Geology of Cape North Area, Northern Cape Breton Island, Nova Scotia

by A.S. Macdonald and P.K. Smith

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PROVINCE OF NOVA SCOTIA
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Hon. Ronald Barkhouse, Minister
John J. Laffin, P. Eng., Deputy Minister

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ABSTRACT

Low- to medium-grade schistose volcanic and sedimentary rocks of the Money Point Group occur along the eastern margin of the Cape North area, abutting medium- to high-grade paragneissic rocks of the Cape North Group to the west. The two Groups of metamorphic rocks appear to be essentially conformable with no evidence for any erosional or tectonic break between them. Both Groups also appear to have been affected by the same sequence of events. Two episodes of penetrative, coaxial folding can be recognized, followed by a third episode of complex chevron/kink folding. The peak of regional metamorphism was attained synchronously with the second episode of penetrative deformation, and can be defined as having been of intermediate pressure, medium- to high-temperature type. Metamorphic grade increases rapidly toward the west from biotite, through cordierite and staurolite, to kyanite and sillimanite zones. The higher grade zones coincide spatially with a synkinematic lit-par-lit granitoid injection complex which is developed mainly within the gneissic rocks of the Cape North Group, but which also overlaps and complicates the contact with the schistose rocks of the Money Point Group to the east. Older, foliated granitic plutons in the area are believed to be late-kinematic products of this metamorphic-anatectic event. Younger, unfoliated granitic plutons which occur adjacent to the Aspy Fault are relatively high-level, crosscutting intrusions. The two penetrative deformations, regional metamorphism, injection and emplacement of foliated granites are believed to be related orogenic events of Late Precambrian to Early Cambrian age. Later nonpenetrative deformation and emplacement of younger unfoliated granitic plutons are probably Paleozoic in age, perhaps produced during the Acadian Orogeny.

INTRODUCTION

The nature and exact age of the George River Group (s.l.) which outcrops over wide areas of Cape Breton Island have been the subjects of protracted debate. In the past, the general tendency was to assign sequences of unfossiliferous low-grade metasedimentary rocks containing crystalline limestone to the George River Group (s.s.). However, there is uncertainty concerning (a) the occurrence of volcanic rocks as part of such sequences, and (b) correlation between low-grade and medium- to high-grade metamorphic sequences.

While the George River Group (s.s.) generally appears to be a typically miogeoclinal package, volcanic rocks are known to occur within the sequence in the Creignish Hills (Milligan, 1970). In addition, there are several areas of mixed metavolcanic and metasedimentary rocks in central and northern Cape Breton Island (Crowdis Mountain, Cheticamp, Ingonish, and Cape North) and on St. Paul Island which have been assigned at various times to either the George River Group or the Fourchu Group (Fig. 1). In northern Cape Breton Island, Neale (1963, 1964) assigned such mixed sequences to the George River Group, while Weibe (1972) assigned the sequence near Ingonish to the Fourchu Group (?). In southeastern Cape Breton Island, Helmstaedt and Tella (1973) correlated the Coxheath volcanics in the Boisdale Peninsula with the upper part of the George River Group, but considered them to be time equivalents, at least in part, of the Fourchu Group. A similar model has been proposed by Keppie (1978).

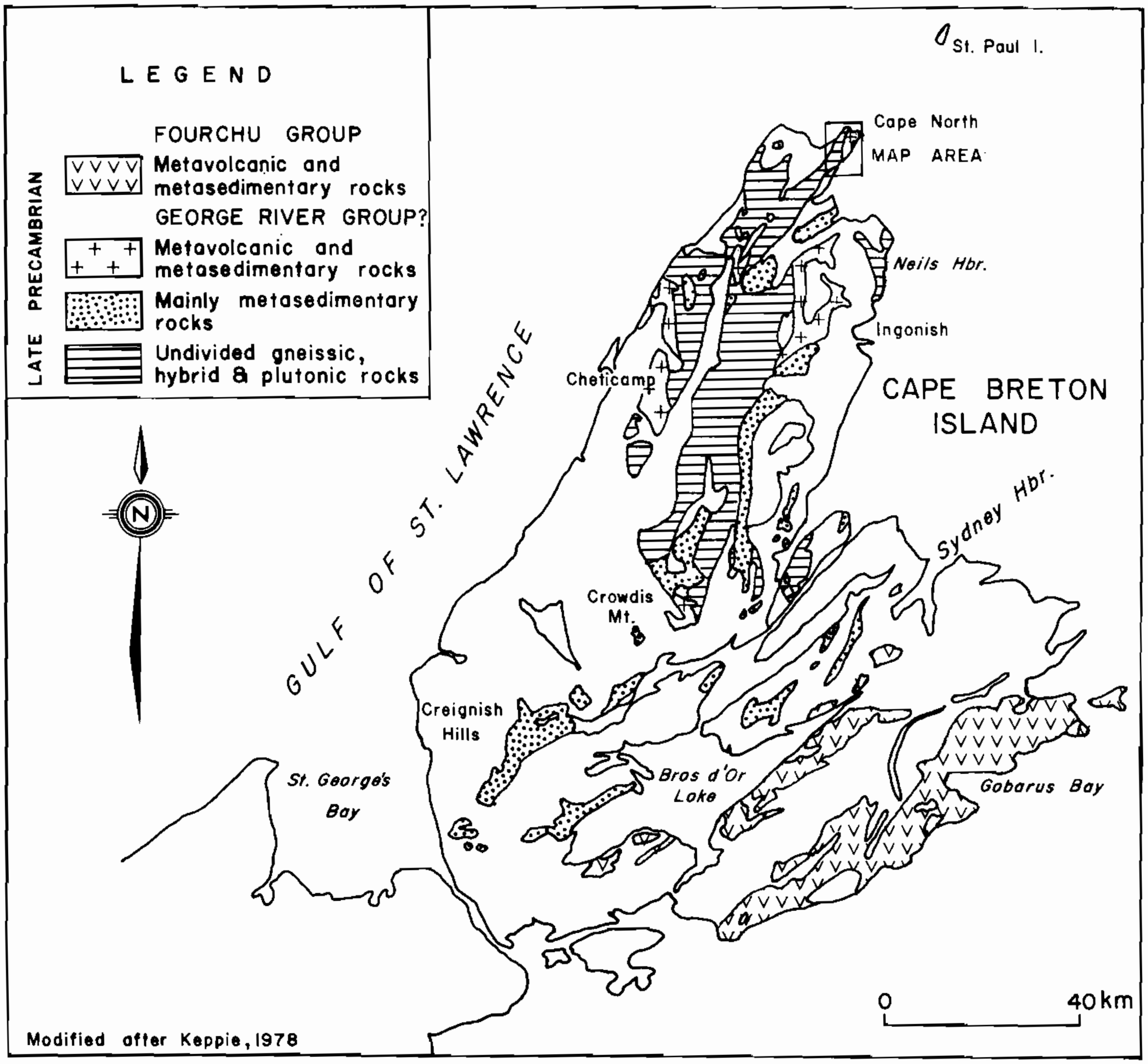


Figure 1. Distributions of Late Precambrian rocks in Cape Breton Island.

Medium- to high-grade metamorphic sequences, with more-or-less abundant granitoid components, occurring in central and northern Cape Breton Island (Fig. 1), have in the past been thought to include rocks belonging to the George River Group (Neale, 1963, 1964). More recently, it has been proposed (Murray, 1977; Keppie, 1978) that an older crystalline basement to the George River Group may occur within such terrain.

The purpose of this study was to contribute to the solution of some of these uncertainties concerning the George River Group by detailed mapping of the well-exposed Cape North peninsula area to establish stratigraphic, structural, metamorphic, and plutonic relationships between a low-grade mixed metavolcanic-metasedimentary sequence and an adjacent medium- to high-grade gneissic sequence to the west.

Previous work in Cape North area has included reconnaissance mapping by Neale (1956, 1964), a local metamorphic study at Money Point (Phinney, 1963), and a reassessment of the geology of Cape North by Neale and Kennedy (1975) in the light of Weibe's (1972) work farther to the south in the Clyburn Brook-Ingonish River area. Several mineral occurrences along the Dingwall-Cape North segment of the Aspy Fault were described by Neale (1964) and some of these have subsequently been investigated (Cannon, 1966; Geisler, 1966).

The Aspy Fault which forms the eastern margin of Cape North has been correlated with the Cape Ray Fault in southwestern Newfoundland (Brown, 1973) which has been interpreted as a cryptic suture between North American and Avalon cratons (Williams, et al., 1972). Neale and Kennedy (1975) queried the location of this suture and suggested that it might lie on the western side of Cape North peninsula.

DESCRIPTION OF LITHOLOGICAL UNITS

Metamorphic Rocks

Two main sequences of metamorphic rocks are recognized in the Cape North peninsula: the predominantly gneissic Cape North Group and the predominantly schistose Money Point Group (Fig. 2, in pocket). This broad division reflects differences both in metamorphic grade and in rock types. Whether or not it also reflects a significant difference in ages is unknown (pending results of radiometric dating); the boundary between the two essentially conformable sequences is relatively sharp and although complicated by lit-par-lit granitic injection shows no evidence for either an erosional or tectonic break.

Stratigraphic relations are obscure because of polyphase folding, S-plane development and metamorphic crystallization. In gneissic rocks, no evidence for "younging" directions could be found whereas in schistose metasedimentary and pyroclastic rocks younging directions are in many places conflicting; current bedding in particular was found to be unreliable due to the development of tectonic mimics, and graded bedding was commonly obscured by S-plane development. Minor F_1 isoclinal folds were recognized, but the exact nature of major F_1 folding could not be determined which means that no rigorous stratigraphic interpretation can be offered because of the distinct possibility of repetition(s) within the sequence.

A broad succession is proposed here which appears to fit the outcrop distributions and the various structural constraints (outlined in the section on structure).

CAPE NORTH GROUP

This sequence is best exposed over a 3 km coastal section stretching southwest from Cape North into St. Lawrence Bay. It comprises medium- to high-grade semipelitic gneisses, pelitic gneisses and marble, frequently cut by amphibolite sheets and abundantly injected by granitoid sheets and lenses. A thickness of approximately 1000-1500 m is exposed in this section.

Semipelitic Gneisses

The semipelitic gneisses are typically medium grained equigranular quartz-feldspar-biotite-hornblende gneisses displaying moderately well-developed compositional banding. The more felsic bands consist of quartz, oligoclase-andesine, orthoclase, biotite, ± muscovite, hornblende and/or garnet. Where most leucocratic, they are easily confused with injected sheets of microgranite. Melanocratic bands consist of hornblende and/or cummingtonite, ± biotite, clinozoisite, sphene and/or garnet in addition to oligoclase-andesine (An_{20-36}), orthoclase and quartz. Some of these bands are also distinctly calcareous, containing significant amounts of calcite and approaching calc-silicate gneisses in mineralogy.

Pelitic Gneisses

Pelitic gneisses are restricted to one or possibly two horizon(s) east of the marble unit. They are coarse grained porphyroblastic mica-rich schistose gneisses composed of biotite, muscovite and quartz with large porphyroblasts of garnet, kyanite and/or oligoclase. Well-crystallized sillimanite occurs locally, apparently as a result of the breakdown of muscovite. Common accessories include graphite, rutile and minor sulphides. These pelitic gneisses very commonly contain pegmatitic laminae and lenses within the foliation and locally are interbanded with granular semipelitic gneisses. They are assumed to have originally been more-or-less carbonaceous, aluminous shales.

Marble and Calc-silicate Gneisses

The marble unit varies from 0 to about 100 m in thickness and forms, in association with pelitic gneiss, a distinctive marker horizon within the gneissic sequence. It consists of medium- to coarse-grained grey or white calcite marble, generally sparsely graphitic and locally slightly dolomitic. Where the marble is interbanded with gneisses at its margins, calc-silicate gneisses are developed. These may also occur as individual melanocratic bands within the semipelitic gneisses. They consist of well-banded, greenish rocks with medium grained, complex mineralogy including hornblende, diopside, clinozoisite, plagioclase, biotite, idocrase, sphene, grossularite(?) garnet, and calcite.

Mylonite

A broad band of mylonitic rocks, up to 0.5 km wide, runs north-south through gneisses of the Cape North Group near their western margin at the St. Lawrence Fault. These are very fine grained blastomylonites or phyllonites with retrograde mineral assemblages, and so could easily be confused with rocks of the Money Point Group (the possibility cannot be excluded that they in fact represent a sliver of the latter sequence faulted into or infolded with the gneisses of the Cape North Group).

On the basis of their retrograde mineralogy and the relative abundance of kink bands and related folds, the development of the mylonites is believed to postdate F_2 folding and concurrent metamorphism, and to predate F_3 folding.

MONEY POINT GROUP

This Group is best exposed in coastal sections south and west of Money Point; the latter exposures occur mainly on sea-cliffs which are accessible only by boat. It comprises low- to medium-grade pelitic, semipelitic and psammitic schists together with a variety of schistose volcanic and pyroclastic rocks. Although these rock units are closely interbedded, it is possible to distinguish predominantly volcanic from predominantly sedimentary formations which can be traced intermittently to the southern limit of the map area in Zwicker Brook (Fig. 2, in pocket).

