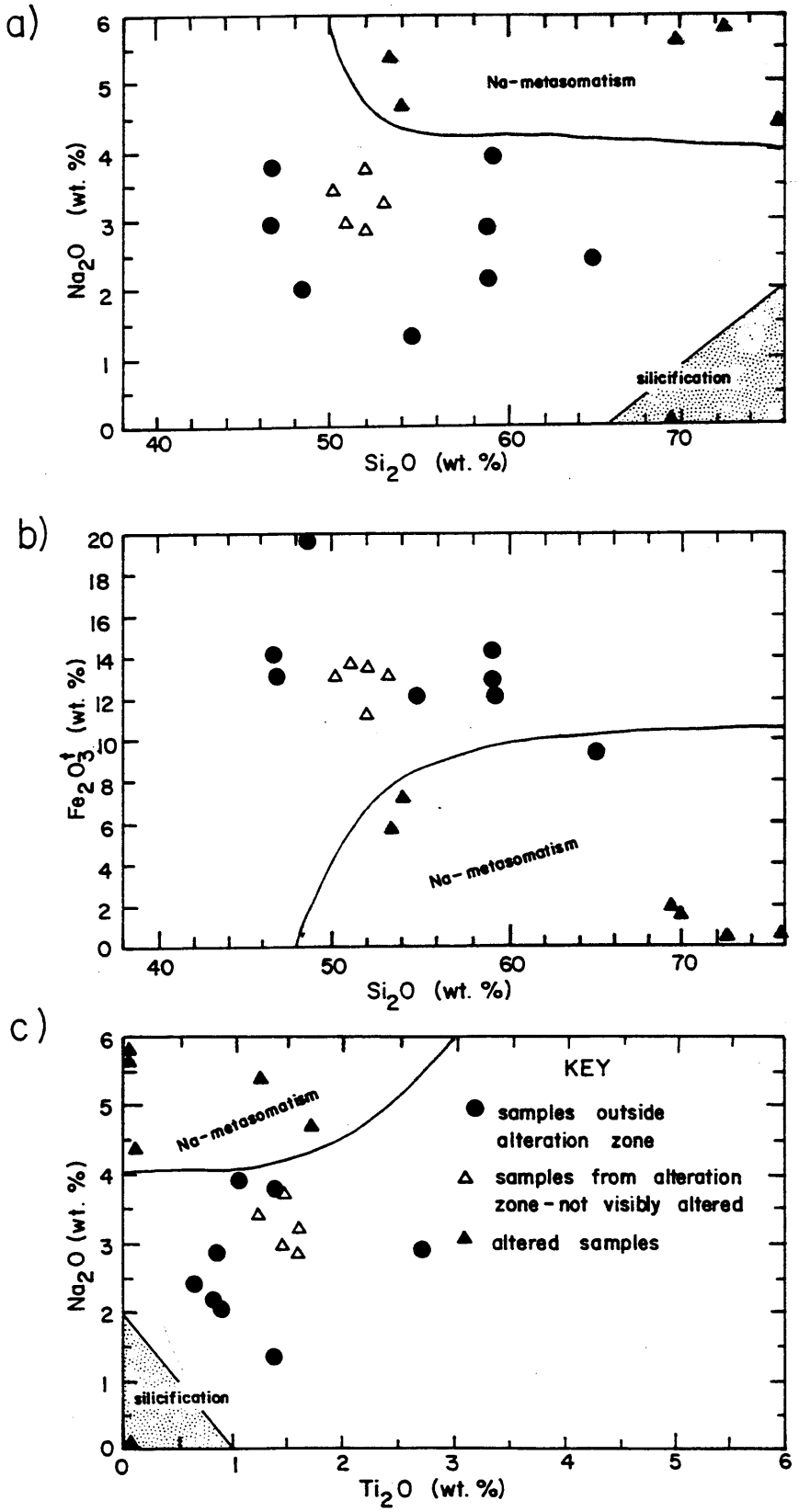


Figure 40: Geochemical features of the Partridge Creek alteration zone.
A) Plot of LOI versus density showing volatile depletion and lowdensity of samples within the alteration zone. Density of pure albite 2.63.
B) Plot of Fe_2O_3 (total iron) versus density showing iron depletion within the alteration zone.
C) Plot of Th versus Zr showing Th enrichment within the alteration zone. Detection limit for thorium is 10 ppm which is why samples cluster near 10 ppm Th.
D) Plot of Rb versus Zr showing Rb and Zr depletion within the alteration zone.

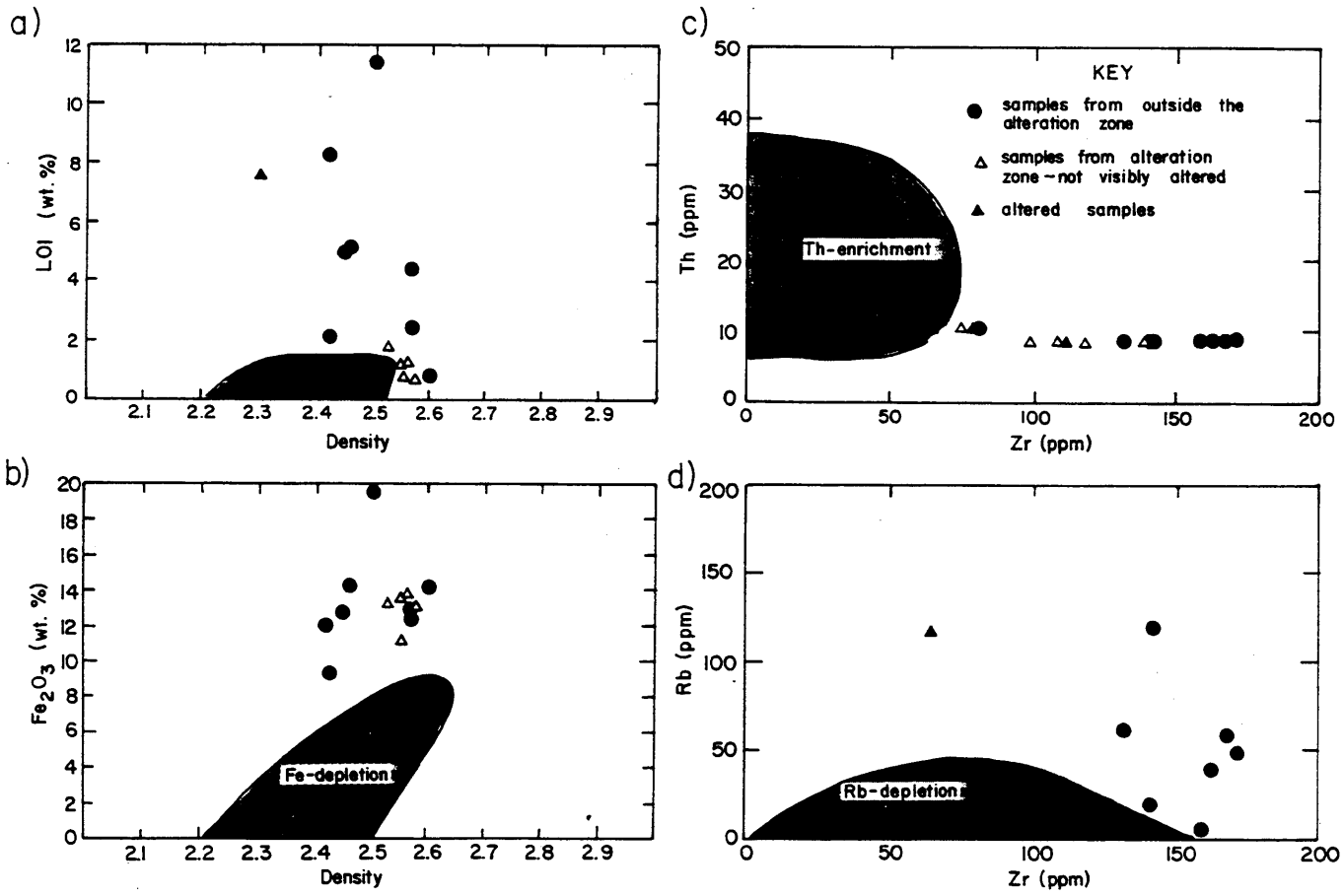


Figure 41: Chondrite-normalized REE plot for visibly altered samples from the Partridge Creek alteration zone.

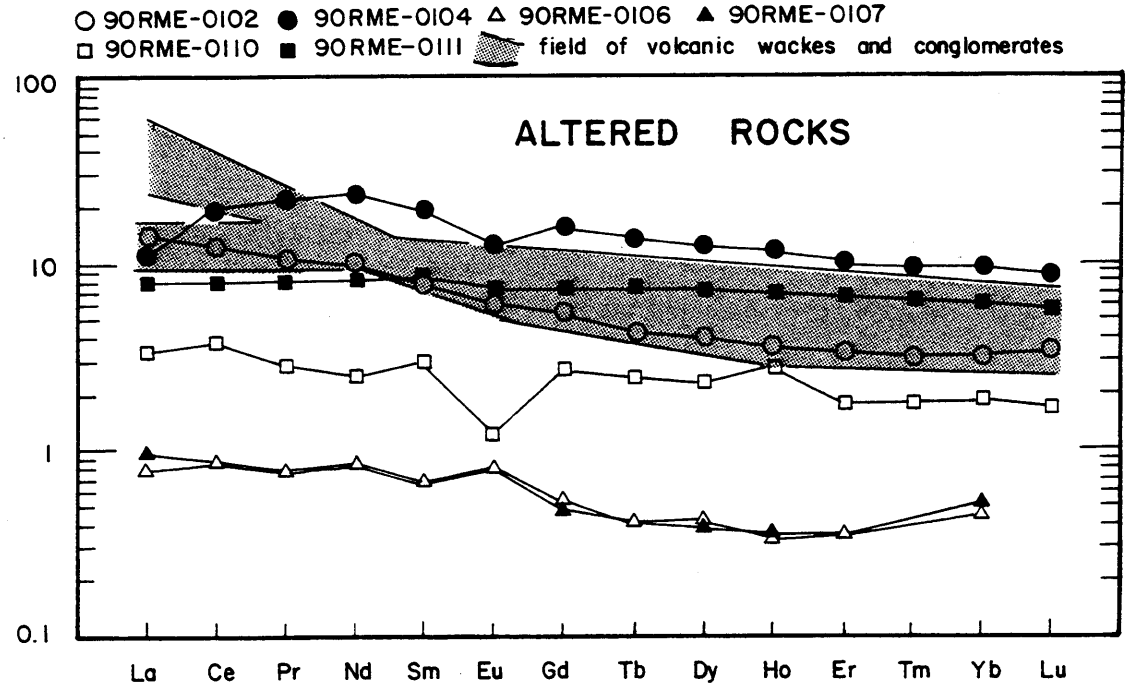


Figure 42: Sketch showing alteration style associated with deposits exhibiting regional semiconformable alteration (after Morton and Franklin 1987; Fyon et al. 1992).