Metavolcanic Schists

Metavolcanic schists occur in two main bands which possibly represent repetition by folding of a single unit, apparently about 300-500 m (?) thick (see discussion in the subsection Structural Synthesis). In addition, a faulted sliver occurs 2 km south of Money Point.

The sequences exposed within each band are shown in Figure 3. They comprise mafic hornblende-biotite-chlorite-epidote schists, intermediate chlorite-biotite schists, schistose crystal and lithic tuffs of intermediate to felsic composition, and schistose meta-rhyolites thinly interbedded with each other and with a variety of pelitic, semipelitic and psammitic schists containing variable amounts of pyroclastic material. The whole package is cut by numerous amphibolite sills, up to 15 m thick.

Detailed correlation between the two main bands (assuming repetition by folding) is difficult, however a crude pattern may be established (Fig. 3) which indicates a very episodic, mixed volcanic package dominated by pyroclastic material.

1. Meta-basalt and mafic meta-tuff

Tuff units are distinguished from basalt by the presence of compositional banding, which commonly shows "pinch and swell" and boudinage structures. Metamorphic mineralogy of both rock types includes amphibole, biotite, chlorite, plagioclase, quartz, ± clinozoisite-epidote, calcite, garnet and opaques.

Both amphibole and biotite are commonly porphyroblastic in habit. The amphibole varies from actinolitic hornblende to hornblende and cummingtonite with increasing metamorphic grade and variation in rock composition. Textures vary from granoblastic to schistose, and are commonly overprinted by random to weakly oriented porphyroblastic growth. Epidote and hematite form common local secondary concentrations in lenses and on fracture surfaces.

2. Intermediate meta-tuffs

These include a wide variety of coarse lithic tuffs, fine grained layered tuffs and crystal tuffs which are interbedded with, and locally grade into, pelites and semipelites.

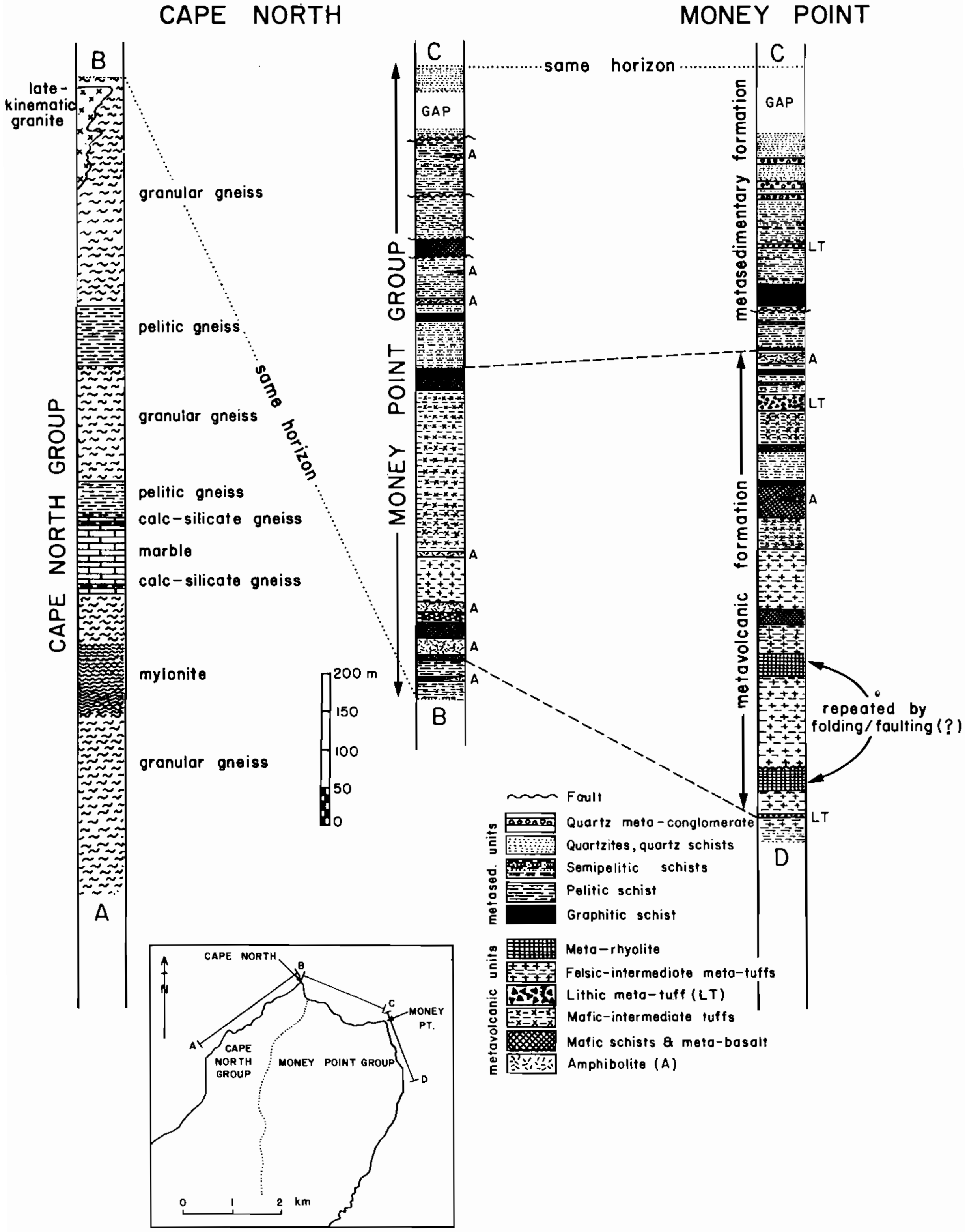


Figure 3. Pseudostratigraphic sections for the Cape North-Money Point shore sections.

Lithic tuffs form relatively massive units up to 15 m thick, containing distorted fragments up to 50 cm long (elongated parallel to L_1-L_2) of green meta-andesite or meta-basalt together with lesser white felsic fragments (pumice ?) and plagioclase porphyroclasts in a schistose matrix of amphibole, biotite, chlorite, quartz, plagioclase, clinozoisite-epidote, and opaques. Only one occurrence of a truly felsic lithic tuff occurs, about 1 km southeast of Money Point; it consists of distorted meta-rhyolite fragments in a chlorite-quartz-feldspar matrix.

Layered tuffs and crystal tuffs display internal layering on a centimetre scale due to alternations in felsic and intermediate composition and interbedding with pelitic, semipelitic and calcareous laminae. However, predominantly tuffaceous units may attain thicknesses up to 40-50 cm. Typically, they consist of banded phyllites or schists composed of varying amounts of amphibole, biotite, chlorite, clinozoisite-epidote, quartz, plagioclase, muscovite, calcite and opaques. Crystal tuff layers are characterized by the presence of abundant porphyroclastic plagioclase (oligoclase-andesine), recrystallized quartz augen, and occasional distorted lithic fragments in fine grained schistose matrices. Associated interbedded metasediments include quartz-biotite-chlorite schists, calc-silicate schists and thin marble laminae.

3. Meta-rhyolite and meta-tuff (?)

Interbedded meta-rhyolites and meta-tuffs (?) form two distinctive horizons occurring within the meta-volcanic formation about 1 km southeast of Money Point. Close similarities in lithological make-up and in thickness (approx. 30 m) suggest that there has been repetition of a single horizon either by folding or by faulting. The two rock types occur as alternately interbanded layers of rhyolite and tuff(?), with individual layers ranging from 20 cm up to 4-5 m in thickness. Meta-rhyolites also occur within the western metavolcanic formation, but only along the southeastern segment of Gulch Brook (Fig. 2, in pocket).

The meta-rhyolites are pink to brown in colour with very fine grained quartz-feldspar-muscovite schistose matrices containing abundant albite phenocrysts showing "pull-apart" structures and pressure-shadows, and resorbed quartz phenocrysts, always highly strained and more-or-less recrystallized.

The meta-tuffs(?) are fine grained grey schistose rocks composed of chlorite, white mica, calcite, quartz, plagioclase and opaques. They are assumed to have been ashes or fine grained tuffs of andesitic composition.

Metasedimentary Schists

The metavolcanic formation(s) subdivides the metasedimentary schists into 3 discrete bands, the easternmost of which is partly repeated by faulting (Fig. 1). The central band appears to occupy the core of a major F_1 fold and therefore, this sequence is probably also repeated.

The sequences exposed within each band are included within the quasi-stratigraphic columns in Figure 3. They comprise various pelitic and semipelitic schists, impure quartzites, quartz-pebble meta-conglomerates, minor calc-silicate schists, and occasional meta-tuff layers, all cut by a number of amphibolite sills.

1. Pelitic and semipelitic schists

These rocks provide the best indicators of metamorphic intensity, showing a progressive and rapid increase from low grade phyllitic schists in the east to medium grade schists in the west. They consist typically of quartz, biotite, muscovite, minor plagioclase, ± chlorite, garnet and opaques. The more pelitic units, in addition, may contain one or more pelitic indicator minerals such as cordierite, chloritoid, staurolite or kyanite. Corundum is also a common accessory mineral, further reflecting the aluminous character of these pelites. Some varieties, particularly from those pelites and semipelites within and adjacent to the metavolcanic units, are dark blue-grey to black in colour and more-or-less graphitic and sulphidic. Typically, all of these rocks are thinly bedded, and closely interbedded with more psammitic and/or tuffaceous units.

2. Quartzites and quartz-pebble meta-conglomerates

Quartzites occur in thin graded beds up to 1.5 m thick, usually interbedded with and grading into pelitic and semipelitic units. Locally they display cyclic repetitions. They apparently represent impure quartz arenites or subgreywackes, composed of quartz, feldspar and phyllosilicates.

Quartz-pebble meta-conglomerates occur interbedded with quartzites and quartz schists in a 50-60 m wide band west of Money Point. Individual conglomeratic bands occur up to 5 m in thickness, and contain clasts up to 5 cm in length. They consist mainly of distorted pebbles of polycrystalline quartz and rare quartz schist in a schistose matrix of quartz, plagioclase, chlorite, muscovite and biotite, together with minor clinozoisite and opaques, ± garnet, cordierite and calcite. In some material, the schistose matrix is richer in biotite, amphibole and opaques and is possibly tuffaceous in part. From their position within the sequence, they are assumed to be intraformational conglomerates.

3. Calc-silicate schists

Thin calc-silicate schist bands occur interbedded with pelitic to semipelitic schists and tuffaceous schists at several localities. The bands vary from quartz-biotite-calcite schists through amphibole-clinozoisite-epidote-calcite schists to almost pure calcite marble. Common accessories include sphene, idocrase, garnet (grossularite?) and various opaque and sulphide minerals.

Intrusive Rocks

A wide variety of intrusive igneous rocks and vein materials cut both the Cape North and Money Point Groups. Some of these are clearly premetamorphic, others are apparently synmetamorphic, and some clearly postmetamorphic. While relative ages can be established with some degree of confidence, estimates of actual ages of emplacement are dependent on the results of various radiometric age-dating studies currently in progress.

AMPHIBOLITE SHEETS

A suite of coarse grained amphibolite sheets up to 15 m thick, occurs within both schistose and gneissic sequences. They are essentially conformable with the gneissic foliation (S_1) and the schistose foliation (S_{0-1}) and could, therefore, be described as sills. Their premetamorphic origin is indicated by their mineralogy and fabric. They are medium- to coarse-grained dark green rocks composed of large amphiboles (cummingtonite and/or hornblende) in a more-or-less schistose matrix of medium grained sphene, clinozoisite-epidote, biotite, quartz and plagioclase together with opaques, chlorite, calcite, and local concentrations of garnet. They appear to occur most frequently within the metavolcanic schist formation and their mineralogy most closely resembles that of the meta-basalt and mafic schist units. Thus the possibility exists that the amphibolites were formed as gabbroic sills comagmatic with the mafic volcanism represented in the Money Point Group.

LIT-PAR-LIT INJECTED GRANITOID ROCKS

This group comprises a variety of garnetiferous granitoid rocks which include coarsely porphyroblastic gneissic biotite granite-granodiorite, foliated leucocratic microgranite, aplite, and pegmatite. These rocks occur as thin sheets, lenses, boudins and ptygmatic folds ubiquitously injecting gneisses of the Cape North Group and the western edge of the Money Point Group (Fig. 4). Injected material makes up 10-50% of this complex which can best be described as a lit-par-lit injection complex. Spatially, this complex corresponds approximately with the medium- to high-grade kyanite and sillimanite metamorphic zones (Fig. 4). Close inspection reveals that the granitoid sheets locally cut the S_1 foliation in the host metamorphic rocks at very low angles, and contain an internal micaceous foliation which parallels the S_2 foliation where it can be distinguished in the adjacent host rocks.

FOLIATED MICROGRANITE PLUTONS

Foliated plutons occur near the eastern limit of the injection complex and probably represent late-kinematic accumulations formed during the same anatectic event as produced the injection complex. The plutons occur as elongate bodies of microgranite and aplite with complex sheeted margins gradational into the injection complex. The smaller pluton located at Cape North is particularly inhomogeneous, containing numerous internal enclaves or screens of gneiss, whereas the larger pluton, farther to the south (Gulch Brook pluton), is more internally homogeneous. Both these plutons possess a distinct internal foliation due to strong preferred orientation of biotite. No chilling of the margins was observed, presumably as a result of the high ambient temperatures of the country rocks at the time of emplacement.

They are typically leucocratic, fine- to medium-grained rocks composed of quartz, microcline, perthitic orthoclase, oligoclase, variable amounts of biotite (<5%), plus minor muscovite and myrmekite. Compositionally, they vary from granite to alkali granite or aplite, but are otherwise homogeneous. Petrographically, they closely resemble the microgranite and aplite sheets of the injection complex.

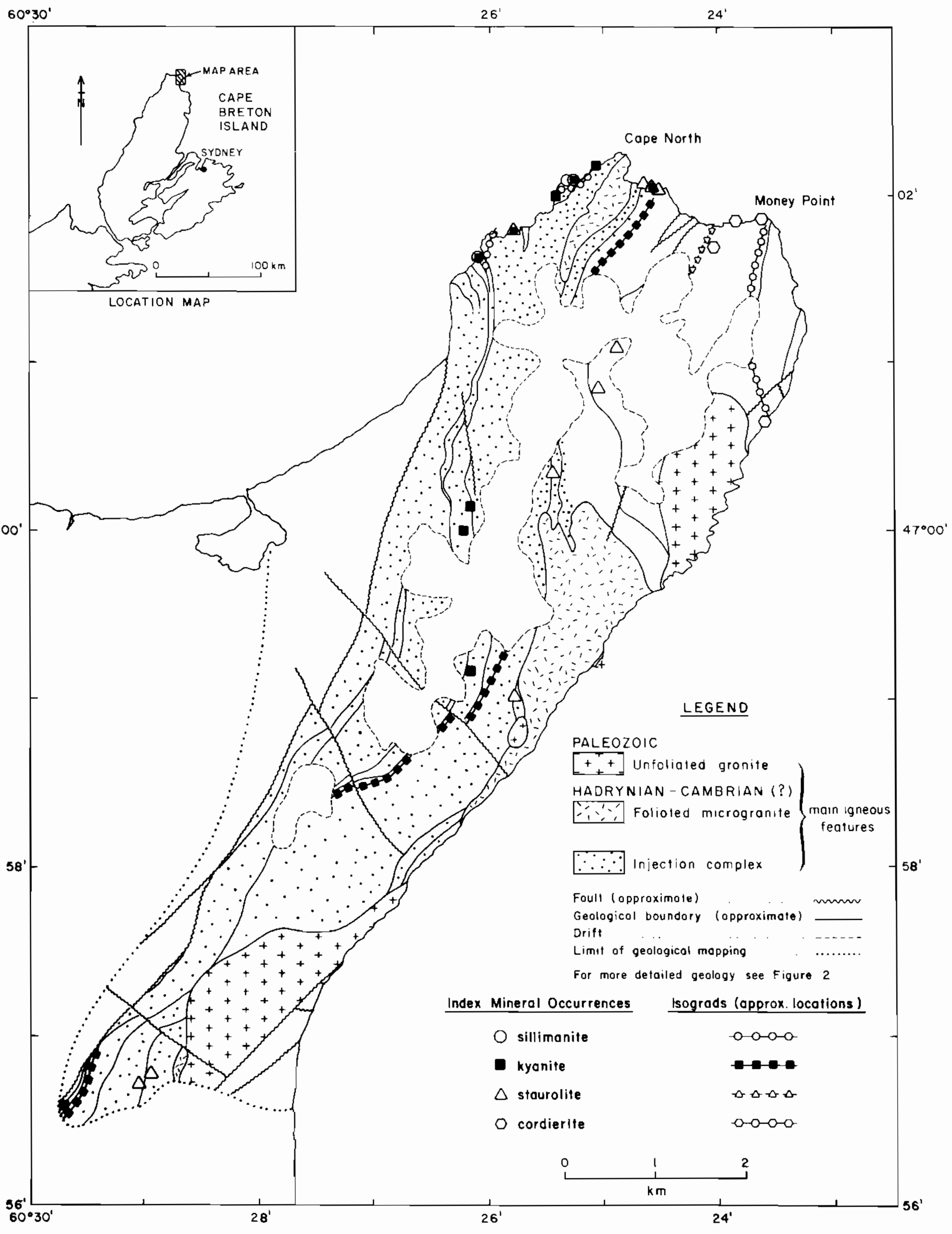


Figure 4. Metamorphic map.

UNFOLIATED GRANITE PLUTONS

Unfoliated coarse grained pink granite plutons (Relay Station and Sugarloaf plutons) occur adjacent to and have been cut by the Aspy Fault. They are very homogeneous bodies displaying simple crosscutting relationships with the country rocks. Intrusive margins are sharply defined and slightly chilled and the adjacent country rocks are hornfelsed and feldspathized over distances of a few tens of metres. In several localities, contacts are faulted. These granites are considered to be postkinematic, relatively high-level plutons of distinctly younger age than the foliated microgranitic plutons.

Typically they are pink subporphyritic granites composed of inequigranular quartz, microcline and perthitic orthoclase, zoned oligoclase and biotite (<10%) with traces of muscovite and secondary chlorite.

Unfoliated coarse grained pink pegmatites of regular tabular shape which crosscut the Money Point schists near the western margins of these unfoliated granite plutons are assumed to be of the same general age as the plutons.

DYKES

A suite of altered basaltic dykes, up to 2.5 m thick, intruded rocks of the Money Point Group. The dykes trend mainly east to northeast and are locally strongly deformed, having been either folded by F_3 kink folds, or boudinaged (where strike directions approximate the S_{0-1} foliation of the country rocks). A local foliation may be developed in the margins of the more highly deformed examples. They are medium grained basalts with intergranular to subophitic textures, composed of altered plagioclase and pyroxene, olivine (?) pseudomorphs, opaques and variable amounts of secondary calcite, chlorite and sericite. One of the dykes contains abundant large plagioclase phenocrysts, but is otherwise similar mineralogically and texturally.

One hornblende microdiorite (lamprophyric ?) dyke, 2 m in width and trending northeast, was found cutting foliated microgranite on the eastern shore of Cape North peninsula. It consists of porphyritic hornblende and K-feldspar in a matrix of plagioclase, hornblende, biotite, K-feldspar, quartz and sphene, together with secondary chlorite and calcite.

Veins

At least three suites of quartz veins are recognized within the area:

(i) Pure quartz veins are abundantly developed within pelitic schist units. These vary from lensoid to irregular in form. They are generally conformable with S_{0-1} foliation and apparently folded by F_2 folds, but are also locally crosscutting. Such veins are believed to have a metamorphic origin.

(ii) Quartz-K-feldspar veins occur commonly in the eastern part of the area, mostly veining rocks of the Money Point

Group, but also locally veining foliated microgranite where they are crosscut by younger pegmatities. They consist mainly of quartz with variable amounts of pink K-feldspar, the latter usually fringing the veins. Black tourmaline, locally accompanied by pyrite, forms local concentrations in such veins southeast of Money Point. The veins are generally lensoid in form, and tend to follow the S_{0-1} foliation in the host schists.

(iii) Quartz-barite-fluorite veins containing pyrite and traces of other sulphides occur as regular crosscutting tabular veins up to 30 cm in width in the northeastern part of the area (Fig. 5). The majority strike east or east-southeast and are characterized by sericitic alteration haloes or fringes in the wall rocks. They are believed to be hydrothermal in origin and related to the younger unfoliated granites. A swarm of these veins occurs in the seacliffs about 0.5 km west of Money Point.

STRUCTURE

Structure of Cape North area is relatively complex and polyphase in nature, belying the apparently simple outcrop patterns. At least five different phases of folding have been recognized. The first four phases affect both the Cape North and Money Point Groups although there are obvious differences in style and intensity, presumably reflecting contrasts in lithology and metamorphic grade between the two Groups. The fifth phase appears to affect only rocks of Carboniferous age.

Only the first two phases of these folding deformations are truly penetrative, i.e. developed on all scales and possessing axial plane foliations. The third phase occurs on both major and minor scales, but lacks significant axial plane foliation, whereas, the fourth and fifth phases occur only on the major scale.

Structural Elements

D_1 DEFORMATION

Mesoscopic F_1 folds are moderately inclined to upright isoclinal folds (Figs. 6-1, 7-1) which plunge at low angles north-northeast or south-southwest (Figs. 6b, 7c). Because of extreme attenuation of the limbs, the asymmetry/symmetry of these folds could rarely be established. The folds are not commonly observed except where strong lithological layering (S_0) occurs, and so are rarely found in such rocks as volcanic schists or in most of the gneissic sequence. However, a micaceous foliation (S_1), which is axial planar to the folds, is both ubiquitous and strongly developed and represents the dominant planar element in the area, ranging from a phyllitic schistosity in the east to a gneissic foliation in the west (Fig. 8A). The predominant dip is steep toward the west (Figs. 6a, 7a); the wide scatter in attitudes results from the effects of later refolding.

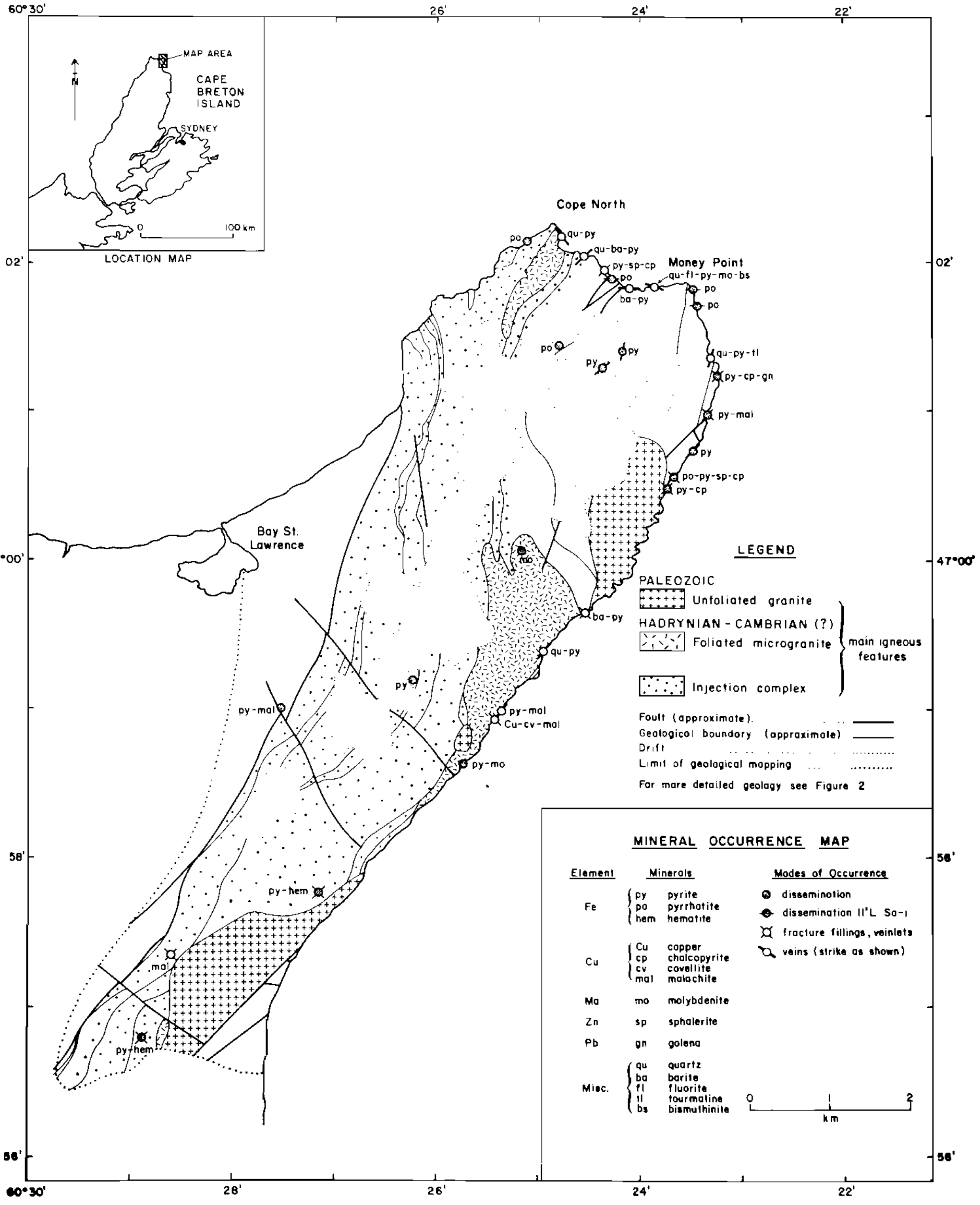


Figure 5. Economic mineral occurrence map.