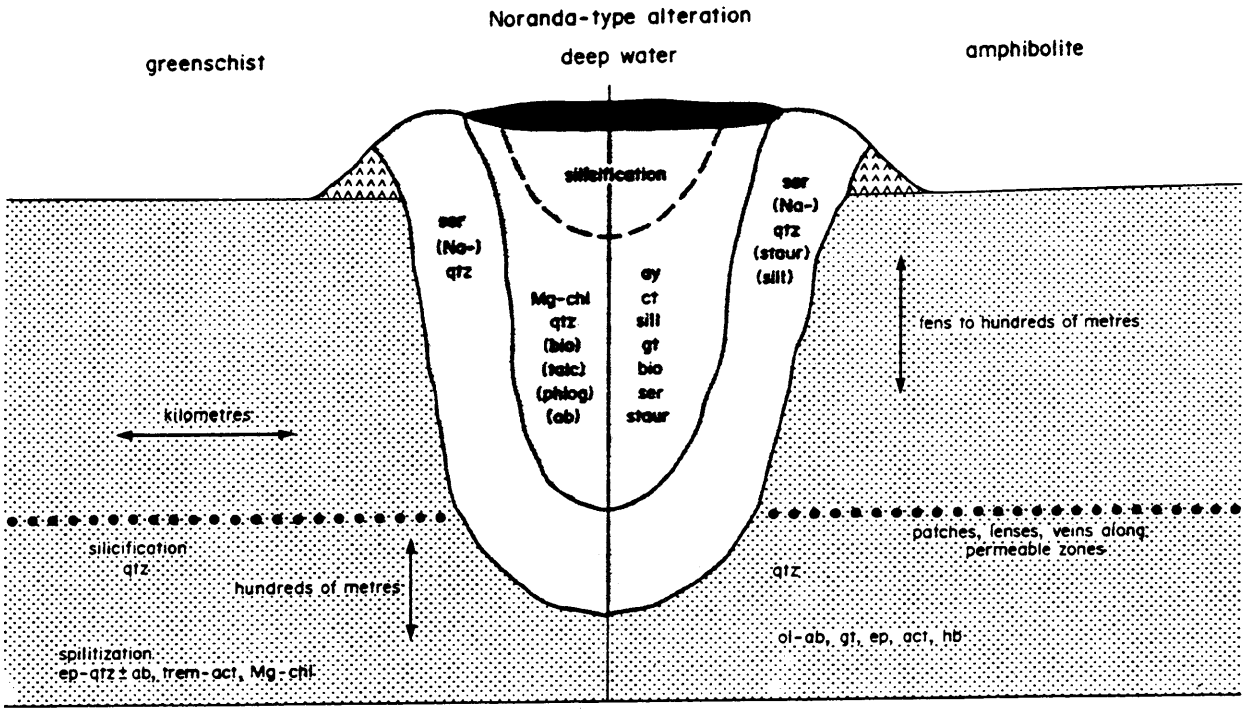


TABLE 17: Chemical analyses of altered samples from the Partridge Creek alteration zone. Sample locations shown in Figure 38.

wt%.	1	2	3	4	5	6
SiO_2	69.42	53.36	54.03	69.85	72.51	75.80
TiO_2	0.04	1.22	1.74	0.03	0.03	0.05
Al_2O_3	1.88	17.00	14.90	14.80	14.50	13.93
Fe_2O_3	18.41	5.62	7.24	1.65	0.44	0.61
FeO	ND	ND	ND	ND	ND	ND
MgO	0.25	4.56	4.71	1.25	0.34	0.10
MnO	0.03	0.09	0.11	0.03	0.01	0.01
CaO	1.72	10.00	9.98	4.75	4.29	0.25
Na_2O	0.06	5.39	4.67	5.63	5.82	4.38
K_2O	0.04	0.32	0.22	0.32	0.32	3.92
P_2O_5	0.33	0.37	0.27	0.03	0.03	0.01
CO_2	0.17	1.38	1.71	0.68	0.82	0.14
S	0.00	0.05	0.01	0.01	0.01	0.01
H_2O^+	3.01	0.59	0.70	0.27	0.26	0.45
H_2O-	0.45	0.01	0.08	0.04	0.02	0.02
LOI	7.61	0.95	1.23	0.68	0.74	0.52
Total	99.79	98.88	98.80	99.02	99.03	99.58
Mg#	20.85	61.64	56.30	60.00	60.48	24.51
Density	2.29	2.51	2.37	2.34	2.30	
ppm						
Ba	21	54	42	42	36	203
Be	<1	<1	<1			
Co	54	12	14	6	<5	<5
Cu	389	14	<5	<5	<5	<5
Mo	<10	<10	<10	<10	<10	<10
Nb	5	5	5	5	5	5
Ni	49	22	15	7	<5	<5
Rb	<5	10	<5	12	12	117
Sc	<2	21	24	<2	<2	4
Sr	9	390	225	366	339	84
Th	15	<10	<10	30	17	<10
V	126	127	223	18	8	5
Y	2	14	42	2	2	8
Zn	7	28	23	11	6	11
Zr	14	111	140	52	52	65

TABLE 17: (continued)

La	1.3	8.9	7.1	0.5	0.6	2.1
Ce	2	20	31	1.4	1.4	6.0
Pr	0.3	2.6	5.5	0.2	0.2	0.7
Nd	1.3	12	28	1.0	1.0	3.0
Sm	0.28	3.1	7.8	0.27	0.27	1.2
Eu	0.08	0.91	1.9	0.12	0.12	0.18
Gd	0.26	2.9	8.2	0.28	0.26	1.4
Tb	0.03	0.41	1.3	0.04	0.04	0.24
Dy	0.3	2.6	8.0	0.26	0.27	1.5
Ho	0.05	0.53	1.7	0.05	0.05	0.04
Er	0.16	1.4	4.3	0.15	0.15	0.75
Tm	bd	0.21	0.64	bd	bd	0.12
Yb	0.18	1.4	4.1	0.20	0.22	0.82
Lu	bd	0.23	0.55	bd	bd	0.11

ND = not determined, bd = below detection limits

Sample No.	Sample Location	Rock Type	Unit	Reference
1)	90RME-0017314530E 4968260N	sil. congl.	3f	this study
2)	90RME-0102313310E 4968040N	albitite	1z	this study
3)	90RME-0104313300E 4979600N	albitite	1z	this study
4)	90RME-0106313270E 4967880N	altered rock	1z	this study
5)	90RME-0107313270E 4967880N	altered rock	1z	this study
6)	90RME-0109313360E 4967730N	sil. congl.	3f	this study
7)	90RME-0110313850E 4967660N	albitite-felsite	1z	this study

Talc

Field party personnel located a new talc occurrence along the east margin of the Canniff Tonalite at UTM 312200E, 4958810N (lot 8, conc. VI, Grimsthorpe Twp.). The new occurrence is north of the Grimsthorpe 1 and 2 occurrences described by LeBaron and van Haaften (1989), and consists of a body of coarsely crystalline, pale green talc associated with anthophyllite-rich rocks.

The talc occurrences noted above are part of a belt of talc occurrences that lie along the western margin of the Elzevier and Weslemkoon tonalites from highway 7 in the south to Weslemkoon Lake in the north (Figure 3). These talc occurrences are hosted in mafic and ultramafic rocks and occur within 2 km of the tonalite intrusions. Mapping in the Grimsthorpe area has further elucidated the origin of the talc occurrences in the Elzevir-Grimsthorpe area.

The talc occurrences are found only in areas where the older gabbros of the Canniff Complex (unit 2) (Figures 3 and 43) occur along the pluton margins. In particular, they occur as isolated pods lying adjacent to larger bodies of the older gabbro, generally in areas that have been more intensely deformed. They are closely associated with

gabbro clast conglomerates of the volcaniclastic succession. The greater abundance of talc bodies in the Elzevir area to the south might reflect better exploration, however, deformation does become more intense to the south, possibly related to the intrusion of the Mount Moriah Syenite and a narrowing of the belt of protomylonitic gabbros and supracrustal rocks, and might be a factor in talc mineralization. As noted under the description of the Canniff Complex, the talc bodies in the Grimsthorpe and Elzevir areas are similar to listwanites reported from the Arabian Shield (Buisson and Leblanc 1986) and the Canadian Cordillera (Nixon and Mammack 1991). In listwanites, the alteration of ultramafic rocks to form talc is related to fluid interaction during tectonic emplacement (Buisson and Leblanc 1986).

Three factors may thus be responsible for talc mineralization in the Elzevir-Grimsthorpe area: (1) a favourable protolith which may have undergone an early deformation of alteration (protomylonitic gabbros of basaltic komatiite composition), possibly similar to that described for listwanites; (2) subsequent metamorphism and fluid movement related to emplacement of tonalite plutons in the area; and (3) deformation associated either with, or subsequent to, tonalite emplacement. Exploration should focus on areas where these three factors occur.

Building Stone

Although the Skootamatta Syenite is close to major roads in the area, it is commonly fractured and jointed and field party personnel did not locate any areas that appeared to be reasonable prospects for extracting the syenite as a building stone. LeBaron *et al.* (1989) describe two prospects from the Skootamatta Syenite. The Mount Moriah Syenite prospect (LeBaron *et al.* 1989) is much more attractive from a building stone production standpoint.

The Killer Creek Gabbro Suite contains a variety of textures and colours, and might make attractive stone products. The best prospects are located north and south of Killer Creek adjacent to the reference localities shown in Figure 4. LeBaron *et al.* (1989) describe the potential of one site along the Skootamatta road by Killer Creek.

Most tonalite prospects lie far from existing roads. This, combined with the fact that several stone prospects are present in the Elzevir Tonalite to the south of the map area (LeBaron *et al.* 1989) make the building stone potential of the Elzevir, Weslemkoon and Canniff tonalites in the Grimsthorpe area unattractive at this time. LeBaron et al. (1989) describe two potential sites in the Weslemkoon Tonalite.

Figure 43: Detailed geology around talc occurrences in the south-central part of the map area showing relation of talc occurrences to older gabbro bodies and tonalite intrusions.

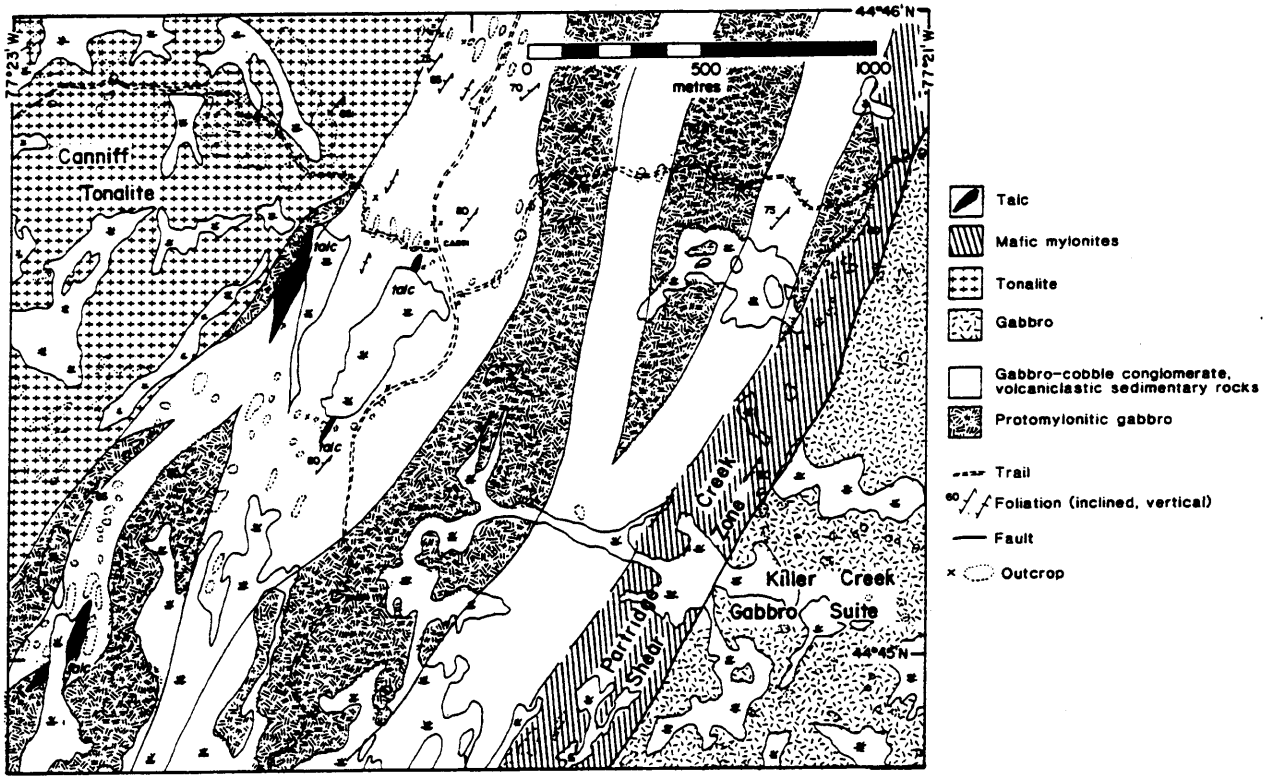


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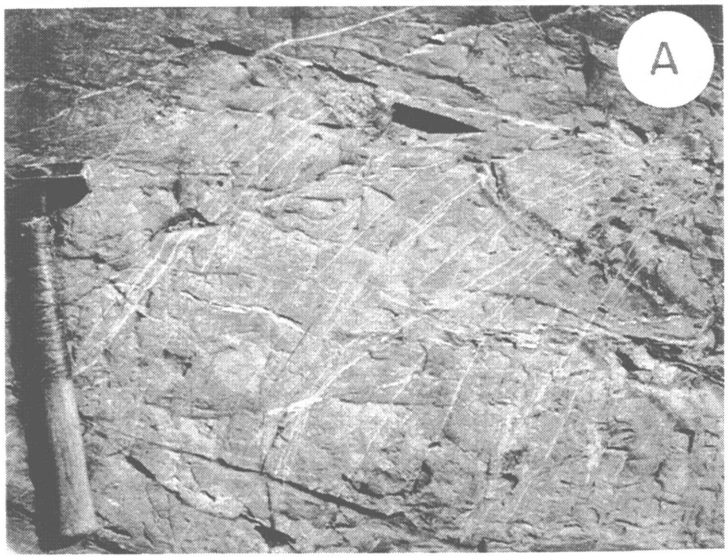
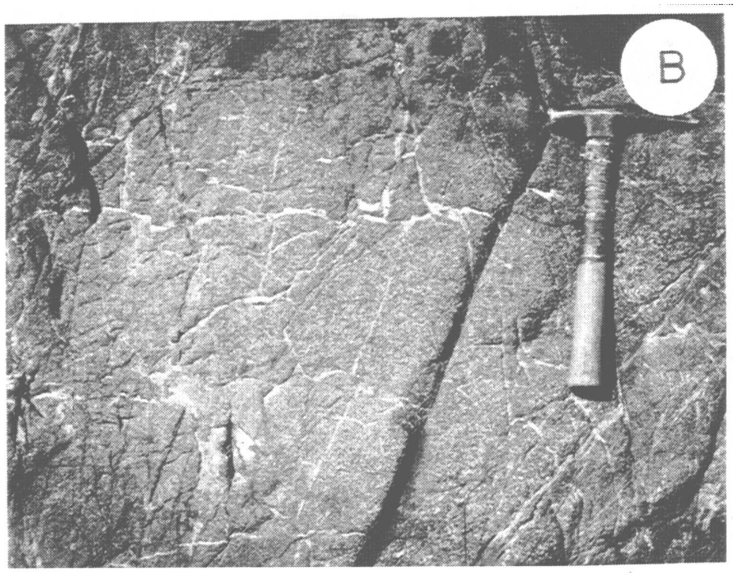
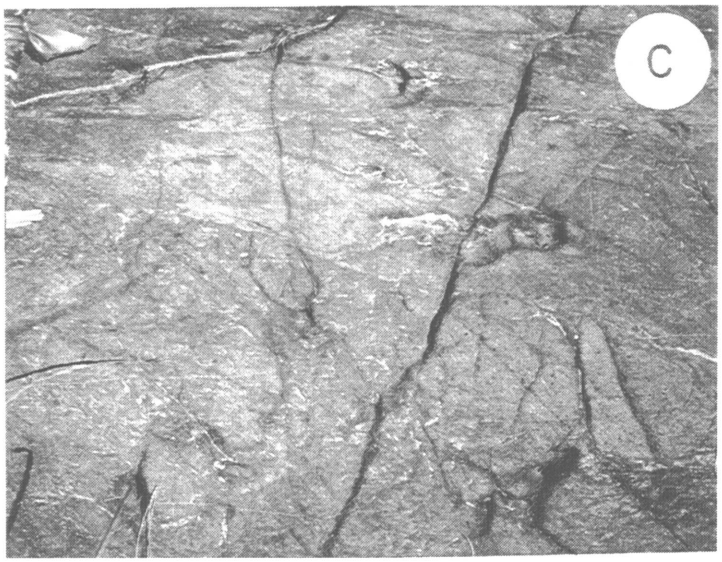
Photo 1: Mafic Metavolcanic Rocks (unit 1).



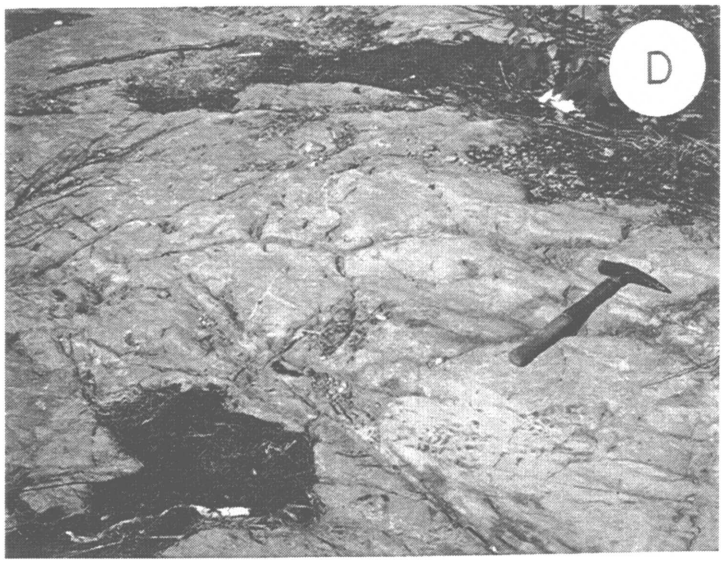
A) Possible pillowed amphibolite (unit 1b) of the Canniff Complex. Note veining characteristic of Canniff Complex metavolcanics. UTM 305840E, 4963800N. Hammer handle is 30 cm long.



B) Ophitic-textured amphibolite (unit 1d) of the Canniff Complex. Note veining characteristic of Canniff Complex metavolcanics. UTM 310020E 4959660N. Hammer handle is 30 cm long.

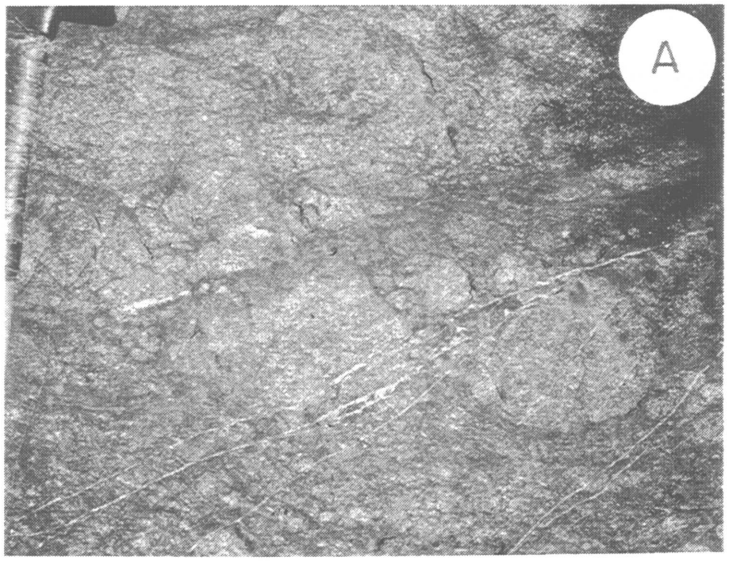


C) Contact between unit 1a overlain by tuffaceous sandstone (unit 3b, matrix to unit 3f) of the Grimsthorpe Group. Arrows highlight the sharp, apparently unconformable contact. UTM 314000E 4969880N. Field of view is 50 cm across.

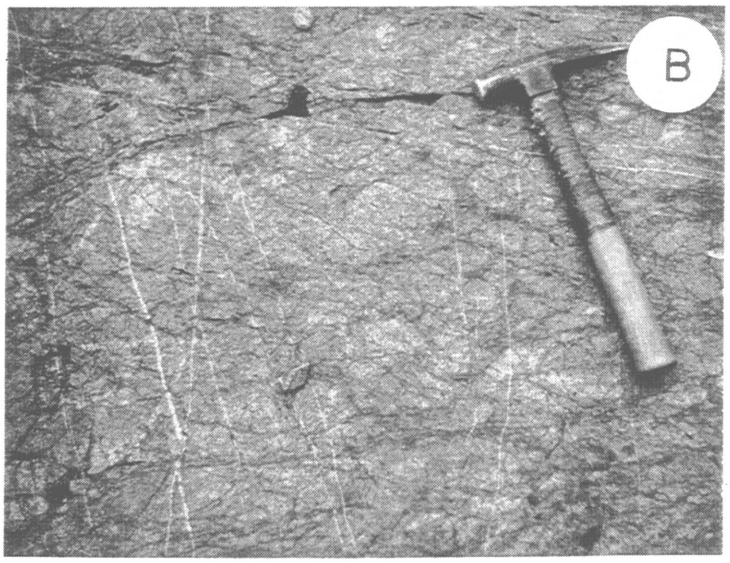


D) Pillowed metavolcanics (unit 1b) of the Grimsthorpe Group, intercalated with tuffaceous metaconglomerates (unit 3f, not visible in photo) along the Skootamatta Road. Compare with photos 1a and 1b. Note lack of veining and better preservation of pillowed texture in this rock. UTM 315120E 4965975N. Hammer handle is 30 cm long.

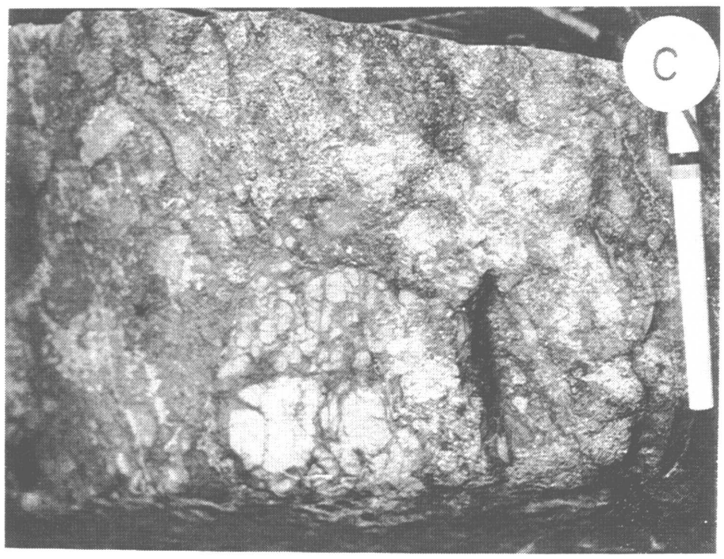
Photo 2: Microbrecciated Mafic Metavolcanic Rocks (unit 1).



A) Microbrecciated mafic amphibolite (unit 1c). This type of volcanic texture is not well documented in the literature. In this outcrop, brecciation pattern is similar to ball-and-pillow and pillow-bed structure found in water-laden sandstones that have undergone soft-sediment deformation. UTM 303980E 4966490N. Field of view is 50 cm across.

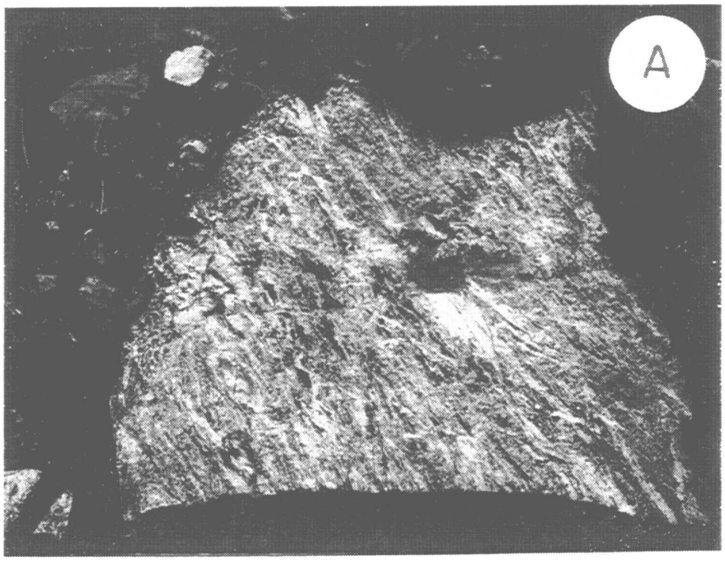


B) Microbrecciated mafic amphibolite (unit 1c). Breccia pattern is more angular, unit may represent internally brecciated flow or unusual form of pillow breccia. UTM 304150E 4965760N. Hammer handle is 30 cm long.