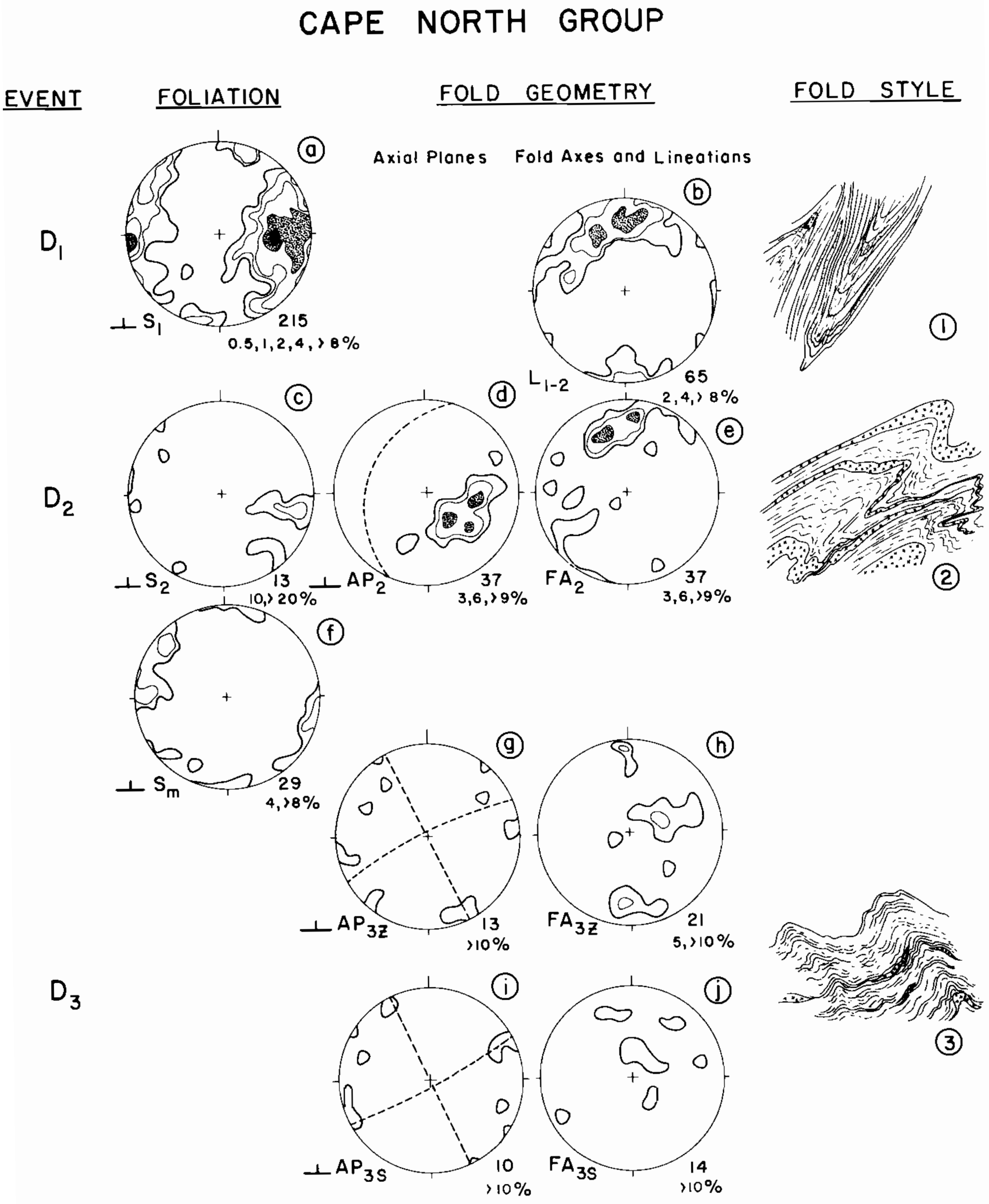


Figure 6. Summary of D_1-D_3 structural data for the Cape North Group. Numbers at lower left of plots correspond to numbers of poles to bedding (⊥S_0) or to gneissic foliation (⊥S_1), and to contour values (% per unit area). π is the pole to the great circle drawn through the contoured data and corresponds to the average fold axis.

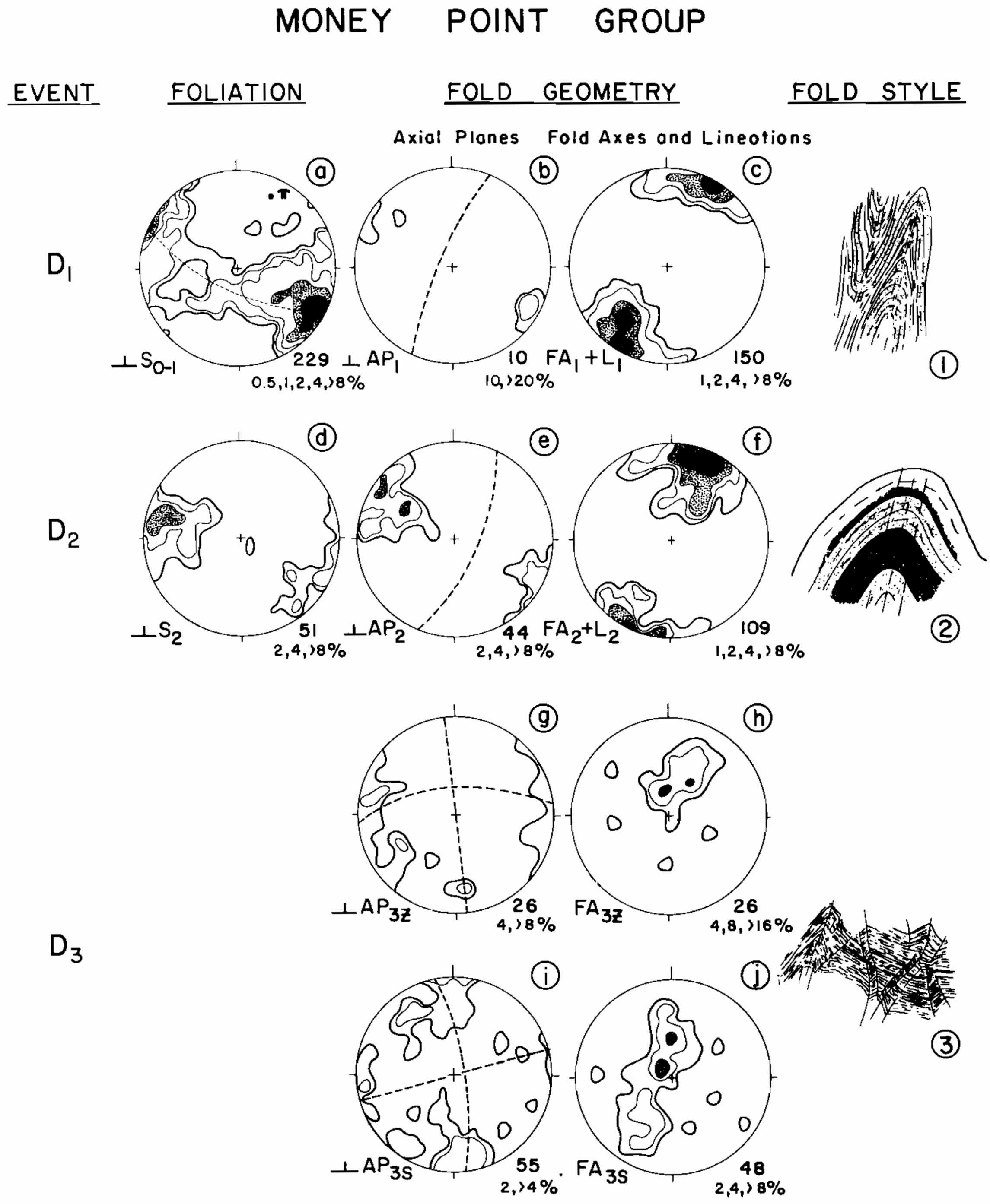


Figure 7. Summary of D_1-D_3 structural data for the Money Point Group. (Refer to Figure 6 for explanation of captions to stereoplots).

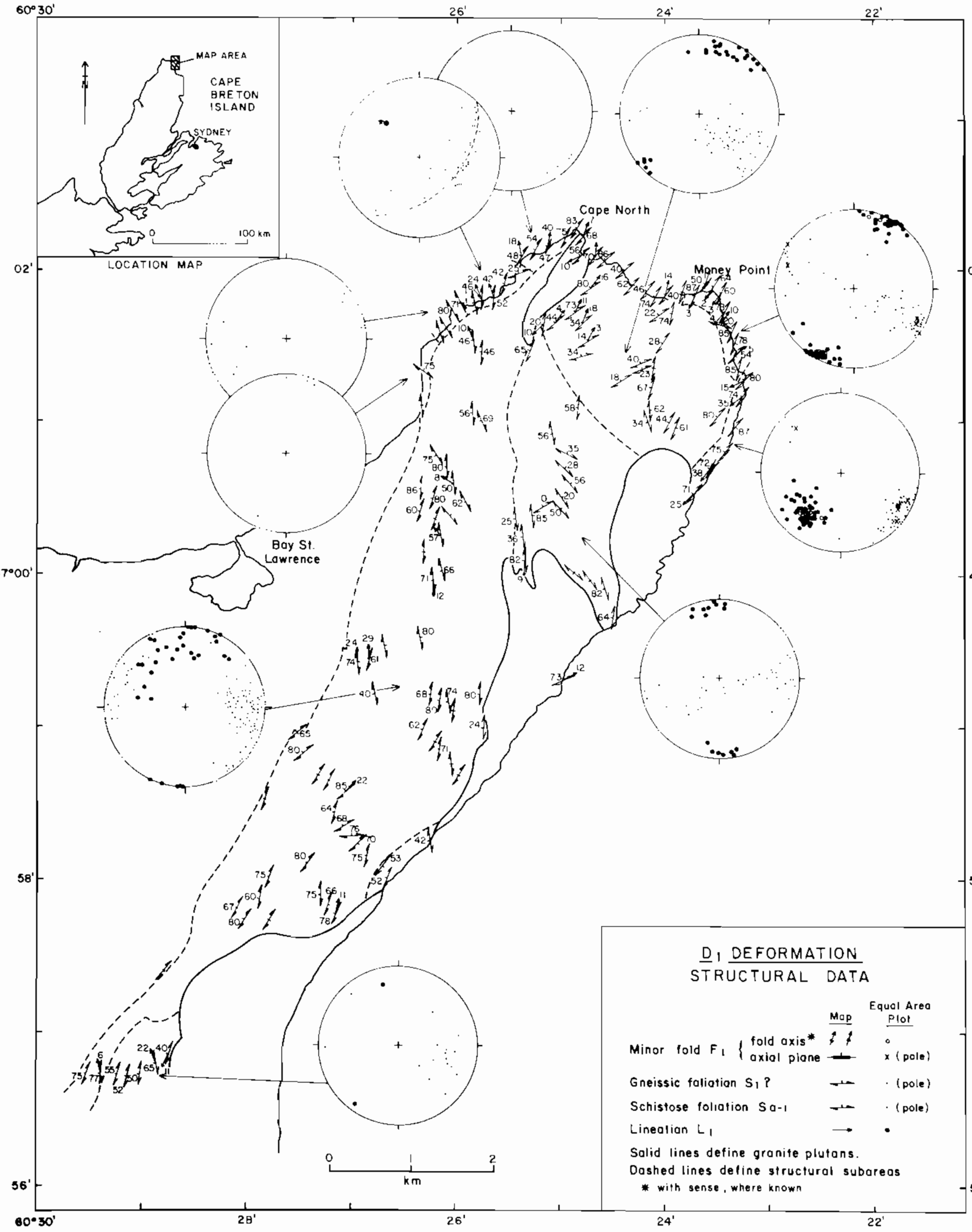


Figure 8A. Structural data map, D_1 structures and subareas.

A strong penetrative lineation (L_1) is commonly present, varying from small-scale rodding on S_1 to distinct S-plane intersections (S_0-S_1). Fragmental rocks such as quartz meta-conglomerate and lithic meta-tuffs may also show strong linear fabrics due to elongation of clasts (e.g. the X:Y:Z ratio for distorted lithic clasts in meta-tuff near Money Point equals approximately 12:2:1, based on measurements of 50 clasts). However such effects may represent a composite of D_1 and D_2 deformations. Indeed, because of the nearly coaxial nature of F_1 and F_2 folding it is often difficult to distinguish L_1 from L_2 lineation, especially within the gneisses (Fig. 6b), where morphological differences between the two ages of lineations are not clear.

D_2 DEFORMATION

Mesoscopic F_2 folds are upright to gently inclined, close to tight folds (Figs. 6-2, 7-2) which plunge at low to moderate angles north to north-northeast or south to south-southwest approximately coaxial with F_1 folds (Figs. 6e, 7f). These folds commonly display dextral asymmetry (Z-shape) when viewed toward the north, especially between Cape North and Money Point. F_2 folds are most commonly developed in pelitic and semipelitic schists, but are generally absent in the gneissic Cape North Group, except for restricted occurrences within the pelitic gneiss formation 0.3-0.7 km southwest of Cape North (Fig. 8B). In the latter occurrences, the F_2 folds have more variable geometry than in the schists, plunging both north to north-northeast and west to southwest although still coplanar (Figs. 6d, e). Both orientations may occur even within a single outcrop. The reason for this variation is not known; it is possible that two coplanar phases of different ages are present, or that they are of the same age and due to inhomogeneous strain in the a-b plane.

A well-developed penetrative crenulation cleavage (S_2) occurs which is axial planar to F_2 folds. This is moderately to steeply dipping, more commonly to the east than to the west within the schists of the Money Point Group (Fig. 7d), whereas within the Cape North pelitic gneiss formation it dips at moderate to steep angles mainly northwest (Fig. 6c).