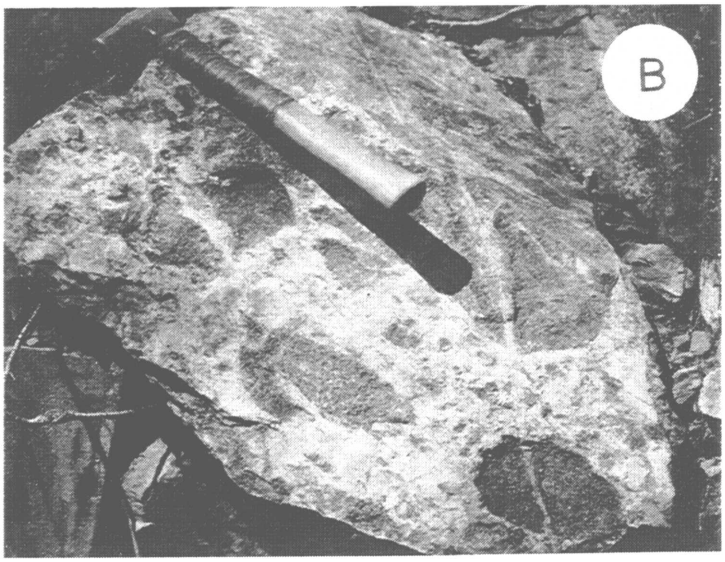


C) Cobble of brecciated amphibolite (unit 1c) within Grimsthorpe Group tuffaceous conglomerate. Here, brecciation appears to be a soft-sediment deformation feature in an intraformational tuffaceous sandstone. UTM 306520E 4964300N. Pen is 13 cm long.

Photo 3: Altered Mafic Metavolcanic Rocks (unit 1).

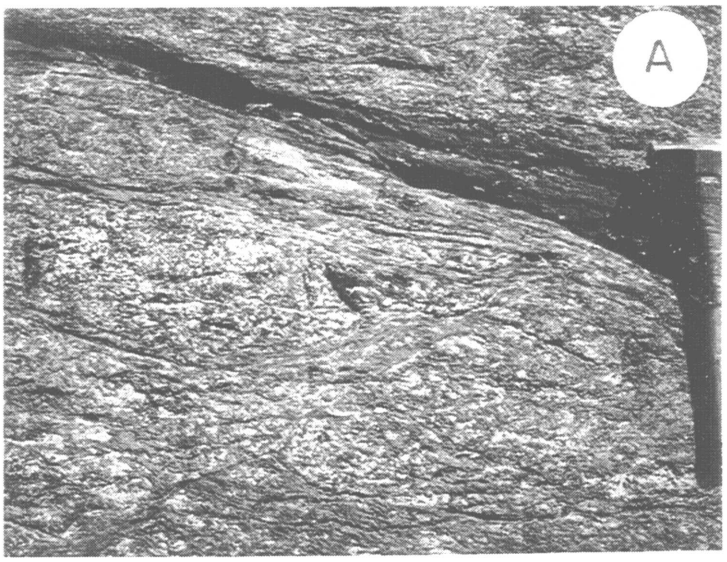


A) Sodium-metasomatized mafic metavolcanic rock along the Skootamatta Road (unit 1z). UTM 313260E 4967800N. Field of view is 30 cm across.

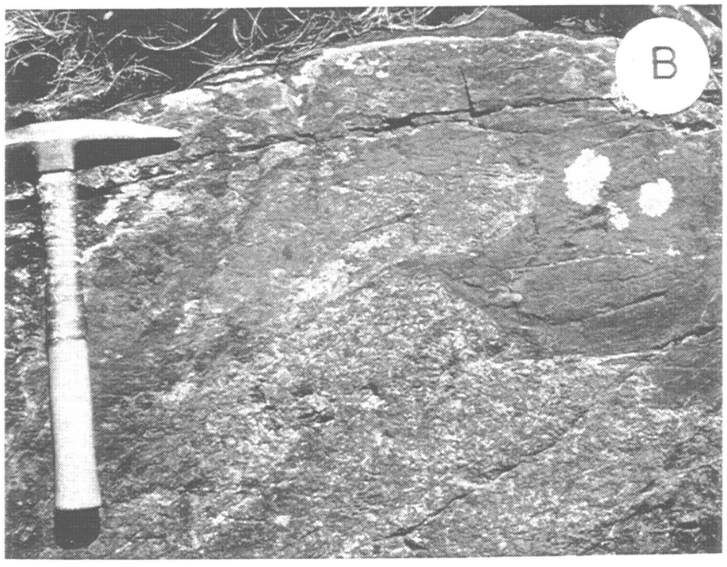


B) Silicified tuffaceous conglomerate from the southwestern trench on the United Reef Petroleums property in Anglesea Township. UTM 314530E 4968260N. Hammer handle is 30 cm long.

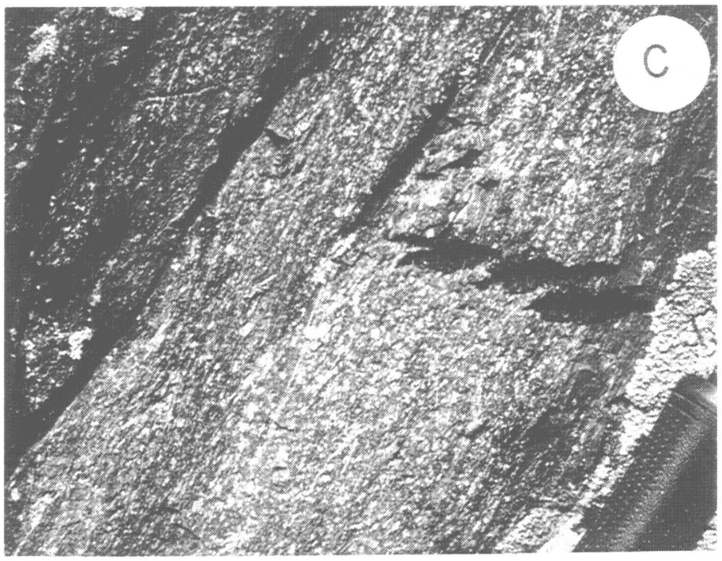
Photo 4: Protomylonitic Gabbros of the Canniff Complex (unit 2).



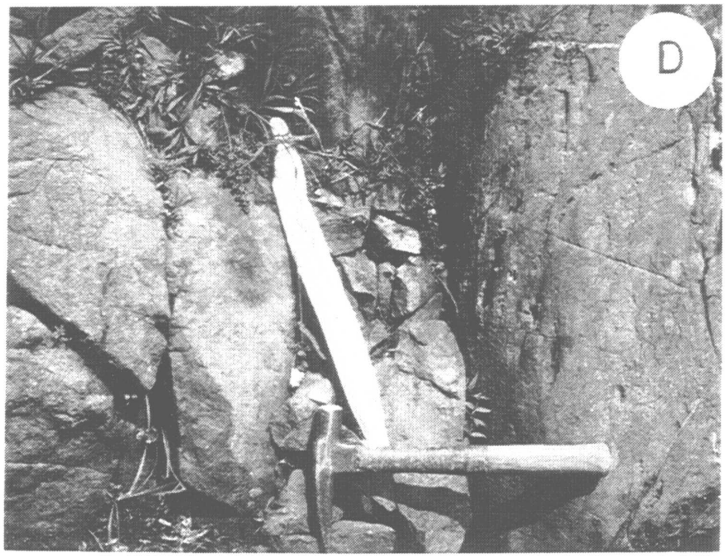
A) Typical medium-grained, protomylonitic gabbro of the Canniff Comples (unit 2). UTM Hammer handle is 30 cm long.



B) Metagabbro of unit 2 (left and centre) cut by fine-grained basaltic dike (unit 5) (upper right). Arrow highlights irregular intrusive contact. UTM 310265E 4959458N. Hammer handle is 30 cm long.



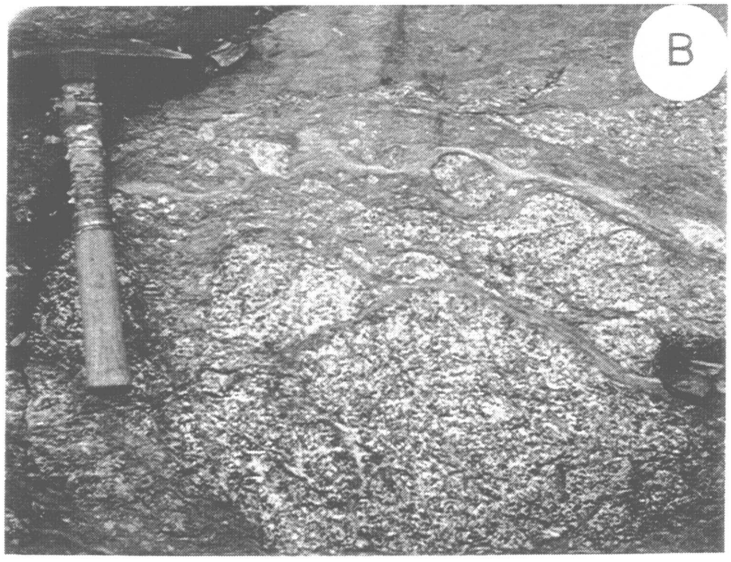
C) Mylonitic metagabbro of unit 2. UTM 313575E 4937250N. Field of view is 25 cm across.



D) Contact between metagabbro of unit 2 (left) of the Canniff Complex and gabbro-clast-bearing tufffaceous conglomerate (unit 3g) of the Grimsthorpe Group. Arrow highlights the sharp contact. See text for further discussion. UTM 310220E 4959600N. Hammer handle is 30 cm long.

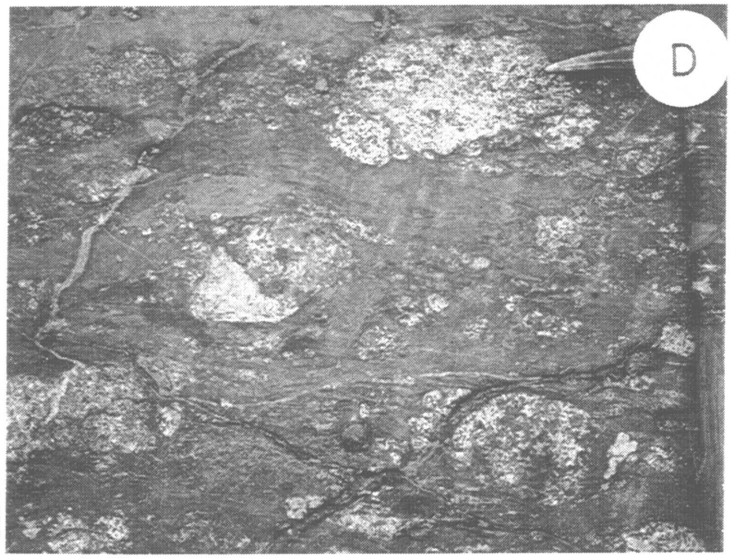
Photo 5: Gabbro-bearing tuffaceous conglomerates of the Grimsthorpe Group (unit 3g).

A) Coarse-grained gabbro clasts within matrix-supported, tuffaceous conglomerate of the Grimsthorpe Group. Note subround character of gabbro clasts compared to angular to subangular character of the volcanic fragments. UTM 314240E 4974160N. Field of view is 20 cm across.



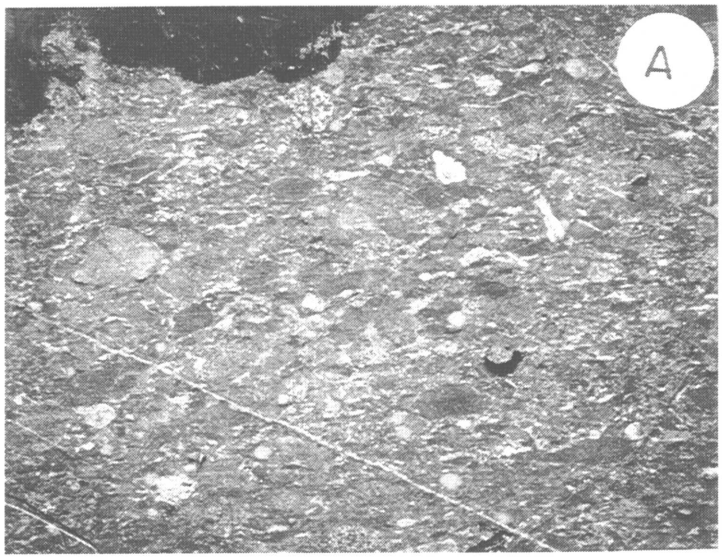
B) Unit 2 metagabbro grading upward into tuffaceous conglomerate. Gabbro fragments along shear boundaries to produce subround fragments (arrow points to an example). In this outcrop, contact may represent a regolith with overlying conglomeratic detritus. UTM 314124E 4967049N. Hammer handle is 30 cm long.