A micaceous foliation (S_2), defined by parallelism of muscovite and biotite, is also found in a variety of granitoid sheets and lenses which inject gneisses and schists lying within the kyanite and sillimanite zones. Frequently, it can be observed that this injected material is folded by F_2 folds and/or displays ptygmatic folds having essentially the same geometry. The internal S_2 foliation can also be seen locally to be essentially parallel with and continuous into the S_2 crenulation cleavage in the country rocks.

Typically a crenulation lineation (L_2) is developed in pelitic schists which parallels F_2 fold axes (Fig. 7f). In the gneisses, because of coarse grain sizes and more granular textures, this lineation can rarely be recognized, therefore L_1 and L_2 are rarely distinguished.

F_2 folds clearly refolded F_1 folds to produce Type 3 interference patterns (Ramsay, 1967), and L_1 lineations are weakly curvilinear

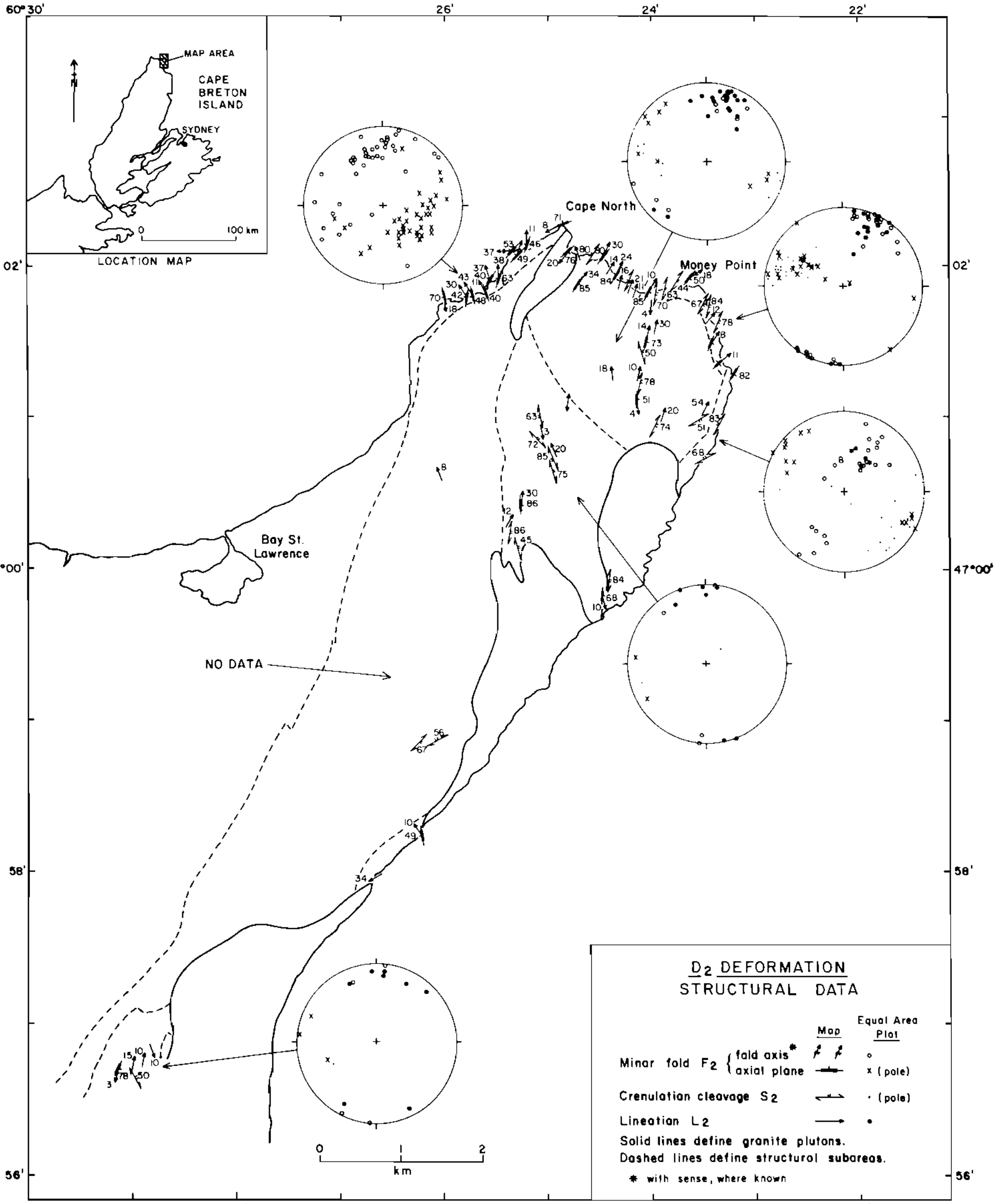


Figure 8B. Structural data map, D_2 structures and subareas.

where they cross F_2 hinge areas. These geometric effects of F_2 folding on the Cape North Group versus the Money Point Group can be appreciated by comparing Figures 6a and 7a. These show that the gneisses of the Cape North Group overall are only slightly affected by F_2 folding compared to rocks of the Money Point Group. This is attributed to a lower ductility contrast within most of the Cape North Group (excluding the pelitic gneiss unit) during the D_2 event.

D_3 DEFORMATION

Grouped under this event are numerous sets of kink bands and related open to close mesoscopic folds with rounded to chevron shapes which are widely developed in all closely foliated rocks (Figs. 6-3, 7-3). They are best developed in schists of the Money Point Group, but are also a common feature in the mylonite band of the Cape North Group (Fig. 8C). At least four sets can be recognized in each Group (Figs. 6g-j, 7g-j), although those in rocks of the Cape North Group are poorly defined because of the small populations measured. Each set displays quite variable geometry, probably inherited from the pre-existing structure, which further obscures definition. In general, the kinks and related folds plunge steeply north and have steep axial planes striking either north-south or east-northeast to west-southwest (Figs. 6i, l; 7i, l). Approximately the same patterns can be recognized in both the schistose and gneissic sequences. Relative ages of the sets could not be determined, but close spatial association suggests that two of the four sets observed within the Money Point Group make up a conjugate system.

Some of the kinking and related folding must post-date emplacement of (i) late-kinematic microgranite because closely-spaced fracture planes in the microgranite are kinked, and (ii) mafic dykes, because they are locally folded, with geometry the same as that of kink bands in adjacent schists.

Effects of F_3 folding on earlier structures are limited due to the generally small scale of the imposed structures. However, where larger scale F_3 folds do occur, e.g. 2 km southwest of Cape North, regional trends may be deflected locally into nearly east-west directions and all contained earlier minor structures reoriented accordingly. Such effects contribute to much of the scatter observed in orientations of D_1 and D_2 structural elements, shown in stereoplots by peripheral scatter as the F_3 folds are steeply plunging (Figs. 6a, 7a).

D_4 DEFORMATION

This event is represented by large-scale upright folding about a northwest plunging axis located about 1 km southwest of Cape North (Fig. 2, in pocket). The axial trace can be followed towards the southeast into rocks of the Money Point Group where it is either truncated by or dies out against a younger unfoliated granite pluton. The geometry of this structure does not closely match that of any of the F_3 sets of minor folds and is therefore tentatively assigned to a later event (D_4). This folding has produced considerable reorientation of earlier structures as evidenced by the spread of poles to the S_1 gneissic foliation on Figure 9A.

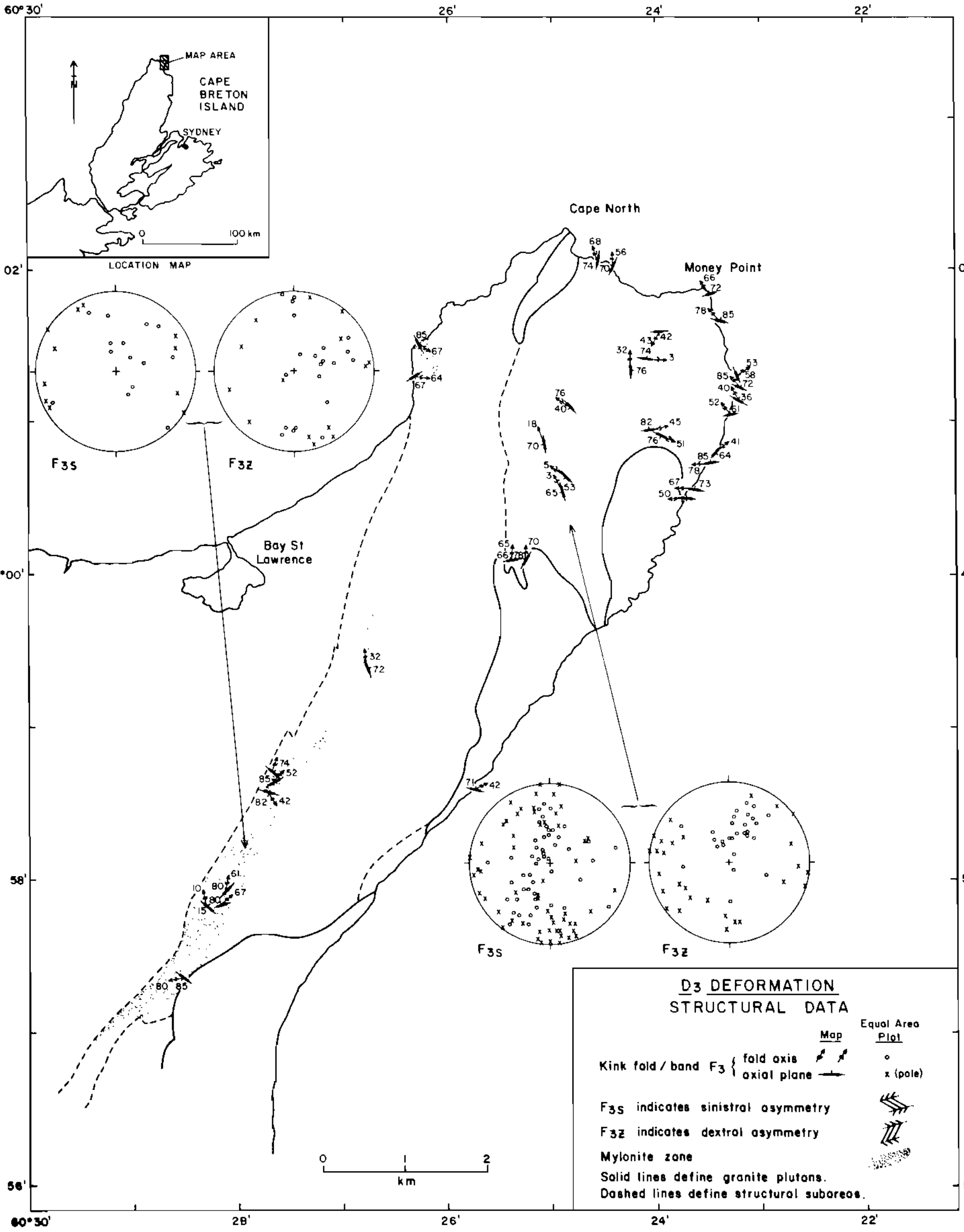


Figure 8C. Structural data map, D_3 structures and subareas.

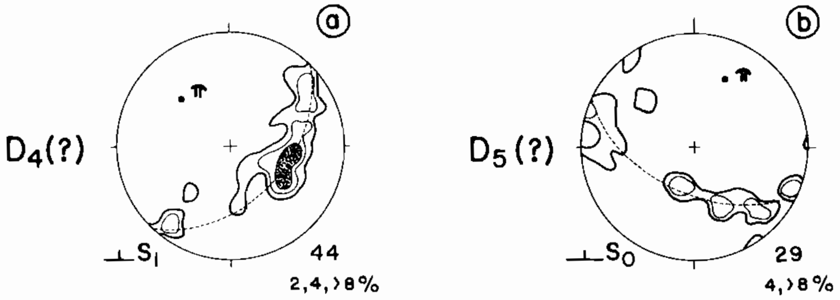


Figure 9. Stereopolots illustrating the effects of (a) D_4 (?) cross folding on gneisses of the Cape North Group southwest of Cape North, and (b) D_5 (?) folding on Carboniferous rocks on the southeastern side of St. Lawrence Bay. (Refer to Figure 6 for explanation of captions to stereoplots).

It would therefore appear that the sinuous deviations from the prevailing outcrop trends are the product of large-scale warping and cross folding (F_3 and F_4?), but because of poor exposures inland it is not usually possible to map these late fold structures directly.

D_5 DEFORMATION

Under this category are grouped those deformational events which can be demonstrated as being wholly or partly post-Carboniferous in age.

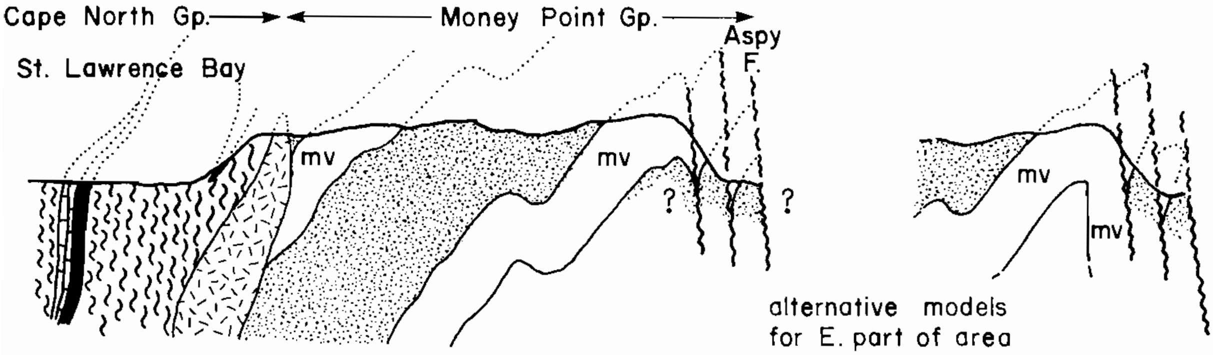
Large scale open to close folding affects Carboniferous rocks west of the St. Lawrence Fault. Measurements of bedding attitudes along the coastal section between the Fault and Bay St. Lawrence indicate this folding to be upright, plunging north-northeast at 30-35° (Fig. 9b). While the geometry of this fold crudely approximates that of some F_3 minor folds, it is not known whether they are in fact of the same age.

Faults in the area are dominated by the Aspy and St. Lawrence Faults which flank and create the Cape North peninsula. Other faults of lesser magnitude, but similar northerly to north-northeasterly trends are common within the area; those occurring in the seacliffs between Money Point and Cape North were observed to be essentially normal faults. The other most common faults were largely inferred from west-northwesterly to northwesterly trending topographic lineaments which apparently offset lithological units. Several very minor thrust faults, with subhorizontal displacements of only a few metres, were also recognized in the seacliffs between Money Point and Cape North, and at Salmon Point on the western side of the peninsula.

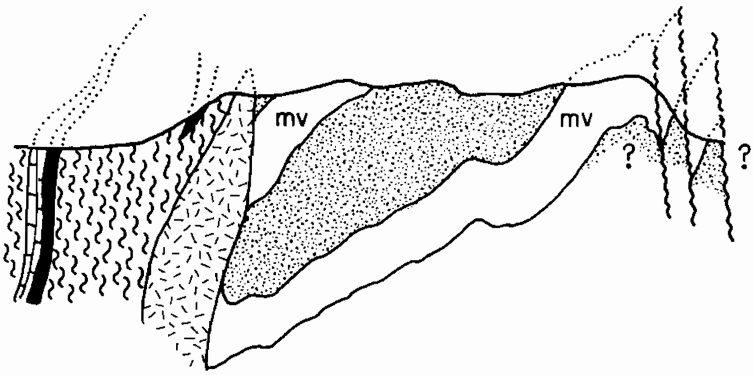
Structural Synthesis

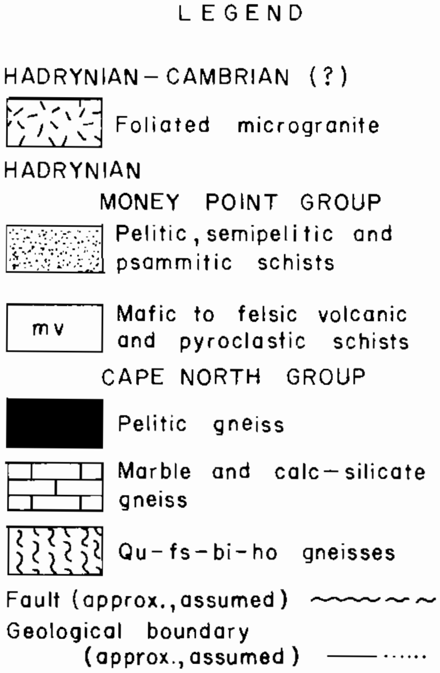
The dominant early structure is interpreted to be a large first-order F_1 synform outlined by apparent repetition of the Money Point metavolcanic formation (cf. alternative interpretations illustrated in Fig. 10). Existence of this structure is based on:

(a) Assuming no repetition of Money Point metavolcanic unit (mv).



(b) Assuming synformal repetition of Money Point metavolcanic unit (mv).





(c) Assuming antiformal repetition of Money Point metavolcanic unit (mv).

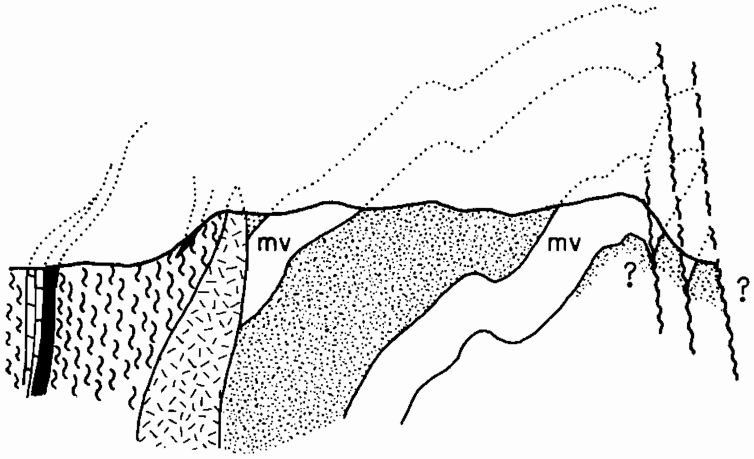


Figure 10. Alternative models for the major structure in Cape North peninsula (cf. cross-sections on Figure 2).

(a) occurrence of minor F_1 isoclinal folds across the area,

(b) assumption that the metavolcanic unit is repeated by folding, specifically by F_1 folding as the widespread dextral asymmetry of F_2 minor folds precludes major F_2 folding to produce such an apparent repetition.

If the Money Point Group is younger than the Cape North Group, as is assumed, then this major structure should be a syncline. Although the two Groups are different lithologically there is no evidence that they are greatly disparate in age as they appear in the field to be essentially conformable sequences, without any major break such as an unconformity or thrust fault between them. However, it is possible that metamorphic crystallization and granitoid lit-par-lit injection could have obscured such features. Due to lack of appropriate markers and the lack of sufficient width of outcrop in the Cape North gneisses, no continuation of the major structure toward the west could be recognized.

Patterns of asymmetry of F_2 minor folds across the area (Fig. 8B) indicate that large second-order F_2 folds are superimposed upon and refolded the inferred F_1 structure (Figs. 2 and 10). Effects of the refolding on outcrop patterns are minimal due to the coaxial geometries of the two phases. However, the generally upright attitudes of the D_1 planar structures may have largely resulted from this refolding, as the patterns of F_2 minor and second-order folding are also consistent with a structural location on the western limb of a very large first-order F_2 antiform.

The coaxial nature of F_1 and F_2 folding suggests that these two phases may have been produced actually by an essentially single progressive deformation. This could have been achieved by buttressing of the developing F_1 major structure somewhere farther to the west of the present area.

Mylonitization of the Cape North gneisses may have occurred either at a very late stage of the D_2 deformation due to semiductile failure of the gneiss package in response to increasingly effective buttressing to the west, or during some later event. Whatever its origin, the mylonitization apparently predates F_3 folding and kinking, although by what time interval is not known.

The F_3 folds and kinks plunge steeply northward and their cumulative effect has been to shorten the complete package along its north-south dimension. Their varied geometries suggest that this was not achieved during a single event. These structures, together with northwesterly trending F_4 (?) major fold(s) have refolded all earlier structures on both minor and major scales and undoubtedly account for the sinuous deviations away from prevailing north-northeast structural trends, i.e. they have produced moderately to steeply plunging warps and cross folds across the major structures.

While the major faults may have been initiated prior to deposition of the Carboniferous rocks and so have contributed to basin development, movements on these and other lesser faults, together with F_5 folding demonstrably postdate the Carboniferous rocks. No folding was recognized in either the Cape North or Money Point Groups which could be confidently correlated with the F_5 folding in the Carboniferous cover rocks, but it is possible that the F_3 and F_4 (?) folds developed within these Groups could also be of post-Carboniferous age.

METAMORPHISM

It has long been known that the metamorphic grade increased rapidly from east to west across Cape North peninsula (Phinney, 1963; Neale, 1964; Neale and Kennedy, 1975). The present study describes the metamorphic mineral fabrics and assemblages, maps out the distribution of the metamorphic zones, and attempts to define the P-T conditions and relative timing of the main metamorphic event.

Metamorphic Fabrics

Petrographic studies support field observations that the following three main prograde fabric elements are developed in the metamorphic rocks (particularly the pelitic rock units): S_1 metamorphic foliation (phyllitic to gneissic), S_2 crenulation cleavage, and porphyroblastic mineral growth.

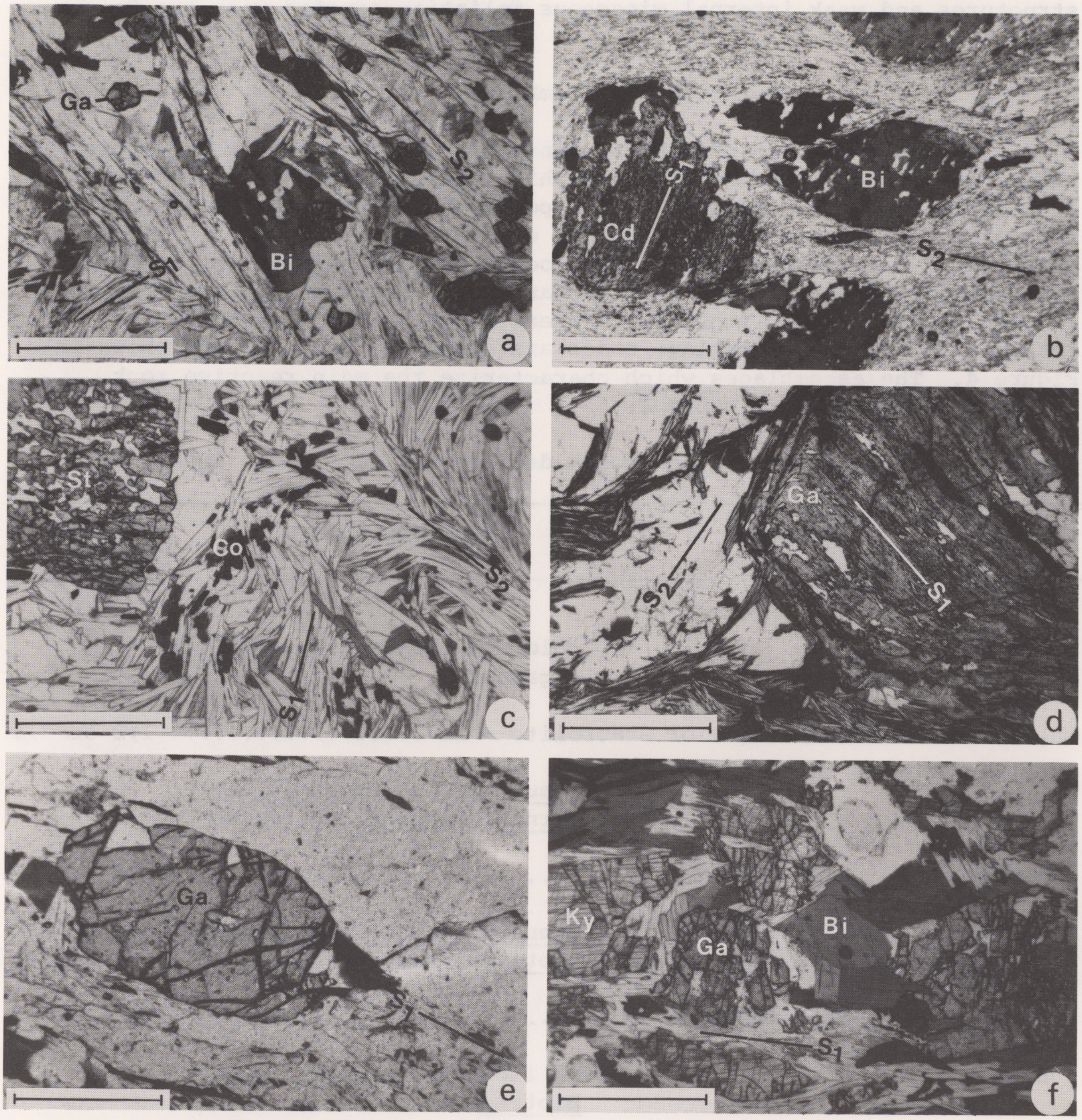
On the eastern side of Cape North peninsula, it can be observed that the S_1 foliation is produced by a low-grade assemblage dominated in pelitic rocks by chlorite, muscovite and possibly biotite (corresponding to lower greenschist facies). It is assumed that similar low-grade regional metamorphic conditions prevailed across the entire area during D_1 deformation, although it is difficult to demonstrate this due to subsequent elevation to a higher metamorphic grade.

The S_2 fabric which is best developed in pelitic schists, tuffaceous schists and pelitic gneisses is produced by a more or less intense crenulation of S_1 phyllosilicates, accompanied locally by neocrystallization of mica within S_2 (Fig. 11).

Widespread occurrence of a porphyroblastic mineral fabric which has overprinted the S_1 fabric and in part the S_2 fabric, reflects imposition of the regional metamorphic peak. Interpretation of the relative timing of this event depends heavily on textural criteria. The porphyroblasts show many of the characteristics of helicitic growth (Fig. 11), however, their growth is interpreted to have been completed before the end of D_2 deformation on the following grounds:

1. Orientation: random to moderate preferred orientation within S_2.
2. Grain shape: euhedral/subhedral to flattened, sigmoidal shapes.
3. Inclusion trails: S_1 trails common, S_2 trails absent or rare.