C) Matrix- to clast-supported tuffaceous conglomerate containg abundant gabbroic fragments similar to unit 2 metagabbros. Note apparent lack of deformation in conglomerate. UTM 316430E 4969120N. 20 cm of hammer is shown.

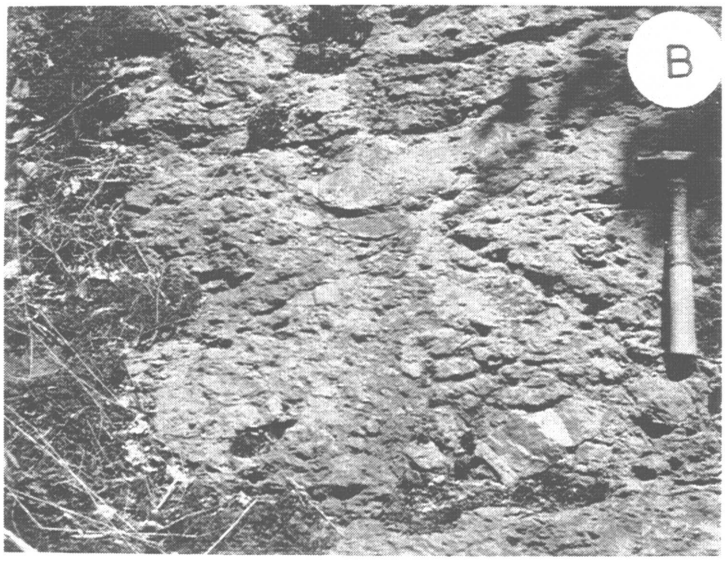


D) Matrix-supported tuffaceous conglomerate containing unit 2 metagabbro clasts. Clast beside hammer tip (upper right, see arrow) apparently preserves shear band indicating gabbro was deformed prior to sedimentation. Note apparent lack of deformation in conglomerate. UTM 316430E 4969120N. Hammer handle is 30 cm long.

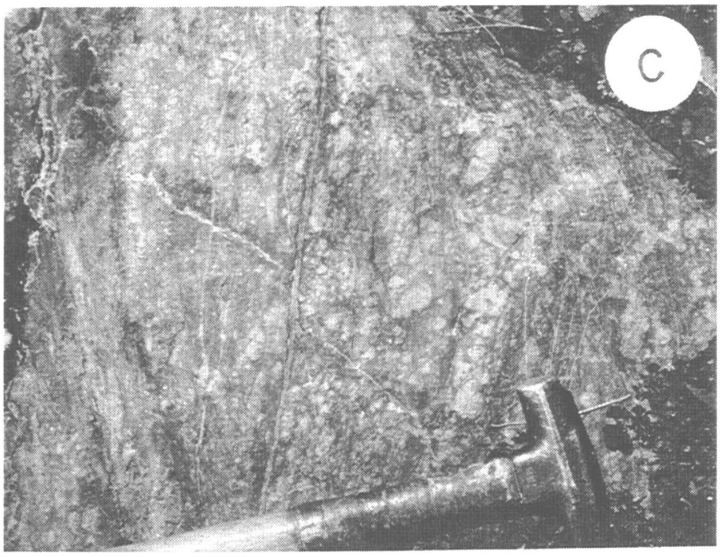
Photo 6: Tuffaceous Conglomerates of the Grimsthorpe Group (unit 3f) showing variety of preserved textures and clast types.



A) Heterolithic, clast-supported tuffaceous conglomerate. UTM 31450E 4966660N. Field of view is 30 cm across.

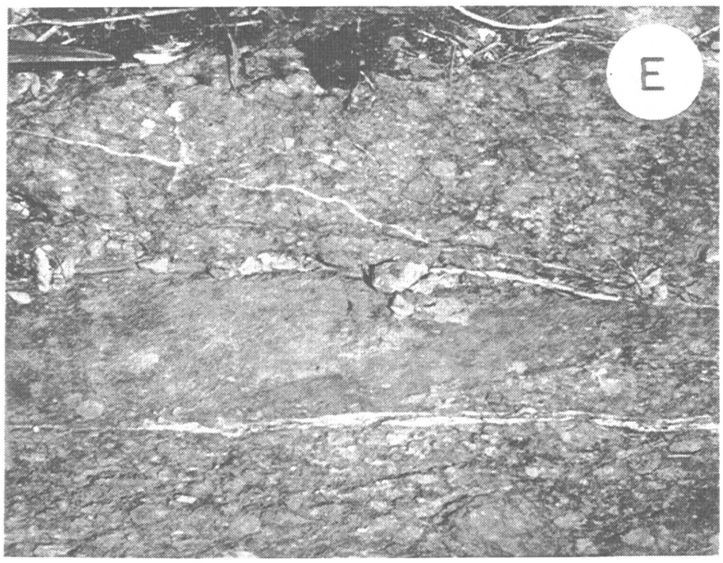


B) Heterolithic, clast-supported tuffaceous conglomerate. UTM 314600E 4967420N. Hammer handle is 30 cm long.

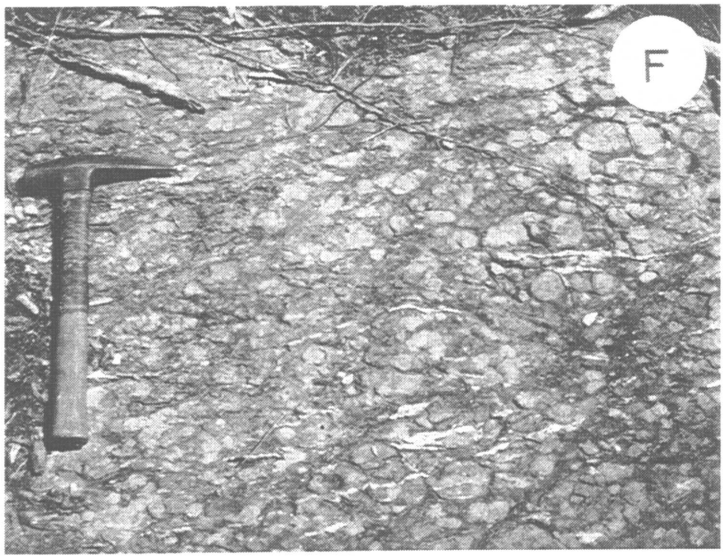


C) Monolithic, clast-supported tuffaceous conglomerate. UTM 304700E 4965980N. Hammer handle is 30 cm long.

D) Heterolithic, clast-supported tuffaceous conglomerate. UTM 313300E 4967700N. Hammer handle is 20 cm long.

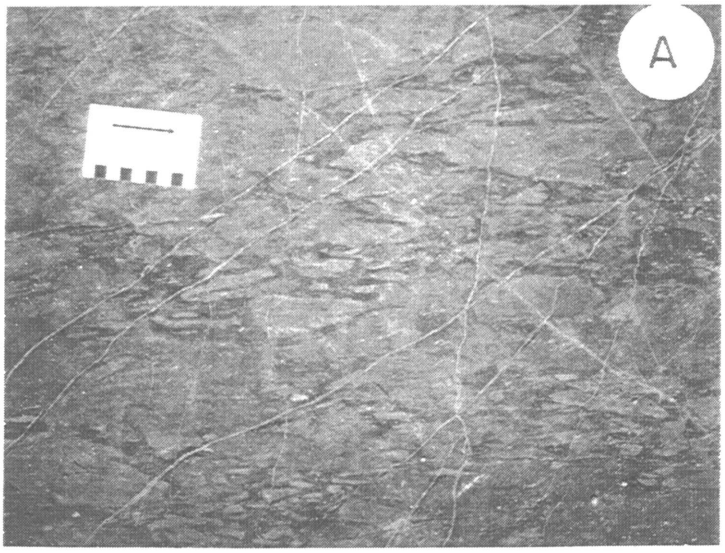


E) Tuffaceous sandstone lens in clast-supported tuffaceous conglomerate. UTM 314220E 4967060N. Field of view is 35 cm across.

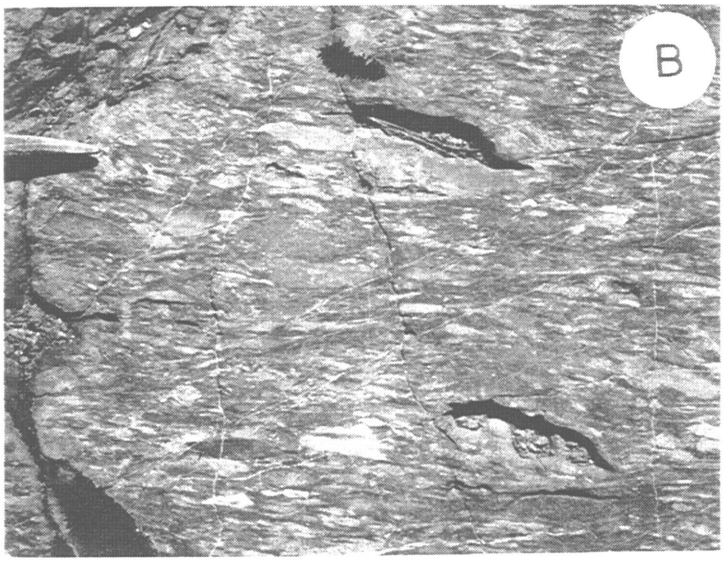


F) Well-rounded, tuffaceous sandstone cobbles in clast-supported tuffaceous conglomerate. UTM 314200E 4967160N. Hammer handle is 30 cm long.

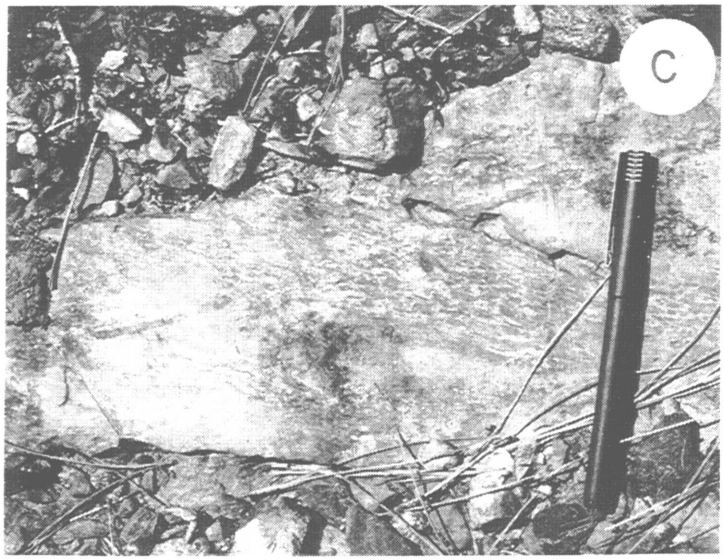
Photo 7: Tuffaceous Conglomerates to Breccias of the Grimsthorpe Group (unit 3f-1g) showing variety of preserved textures and clast types.



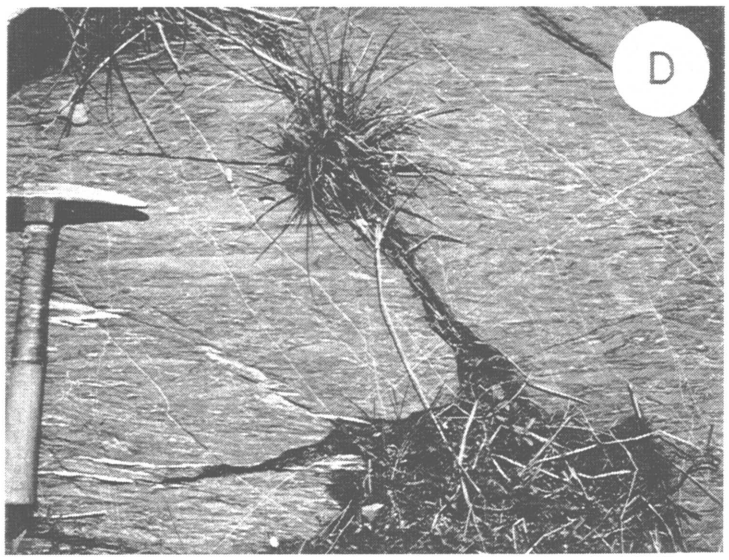
A) Monolithic, matrix-supported tuffaceous conglomerate to tuff breccia. UTM 314920 4976000N.



B) Heterolithic, clast-supported tuff breccia to tuffaceous conglomerate (debris flow) UTM 305110E 4965580N. Field of view is 40 cm across.

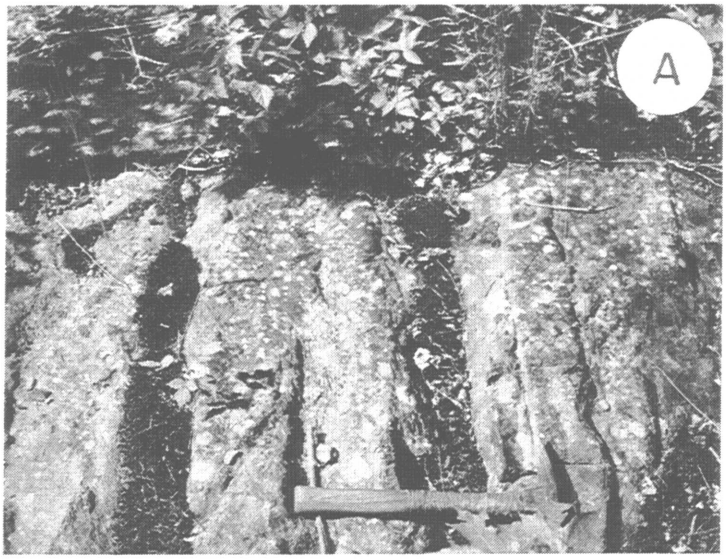


C) Hyaloclastite bed (unit 1h) within tuffaceous conglomerates and breccias. Hyaloclastite may have been transported. UTM 303940E 4966690N. Pen is 15 cm long.



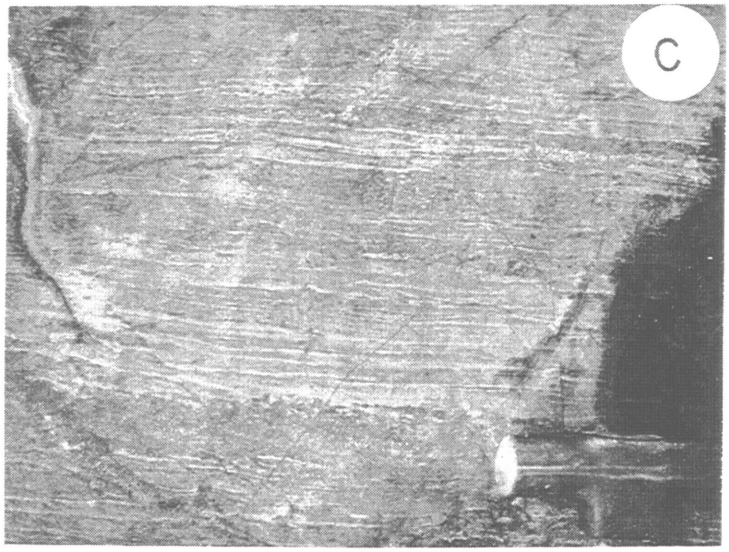
D) Flattened, monolithic, clast-supported tuff breccia to tuffaceous conglomerate. UTM 304990E 4964040N. Hammer handle is 30 cm long.

Photo 8: Tuffaceous sandstones and mudstones of the Grimsthorpe Group (units 3b, 3d) showing variety of preserved textures and sedimentary features.

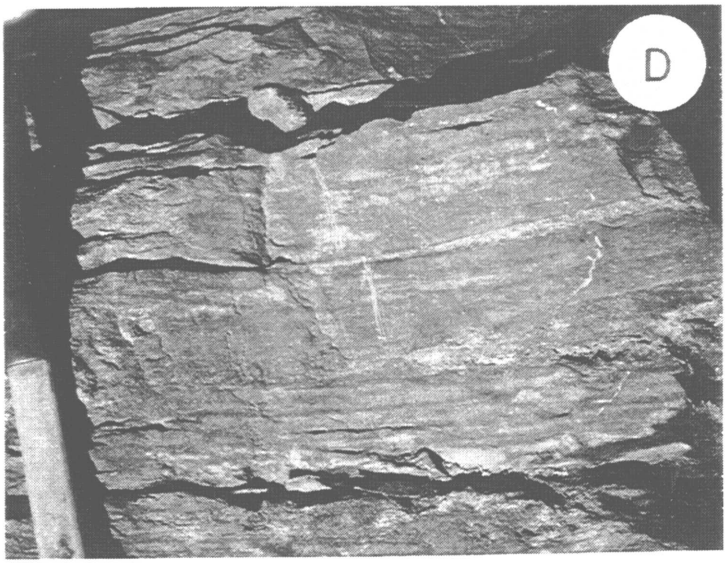


A) Medium-bedded tuffaceous wackes (turbidites). Hammer handle is 30 cm long, and straddles one bed (resistant, coarse base on left and recessive, muddy top on right). UTM 314270E 4968280N.

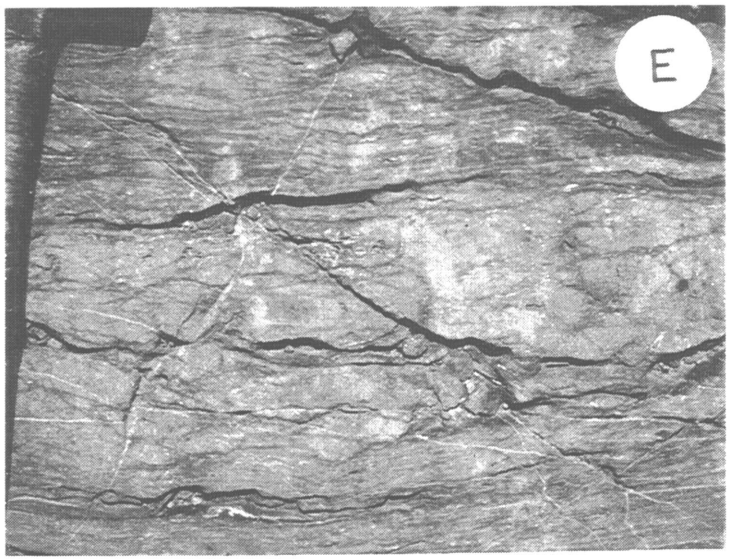
B) Tuffaceous wacke turbidites from the Grimsthorpe Group in the Elzevir area. Arrow indicates top of bed. Bar indicates bed thickness. Field of view is 30 cm across. UTM 301200E 4932650N.



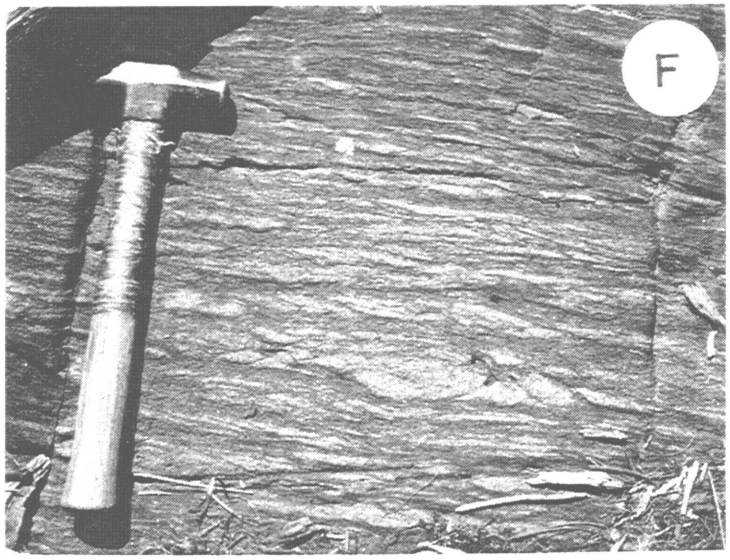
C) Tuffaceous eack bed interbedded with thinly bedded tuffaceous mudstones. Field of view is 20 cm across. UTM 304770E 4967810N.



D) Medium bedded tuffaceous sandstone bed in centre of photo exhibits ball-and-pillow structure. Unit is interbedded with soft-sediment deformed tuffaceous siltstones and mudstones. Field of view is 25 cm across. UTM 309600E 4958990N.

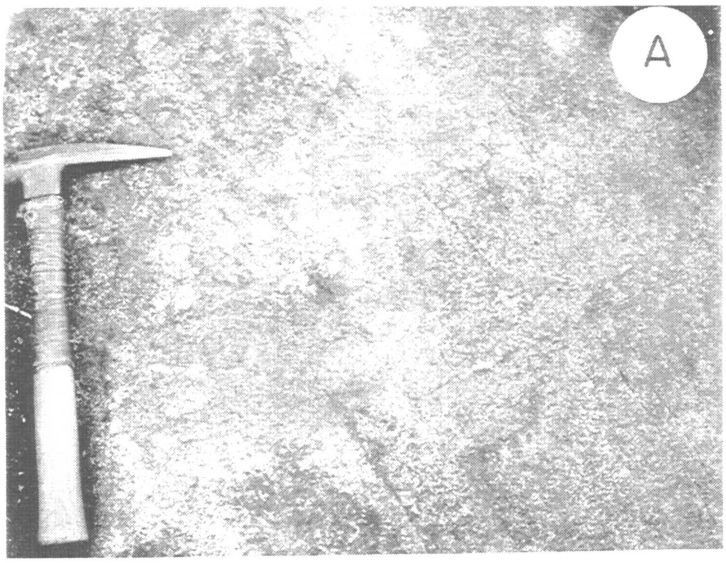


E) Thinly bedded tuffaceous mudstones. Outcrop has been silicified by contact metamorphism of the Weslemkoon Tonalite. Field of view is 30 cm across. UTM 312710E 4975650N.

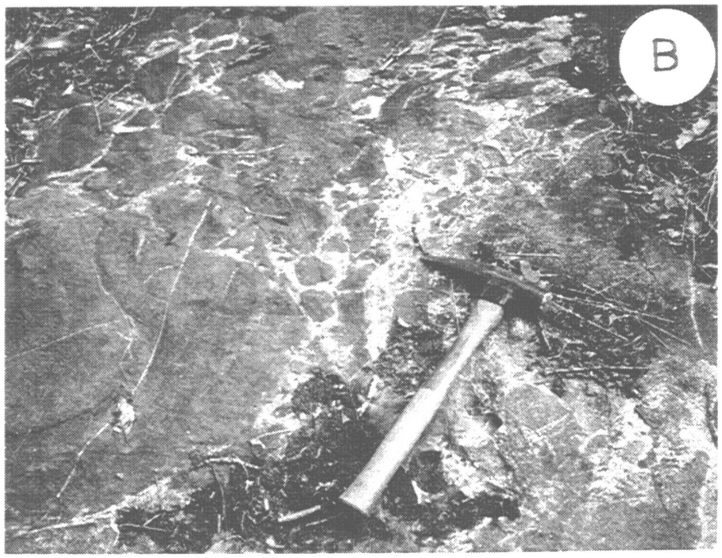


F) Possible hummocky cross-stratification in tuffaceous sandstone unit. Hammer handle is 30 cm long. UTM 309600E 4958990N.

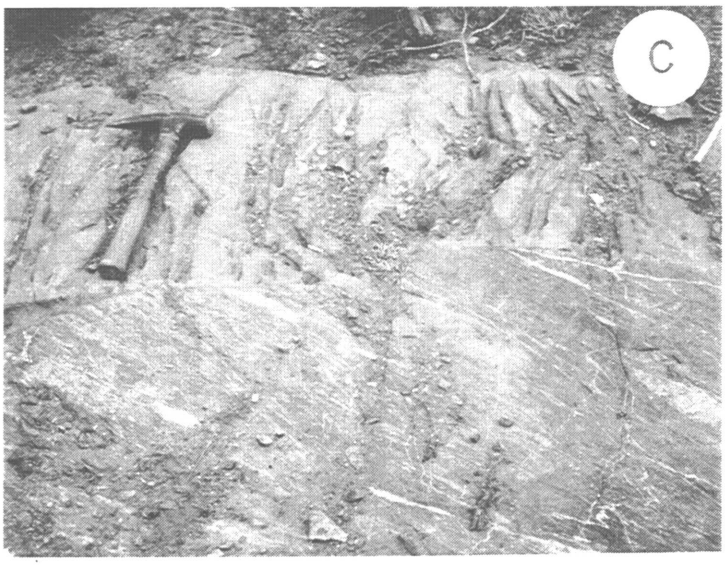
Photo 9: Unit 5 Gabbroic Plutons and Dikes.



A) Melanocratic, fine- to medium-grained gabbro. From large gabbro intrusion along the hydro-transmission line in Effingham Township. UTM 312760E 4975700N. Hammer handle is 30 cm long.