This textural interpretation for the timing of the peak of metamorphism (as essentially synchronous with the D_2 deformation) is supported by the structures and internal fabrics observed in the injected granitoid bodies associated with the higher grade metamorphic rocks (see section on Lit-par-Lit Injected Granitoid Rocks). These injected bodies were presumably generated during the metamorphic peak and yet show fold



a. Garnet-biotite-muscovite schist (Sample N01-1094, Money Point Gp.)
Small garnet porphyroblasts and large deformed biotite porphyroblast in muscovite-rich matrix showing strong S_2 crenulation cleavage.

b. Biotite-cordierite schist (Sample N01-0052, Money Point Gp.)
Biotite and cordierite porphyroblasts, containing S_1 inclusion trains, in fine grained quartz-sericite matrix showing S_2 crenulation cleavage.

c. Corundum-bearing staurolite-mica schist (Sample K16-1121, Money Point Gp.)
Large staurolite porphyroblast, containing S_1 inclusion trains, in matrix of muscovite, biotite, quartz and corundum showing strong S_2 crenulation cleavage.

d. Garnet-mica-quartz schist (Sample N01-0109, Money Point Gp.)
Large garnet porphyroblast with S-shaped S_1-inclusion trains and overgrowth.

e. Biotite-garnet-feldspar-quartz gneiss (Sample K16-0019, Cape North Gp.)
Large flattened garnet porphyroblast aligned parallel with S_1 foliation (possibly S_{1-2} composite foliation)

f. Garnet-kyanite-mica gneiss (Sample K16-1121, Cape North Gp.)
Garnet and kyanite porphyroblasts in S_1 foliated matrix of coarse biotite, muscovite, feldspar and quartz.

*Abbreviations used on photomicrographs to identify mineral phases:
Bi = biotite, Ga = garnet, Cd = cordierite, St = staurolite
Co = corundum, Ky = kyanite.
Bar scales are approximately 1 mm in length.

Figure 11. Prograde fabrics in pelitic rocks of the Money Point and Cape North Groups*.

structures and weak internal micaceous foliation equated with the D_2 event.

Metamorphic Assemblages

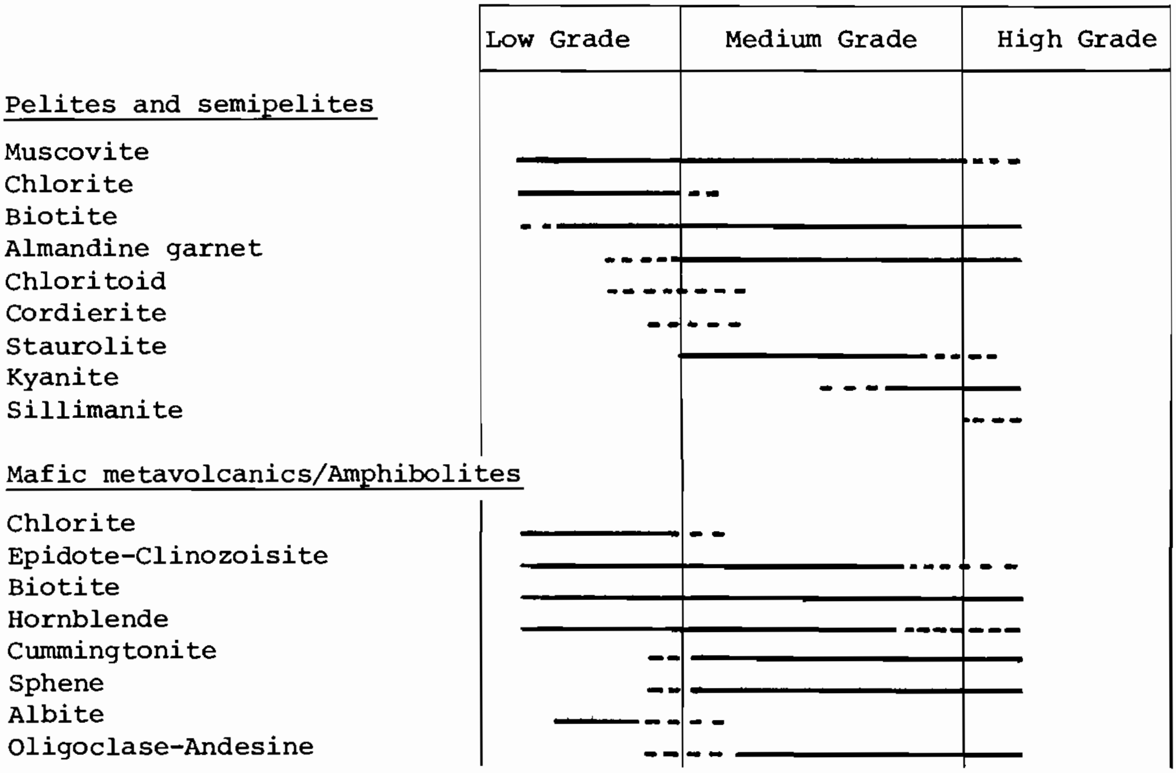
Changes in porphyroblast mineralogy from east to west across the area indicate increasing metamorphic intensity in that direction. In pelitic rocks the incoming of new pophyroblast species permits the definition of three isograds (ideally equivalent to isoreaction lines (Winkler, 1974), although restricted occurrence of pelitic units within the gneissic sequence means that appearance of index minerals is probably largely controlled by lithology in these rocks). The isograds and intervening mineral assemblage zones are listed in Table 1, and shown in Figure 4. The assemblages which characterize the main reactive rock types are summarized in Table 2.

Table 1. Pelitic isograds and zones defined for Cape North area.

Grade	Isograd	Zone Assemblage	Reaction # (Table 3)
Low		chlorite, muscovite, biotite* ± garnet	
	Cordierite - or Staurolite - in		1,2 or 3,4
		staurolite (or cordierite), garnet, biotite, muscovite	
Medium	Kyanite - in		5 - 8
		kyanite, staurolite, garnet, biotite, muscovite	
	Sillimanite - in		9 - 10
High		sillimanite, kyanite, garnet, biotite	

indicates porphyroblastic habit ________*

Table 2. Metamorphic mineral assemblages in reactive rock types, Cape North area.



Possible reactions for the appearance of the index minerals which appear compatible with petrographic observations are listed in Table 3. Only in the cases of cordierite and sillimanite are there mineralogical and textural evidence to favour specific reactions.

Table 3. Possible metamorphic reactions⊕ for the appearance (and disappearance) of index pelitic minerals

Cordierite - in:

chlorite + muscovite = cordierite + biotite + Al_2SiO_5 + H_2O...........(1)
*muscovite + chlorite + quartz = cordierite + biotite + H_2O...........(2)

Staurolite - in:

almandine + chlorite + muscovite = staurolite + biotite + quartz + H_2O.(3)
chlorite + muscovite = staurolite + muscovite + quartz + H_2O ....(4)

Kyanite - in:

chlorite + muscovite + quartz = Al_2SiO_5 + biotite + H_2O ....(5)
chloritoid + muscovite + quartz = Al_2SiO_5 + biotite + H_2O ....(6)
staurolite + muscovite + quartz = Al_2SiO_5 + biotite + H_2O ....(7)
Fe-staurolite + quartz = Al_2SiO_5 + almandine + H_2O ....(8)

Sillimanite - in:

*muscovite + albite + quartz + H_2O = Al_2SiO_5 + melt ....(9)
staurolite + muscovite + quartz = Al_2SiO_5 + biotite + H_2O.............(10)

⊕ = reactions quoted in Winkler (1974), and in Thompson and Norton (1968)
* = reaction favoured by petrographic evidence.

From the map distribution of the pelitic isograds (Fig. 4), it appears that the isograds are subparallel to the main lithological boundaries. This distribution probably reflects the composite effects of lithological control on the appearance of index minerals, and of the syntectonic (D_2) nature of the metamorphism. The subsurface configuration of the isograd surfaces is not known, but they are assumed to be steep.

Widths and pelitic mineral assemblages of the zones defined by the isograds are compatible with a continuous east-west transition from low-grade to the beginning of high-grade metamorphism. However, this occurs westwards away from the core of the inferred major F_2 antiform, so that the metamorphic high apparently does not coincide with any structurally high feature of D_2 age.

Conditions of Metamorphism

COMPARISON WITH EXPERIMENTAL DATA

Experimentally determined reactions relevant to the conditions of metamorphism are shown on the P-T diagram of Figure 12. The P-T path of the progressive low- to high-grade metamorphism can be defined using isograd reactions (Table 3) and noting the following points:

(a) Kyanite is the predominant Al_2SiO_5 polymorph present; sillimanite appears only at the highest grade attained; andalusite is never present.

(b) Sillimanite appears to have formed from the breakdown of muscovite, not of kyanite which apparently remains stable implying that the highest P-T conditions attained can be approximately defined on Figure 12 by the intersection of reaction (9) with the kyanite-sillimanite boundary.

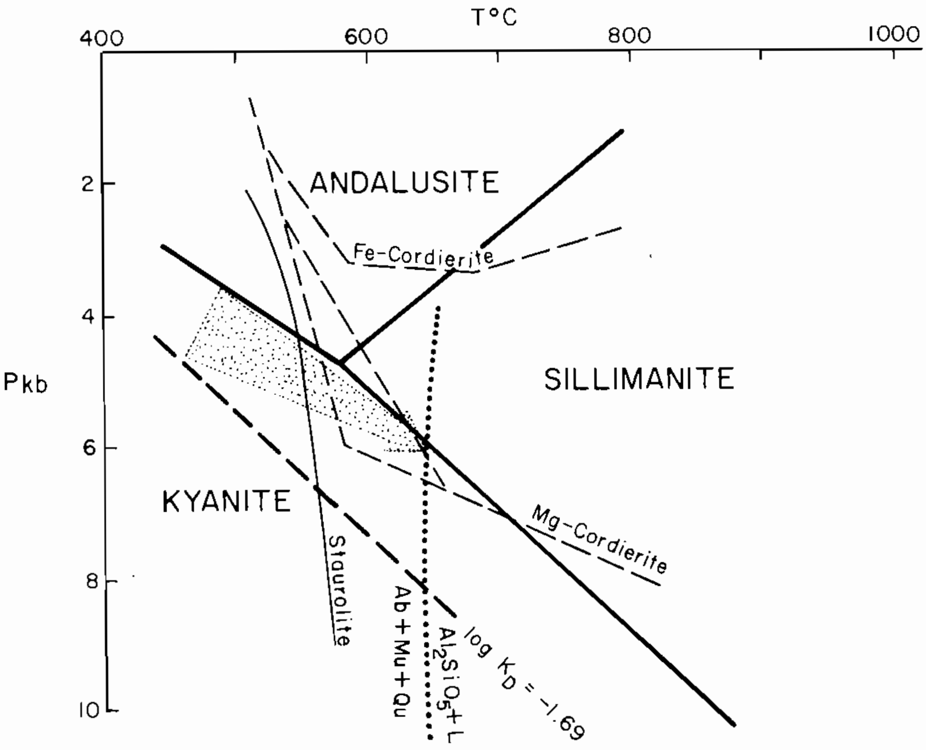
(c) The slope of the metamorphic path (= prevailing geothermal gradient) cannot be closely defined, but is constrained by the occurrence of cordierite at the beginning of medium-grade metamorphism to pressures of 4-6 kb. As the horizontal distance between high and low grades is about 4 km, the maximum permissible pressure difference due to loading is only about 1 kb which tends to favour a relatively high geothermal gradient. The evidence therefore suggests that the event was of intermediate pressure, medium- to high-temperature type, presumably transitional between Abukuma and Barrovian facies series, but closer to the latter (Winkler, 1967).

GEOTHERMOMETRY AND GEOBAROMETRY

In an attempt to independently confirm the P-T conditions of metamorphism and perhaps define them more accurately two determinative methods were used:

1. Calcite-dolomite geothermometer (Goldsmith, et al., 1955; Goldsmith and Newton, 1969).

This method was applied to samples from the locally dolomitic marble unit of the Cape North Group which lies within the kyanite zone.



Al_2SiO_5 Triple Point is "compromise point" of Greenwood (1976)

Figure 12. Schematic representation of the pressure-temperature conditions prevailing during the peak of regional metamorphism (shown by dotted arrow in relation to experimentally determined reaction lines). Significance of the line $\log K_D = -1.69$ is discussed in text.

The amount of $MgCO_3$ in solid solution in magnesian calcite reflects temperatures for equilibration between magnesian calcite and dolomite, which presumably occurred during regional metamorphism. Postmetamorphic exsolution, leaching by weathering etc. may have reduced the amount of $MgCO_3$ in solid solution so that indicated temperatures are only minima.

Six samples of marble containing both calcite and dolomite (as determined by staining and by XRD) were used. The d_{112} spacings of Mg-calcite in the samples were determined by both powder camera and diffraction techniques (Table 4). The mol % of $MgCO_3$ in the calcites was found by using the graph of Goldsmith, et al. (1955), and the temperature of equilibration of coexisting calcite and dolomite was found by using the graph of Goldsmith and Newton (1969). Agreement between the two X-ray techniques is poor; the results obtained with the powder camera are presumed to be the more accurate.