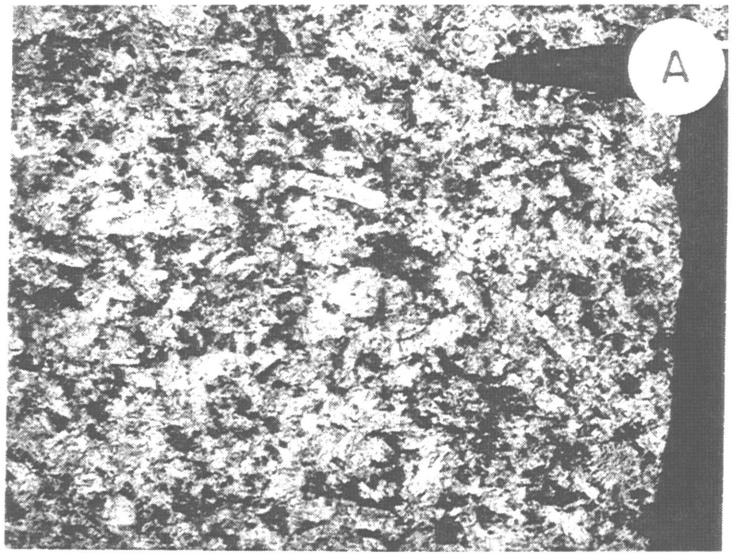
B) Intrusion breccia within unit 5 consisting of astamosing veinlets of anorthositic gabbro composition. North of Skootamatta Lake. UTM 315423E 4975370N. Hammer handle is 30 cm long.



C) Unit 5j dike with well-developed cooling joints oriented perpendicular to dike margin. Note that dike cross-cuts foliation in unit 3f tuffaceous conglomerate. UTM 306740E 4964080N. Hammer handle is 30 cm long.

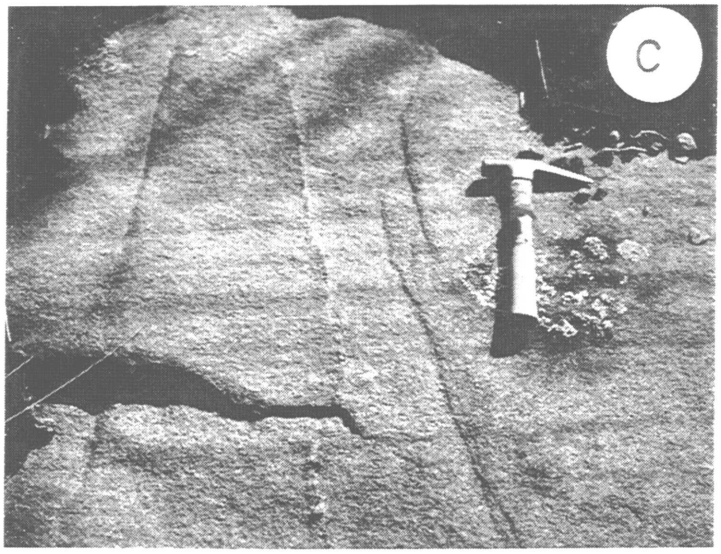
D) Fine-grained, unit 5 dike with chill margins crosscutting Grimsthorpe Group tuffaceous sandstones and mudstones. UTM 305210E 4967630N. Hammer handle is 30 cm long.

Photo 10. Killer Creek Gabbro (unit 7).



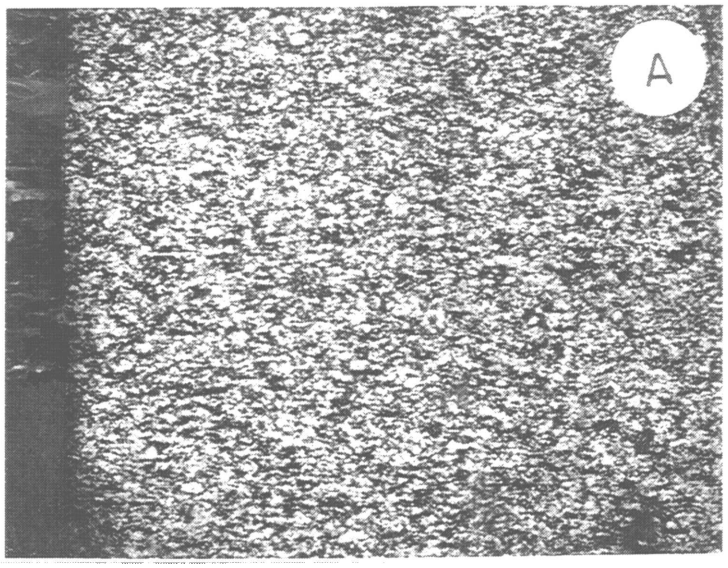
A) Medium-grained, mesocratic gabbro (unit 7a) typical of the Killer Creek Gabbro. Note well-preserved plagioclase laths attesting to lack of penetrative deformation within the body. UTM 316890E 4967180N. Field of view is 20 cm across.

B) Igneous layering in the Killer Creek Gabbro. Melanocratic, feldspar-porphyritic gabbro to the left and mesocratic gabbro to the left. UTM 317370E 4965160N. Hammer handle is 30 cm long.

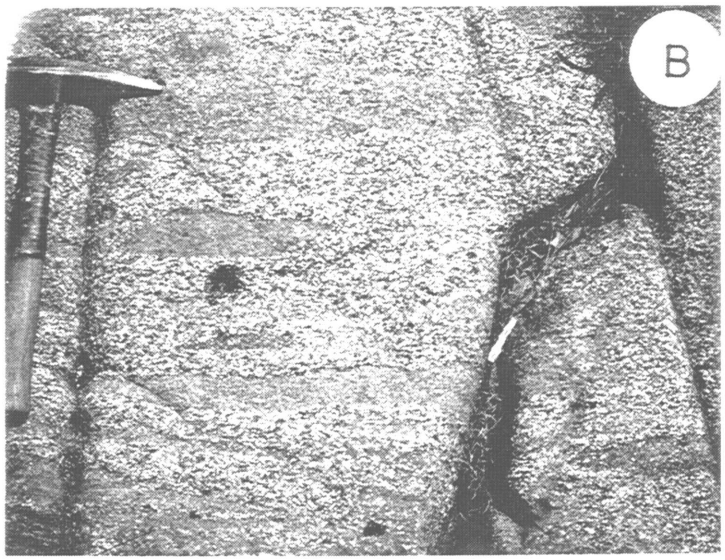


C) Igneous layering in gabbroic anorthosite of the Killer Creek Gabbro. UTM 321000E 4965550N. Hammer handle is 30 cm long.

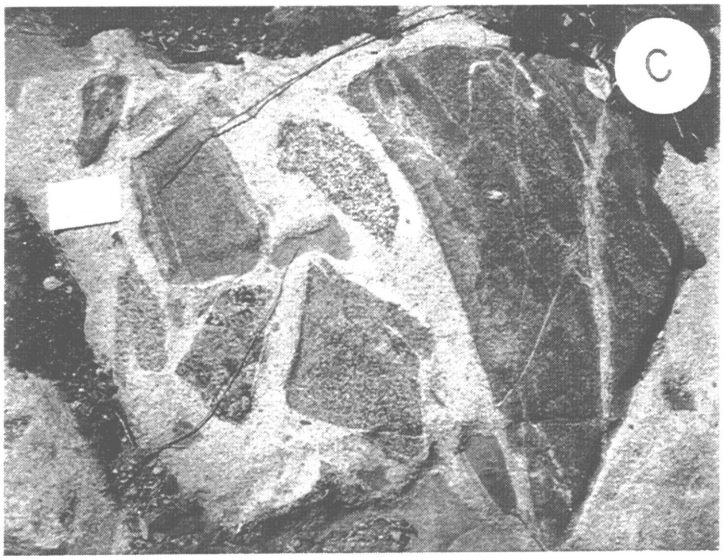
Photo 11: Dioritic and Tonalitic Intrusive Rocks of the Elzevir Suite (unit 8).



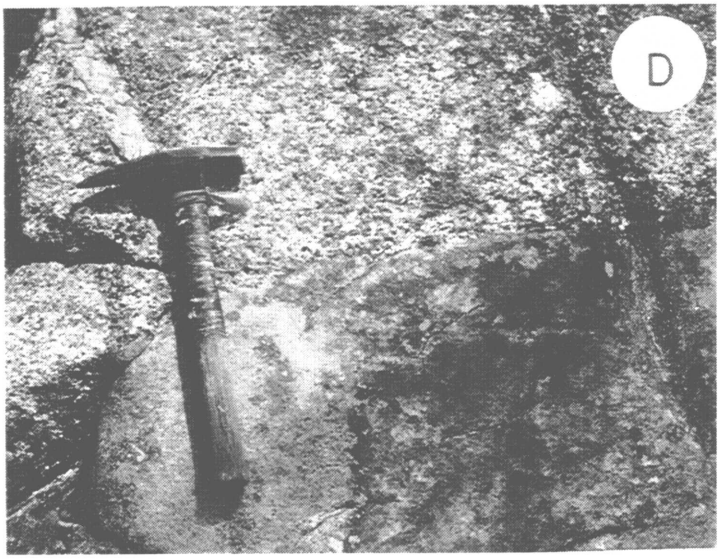
A) Medium-grained diorite of the Lingham Lake Complex. UTM 306140E 4962660N. Field of view is 15 cm across.



B) Schlieren in medium-grained diorite of the Lingham Lake Complex. UTM 308080E 4959240N. Hammer handle is 30 cm long.

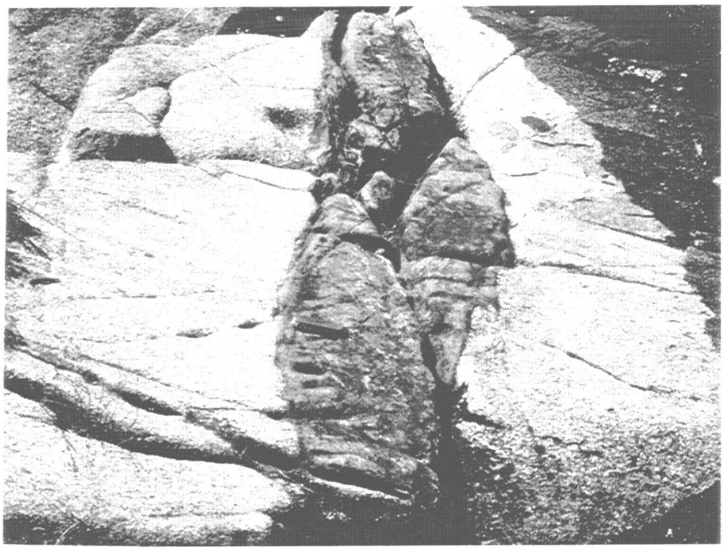


C) Intrusion breccia at the eastern margin of the Weslemkoon Tonalite containg unit 5 gabbro clasts in a tonalitic matrix. UTM 314590E 4977230N.



D) Fine-grained, late tonalite dike (unit 8f) (lower) cutting clotty-textured tonalite (upper) of the northern mass of the Elzevir Tonalite. UTM 320380E 4959080N. Hammer handle is 30 cm long.

Photo 12: Unit 10 dike cutting Lingham Lake Tonalite. UTM 308380E 4959650N. Knife is 10 cm long.



CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm@	0.155 0	square inches	1 square inch	**6.451 6**	cm@
1 m@	10.763 9	square feet	1 square foot	**0.092 903 04**	*m@
1 km@	0.386 10	square miles	1 square mile	2.589 988	km@
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm#	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm#
1 m#	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m#
1 m#	1.308 0	cubic yards	1 cubic yard	0.764 555	m#
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

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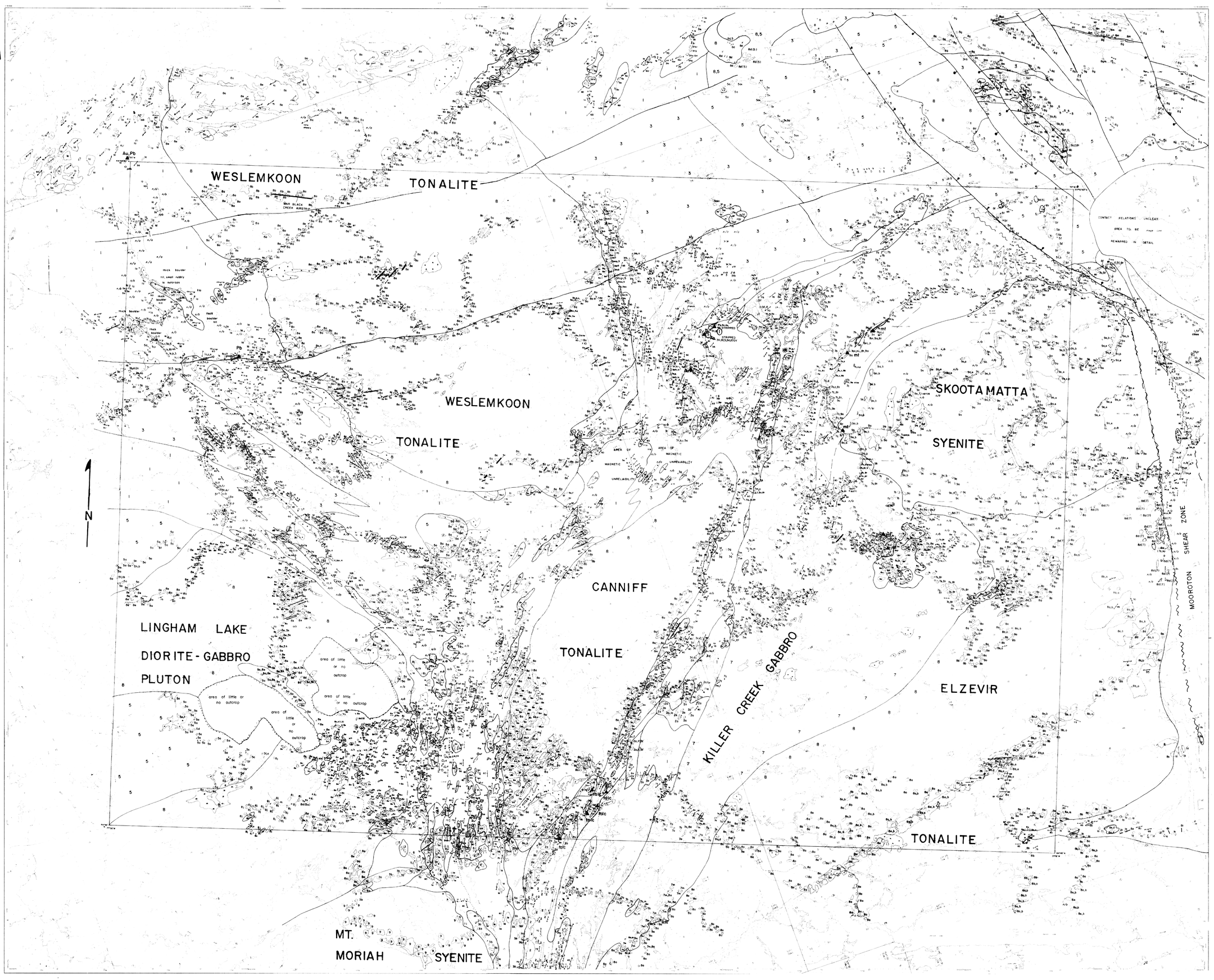

LEGEND[a]

PHANEROZOIC

CENOZOIC

QUATERNARY

PLEISTOCENE AND RECENT

Sand, gravel, till, ground moraines, and organic deposits

UNCONFORMITY

PALEOZOIC

ORDOVICIAN

11 **Sandstone, grilstone, commonly hematite-stained, poorly sorted**

UNCONFORMITY?

PRECAMBRIAN[c]

LATE PROTEROZOIC[d]

Late Tectonic to Posttectonic Intrusive Rocks

INTRUSIVE CONTACT

10 **Mafic Intrusive Rocks**

10 Fine-grained, weakly metamorphosed, diabase dikes (ca. 900 Ma)

INTRUSIVE CONTACT

MIDDLE TO LATE PROTEROZOIC

ELZEVIR TERRANE

9 **Alkalic Intrusive Rocks (ca. 1085 Ma)**

9 Syenite, unsubdivided
9a Medium-grained biotite syenite
9b Fine-grained biotite syenite
9c Coarse-grained biotite syenite
9d Lamprophyre
9e Medium-grained, grey, biotite-hornblende monzonite
9m Sheared syenite

INTRUSIVE CONTACT

8 **Intermediate to Felsic Intrusive Rocks (ca. 1250-1270 Ma), Elzevir and Methuen Suites**

8a Tonalite to trondhjemite
8b Granodiorite
8c Migmatite formed by tonalite veins and screens of country rock
8d Intrusion breccia
8e Melanocratic
8f Fine-grained, foliated, sugary-textured tonalite dikes
8g Monzogranite to syenogranite (Abinger Granite, Methuen Suite, in Bon Echo Provincial Park only)
8h Hematite-stained tonalite to granodiorite
8j Quartz diorite
8k Aplite
8m Mylonitic granite
8t Tonalite to granodiorite dikes

Mafic Intrusive Rocks (ca. 1270-1280 Ma)

7 **Diorite to Gabbroic Rocks (Killer Creek Gabbro Suite)**

7a Medium-grained gabbro
7b Melanocratic, medium-grained gabbro
7c Anorthosite, anorthositic gabbro, gabbroic anorthosite
7d Coarse-grained gabbro
7f Fine-grained gabbro, commonly feldspar porphyritic
7g Medium-grained gabbro, feldspar porphyritic
7h Hornblendite, commonly magnetite-bearing
7m Mylonitic gabbro
7n Medium-grained gabbro, feldspathoid bearing (secondary alteration?)

FAULTED CONTACT?

Felsites and Mylonites

6 **Felsic to Intermediate Gneisses**

6a Finely-laminated, pink, buff, or grey weathering, quartzofeldspathic gneisses (felsites), locally containing garnet, plagioclase or magnetite porphyroblasts
6b Finely-laminated, green to dark green, biotite-hornblende-plagioclase mafic gneisses
6c 6a and 6b, finely interbedded
6h Grey to dark grey, massive, biotite-hornblende-quartz-plagioclase gneiss, commonly with magnetite porphyroblasts (possible metavolcanic)

FAULTED CONTACT?

Mafic Intrusive Rocks (ca. 1270-1290 Ma)

5 **Diorite to Gabbroic Rocks**

5a Medium-grained gabbro
5b Melanocratic, medium-grained gabbro
5c Anorthosite, anorthositic gabbro, gabbroic anorthosite
5d Coarse-grained gabbro
5f Fine-grained gabbro, commonly feldspar porphyritic
5g Medium-grained gabbro, feldspar porphyritic
5h Hornblendite, commonly magnetite-bearing
5j Fine-grained gabbro dikes with well-developed cooling joints
5m Mylonitic gabbro
5x Gabbroic intrusion breccia

INTRUSIVE CONTACT

GRENVILLE SUPERGROUP

Metasedimentary Rocks

4 **Siliceous Clastic Metasedimentary Rocks**

4a Meta-arenite, metaquartzarenite
4b Metawacke
4c Metasiltstone, metapelite
4f Metaconglomerate, polymictic, matrix-supported
4g Metaconglomerate, polymictic, clast-supported
4j Calcarenite
4m Mylonite derived from unit 4 lithologies
4r Rusty schist

3 **Siliceous Clastic Metasedimentary Rocks, may include Felsic and Intermediate Metotuffs and Metasedimentary Rocks of Mainly Volcanic Provenance**

3a Hornblende-plagioclase gneiss ("para-amphibolite")
3b Biotite-hornblende-quartz-plagioclase gneiss; black to dark grey weathering (mafic meta-arenite, mafic metawacke)
3c Hornblende-plagioclase schist and gneiss (metatuff)
3d Volcanic wackes, arkose (intermediate to felsic metalithrarenites)
3e Fine- to medium-grained, thinly layered amphibole-dolomite gneiss, brown to black weathering (mafic calc-arenite, possibly tectonic in origin)
3f Polymictic, matrix-supported conglomerate, with mafic matrix (similar to 3a, b)
3g Dark green, heterolithic, matrix-supported, conglomerate with mafic matrix and abundant gabbro (mainly unit 2a) and mafic metavolcanic clasts (possible debris flow, basal conglomerate)
3k Calc-silicate rocks
3m Mylonitic rocks of unit 3
3n Cordierite-bearing
3r Rusty schist derived from unit 3 rocks

UNCONFORMITY?

Mafic Intrusive Rocks (ca. 1290 Ma)

2 **Gabbroic and Talcose Rocks**

2a Protomylonitic, medium-grained gabbro
2s Massive to schistose, brown-red talcose rocks, with varied amounts of hematite, magnetite, carbonate, chlorite, serpentine derived from mafic intrusives
2t Massive to schistose,soft, pitted weathered surface, green-grey to white talcose rocks, with minor carbonate, chlorite, serpentine derived from mafic intrusives

INTRUSIVE CONTACT

Metavolcanic Rocks

Felsic to Intermediate Metavolcanic Rocks

1 **Mafic Metavolcanic Rocks**

1a Massive, fine-grained, dark green to black weathering amphibolite (massive flow?)
1b Pillowed, fine-grained, dark green to black weathering amphibolite (pillowed flow)
1c Microfractured to microbrecciated, fine-grained, dark-green to black weathering amphibolite (brecciated flow?)
1d Massive, fine to medium-grained, dark green amphibolite, diabasic textured (thick flows gabbroic sills)
1e Fine-grained, dark-green to black, chlorite-amphibole schist
1f Layered to bedded, fine-grained, dark green to black amphibolite (tuff, locally lapilli tuff)
1g Breccia, tuff breccia
1h Hyaloclastite
1k Fine-grained, dark green to black, amphibolite with well developed feather amphibolite texture
1m Mylonitic amphibolite
1p Massive, fine-grained, dark green to black weathering amphibolite, feldspar porphyritic
1r Gossan zones, rusty schist horizons
1s Unit 1 rocks with pervasive carbonate
1z Albitized and silicified rocks derived mainly from unit 1

[a] *This is a field legend and may be changed as the result of subsequent laboratory investigations.*

[b] *Unsubdivided outcrops include small outcrops where subdivision was not possible and outcrops plotted from other sources and which were not visited by field party personnel.*

[c] *The Precambrian legend is a lithologic one, and stratigraphic order is only in part implied by numerical order.*

[d] *All Precambrian rocks have been subjected to regional metamorphism, many non-metamorphic terms are used for the sake of brevity and where the protolith is established.*

SYMBOLS

- Bedding, top known (inclined, overturned)
- Bedding, top unknown (inclined, vertical)
- Pillow top, (inclined, overturned)
- S$_1$ Foliation (horizontal, inclined, vertical)
- S$_2$Foliation (horizontal, inclined, vertical)
- Gneissosity (horizontal, inclined, vertical)
- Lineation, with plunge
- Geological boundary, observed
- Geological boundary, position interpreted
- Fault (observed, assumed). Dot indicates downthrown side
- Mineral occurrence, former mine, stone quarry
- Igneous layering in plutonic rocks
- A Alteration (silicification, Na-metasomatism)

ABBREVIATIONS

Au ..... gold Pb ..... lead
mt ..... magnetite qv ..... quartz vein

OCCURRENCES

1 United Reef Petroleums

SOURCES OF INFORMATION

Base map derived from Ontario Basic Mapping maps, Survey and Mapping Branch, Ontario Ministry of Natural Resources.

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Geology of Cashel Township; Ontario Department of Mines, Geological Report 67, 110p., by S.B. Lumbers, 1968.

Geology of Marble Lake area; Ontario Geological Survey, Report 238, 63p., by J.M. Moore and R. Morton, 1985.

Unpublished data, P.L. Baron, Southeastern Resident Geologist's office, Ontario Geological Survey, Tweed.

Geology not tied to survey lines.

Magnetic declination approximately 11°14'W in 1993.

Metric conversion factor: 1 foot = 0.3048 m.

CREDITS

Geology by R.M. Easton and F.D. Ford, 1990.

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Ministry of Northern Development and Mines

Ontario

Mines and Minerals Division
Ontario Geological Survey

Map P.3267

PRECAMBRIAN GEOLOGY

GRIMSTHORPE AREA

HASTINGS AND LENNOX AND ADDINGTON COUNTIES

NTS Reference: 31 C/14SW

ODM-GSC Aeromagnetic Map 97G

OGS Geological Compilation Maps: 2544 and 2578

Scale 1:20 000

500 m 0 0.5 1 km

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