The apparent equilibration temperatures cover a wide range (400-675°C) with the majority probably occurring at the lower end of the range (Table 4). These probably indicate extensive re-equilibration of the marble unit at lower temperatures (lower greenschist facies?), perhaps during the thermal event associated with intrusion of the younger granites.

Table 4. Data for calcite-dolomite geothermometry.

Sample #	d_{104}(Å) Mg-Calcite		d_{104}(Å) Pure Calcite
	Powder Camera*	XRD+	
N01-0080	3.033	3.033	
N01-0131	3.031	3.033	
K16-0016	n.d.	3.034	3.036
K16-1003	3.008	3.033	
K16-1004	n.d.	3.033	
K16-1125	3.026	3.033	
Arith Mean	3.025	3.033	
Δd_{104}	0.011	0.003	...where $\Delta d_{104}=d_{104}$ Pure Calcite - d_{104}Mg-Calcite
Mol % $MgCO_3$	~4	~2	
T°C Mean	500	400	
Range	400-675	350(?)-400	

n.d. indicates not determined
* determinations by Dr. Castelitz, Nova Scotia Technical College
\+ determinations by A. S. Macdonald at Acadia University.

2. Garnet-plagioclase geothermometer and geobarometer (Ghent, 1976)

This method applies to metamorphic plagioclase-garnet-Al_2SiO_5-quartz assemblages, in which it has been shown that garnets coexisting with plagioclase tend to become increasingly calcic with increasing metamorphic grade. Thus the ratio of grossularite to anorthite components in garnet and plagioclase respectively increases with increasing P/T. This ratio, expressed in mole fractions, is the distribution coefficient, K_D, for partitioning of CaO between garnet and plagioclase. Ghent (1976) has shown that log K_D defines a line in P/T space, i.e. a range of P/T conditions within which the particular garnet-plagioclase-Al_2SiO_5-quartz assemblage should have equilibrated.

In this study, three widely separated samples from kyanite-bearing pelitic gneiss of the Cape North Group were used for EMP determination of garnet and plagioclase compositions. The results are shown in Table 5, and Figure 12. The mean value for log K_D was determined to be -1.69. It can be seen in Figure 12 that this line plots well within the kyanite field, and suggests pressures in the range 7-8 kb for medium- to incipient high-grade metamorphism. These pressures are approximately 2 kb greater than those anticipated from the petrographic and reaction evidence previously described. However, use of the garnet-plagioclase geothermometer-geobarometer yields a maximum estimate of pressure at any given temperature. This is in part because the method uses a maximum estimate of the grossular component (X_{gr} = molCaO/(molCaO + molFeO + molMnO + molMgO), but the garnets from Cape North generally contain significantly higher andradite than grossular component so that this estimate may be far too high.

Table 5. Compositions of plagioclase and garnet rims, and calculated distribution coefficients (K_D)

Sample #	No. of grains	Plagioclase			Garnet					X_{An}	X_{gr}	log K_D
		Or	Ab	An	ad	sp	gr	py	al			
NO1-0086	9	0.63 ±0.31	73.41 ±1.12	25.96 ±0.98	4.72 ±2.10	15.39 ±1.21	2.54 ±2.34	16.27 ±1.20	61.03 ±1.32	0.2596	0.0714	-1.68
NO1-1164	5	0.65 ±0.18	74.83 ±1.07	24.52 ±1.05	4.76 ±1.55	18.72 ±1.47	2.11 ±1.91	15.43 ±1.06	58.89 ±1.17	0.2452	0.0671	-1.71
K16-1080	4	0.52 ±0.39	77.33 ±1.23	22.15 ±1.46	6.08 ±1.91	10.63 ±0.83	0.72 ±0.88	16.71 ±1.05	65.99 ±1.29	0.2215	0.0612	-1.68

Where ad = andradite, sp = spessartine, gr = grossularite, py = pyrope, al = almandine

X_{An} = mole fraction anorthite, X_{gr} = mole fraction grossularite

$\log K_D = 3 \log X_{gr} - 3 \log X_{An}$

EMP analyses by B. MacKay, Dalhousie University, Halifax

Timing of Metamorphism

The relative timing of deformational, metamorphic, and plutonic events is illustrated schematically in Figure 13. Note that the duration of the intervals between the various events is not yet known.

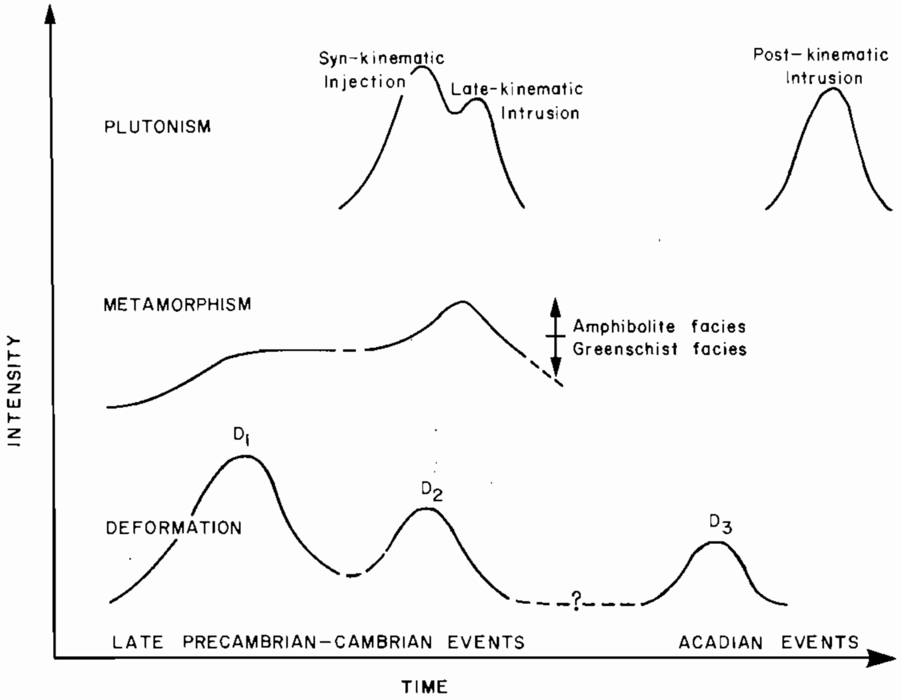


Figure 13. Inferred relative timing of deformation, metamorphism and plutonism.

It has been shown that the metamorphic peak was more or less synchronous with D_2 deformation. This event was probably continuous from the low-grade regional metamorphism which is interpreted as having accompanied D_1 deformation.

As in similar terrains elsewhere in the world (e.g. the Grampian Highlands of Scotland), a granitic injection complex coincides spatially with the kyanite and sillimanite zones. This complex presumably results from anatexis, at slightly greater depths than presently exposed, accompanied by synkinematic injection into overlying rocks. This event is believed to have culminated with the late-kinematic emplacement of elongate, foliated microgranite plutons along the eastern limit of the injection complex.

Retrograde metamorphic effects are widespread and apparently spatially associated with: (i) mylonites (D_{2-3}), (ii) kink folds/bands (D_3), and (iii) shearing/cataclasis adjacent to St. Lawrence and Aspy Faults. The principal effects are (a) chloritization of biotite, garnet, and amphiboles, (b) sericitization of feldspar, and (c) hematization of magnetite and ilmenite.

GEOCHEMISTRY

Two groups of rocks were selected for major and trace element geochemical studies: (a) metavolcanic rocks of the Money Point Group, and (b) granites of the older and younger plutons. These studies were undertaken in order to characterize these groups, to define their petrogenesis, and to assess, if possible, their economic potential.

Metavolcanic Rocks of the Money Point Group

The problem of evaluating the chemistry of altered or metamorphosed volcanic rocks has been discussed by Irvine and Baragar (1971) and more recently by such workers as Winchester and Floyd (1976, 1977) who advocated the use of relatively immobile trace elements for this purpose. As the results of determinations for these elements in the Money Point volcanics were not available at the time of writing, reliance has been placed on interpretation of the major element values, broadly following the approach by Irvine and Baragar (1971).

The material sampled for chemical analyses was the freshest, most homogeneous material available from those metavolcanic rocks occurring mainly within the low-grade zone south of Money Point (Fig. 2, in pocket). Both presumed flow material and fine grained tuffaceous material were used, but heterogeneous material, such as in lithic tuffs and banded tuffs, was avoided.

Results of chemical analyses of 22 selected samples are shown in Table 6. These show a wide compositional range, with the majority being basaltic to andesitic (44-55% SiO_2) and a few being rhyolitic (67-75% SiO_2). Although there is some suggestion that these rocks represent a bimodal suite (Fig. 14b), as was proposed by Neale and Kennedy (1975), it should be noted that the mafic-intermediate and felsic flows and fine grained tuffs are interbedded with a thick sequence of lithic tuffs of predominantly intermediate composition. Thus the volcanic suite as a whole should probably not be considered as compositionally bimodal.

The rocks are quite altered as is indicated by the variable (in some cases high) losses on ignition, and ferric to ferrous iron ratios (Table 6). Another indication of the degree of alteration of these rocks is illustrated in Figure 14a which shows, in terms of their alkalies at least, that about one third of the samples lie outside the normal igneous spectrum (Hughes, 1973). This suggests that caution should be exercised when interpreting the (K_2O+Na_2O) vs. SiO_2 plot (Fig. 14b). As a precaution, a plot of TiO_2 vs SiO_2 (Whitehead and Goodefellow, 1978) was also used (Figure 14c). In both plots, the majority of the samples plot in the subalkaline field, suggesting that the primary affinities of these volcanics were either calc-alkaline or tholeiitic.

Using major-element values, several plots can be used to help discriminate between these two possibilities:

(a) In a plot of FeO^T/MgO vs. SiO_2 (Miyashiro, 1974) the mafic to intermediate volcanics plot mainly in the tholeiitic field whereas the felsic volcanics plot in the calc-alkaline field (Fig. 15a).

Table 6. Chemical analyses and CIPW norms for the Money Point metavolcanic rocks.

CAPE NORTH VOLCANICS

	NO1-1026	NO1-1024	K16-1172B	NO1-1034B	NO1-1035B
SiO_2	75.40	73.80	76.30	67.30	54.50
TiO_2	0.22	0.23	0.12	0.64	1.39
Al_2O_3	13.80	13.50	13.50	14.60	15.80
Cr_2O_3	0.00	0.00	0.00	0.00	0.00
Fe_2O_3	0.66	0.53	0.66	2.43	3.03
FeO	0.10	0.10	0.10	1.87	6.05
MnO	0.02	0.02	0.01	0.13	0.33
MgO	0.19	0.19	0.18	1.62	3.47
CaO	1.03	1.07	0.37	1.71	6.97
Na_2O	5.90	4.83	5.92	2.87	4.24
K_2O	2.21	2.94	1.01	2.87	1.03
P_2O_5	0.03	0.03	0.02	0.12	0.35
L.O.I.	1.20	1.38	0.77	1.54	2.06
TOTAL	100.76	98.62	98.96	97.70	99.22
q	30.40	32.86	37.68	34.61	6.07
or	13.13	17.88	6.08	17.66	6.27
ab	50.14	42.03	51.01	25.26	36.93
an	4.66	5.26	1.74	8.01	21.66
di	0.21	0.00	0.00	0.00	9.53
hy	0.38	0.49	0.46	5.58	11.68
mt	0.00	0.00	0.01	3.23	4.31
hm	0.66	0.55	0.67	0.00	0.00
il	0.26	0.26	0.23	1.26	2.72
ru	0.09	0.10	0.00	0.00	0.00
ap	0.07	0.07	0.05	0.29	0.84
c	0.00	0.51	2.08	4.11	0.00
TOTAL	100.00	100.00	100.00	100.00	100.00

	NO1-1035	NO1-1029	NO1-1025	NO1-0029C	NO1-1036
SiO_2	53.90	53.90	52.90	52.70	50.10
TiO_2	1.37	1.06	1.12	2.31	2.22
Al_2O_3	15.20	15.30	15.10	15.20	13.80
Cr_2O_3	0.00	0.00	0.00	0.00	0.00
Fe_2O_3	4.15	3.52	1.72	6.95	1.98
FeO	5.20	7.20	5.85	5.58	9.20
MnO	0.19	0.25	0.22	0.64	0.38
MgO	3.87	4.00	5.02	2.84	5.07
CaO	7.11	5.11	5.87	4.63	8.39
Na_2O	4.26	4.31	1.57	4.36	3.24
K_2O	1.60	0.94	3.67	1.62	0.48
P_2O_5	0.40	0.19	0.23	1.07	0.47
L.O.I.	1.63	3.28	7.38	1.12	3.26
TOTAL	98.88	99.06	100.65	99.02	98.59
q	3.10	4.85	8.19	5.78	3.41
or	9.75	5.81	23.27	9.82	2.98
ab	37.11	38.12	14.24	37.81	28.75
an	18.15	20.51	24.99	16.37	22.76
di	12.69	3.89	3.77	0.00	14.61
hy	11.28	20.37	20.02	17.09	18.91
mt	4.28	3.88	2.67	5.66	3.01
hm	0.00	0.00	0.00	0.00	0.00
il	2.68	2.10	2.28	4.50	4.42
ru	0.00	0.00	0.00	0.00	0.00
ap	0.96	0.46	0.57	2.54	1.14
c	0.00	0.00	0.00	0.43	0.00
TOTAL	100.00	100.00	100.00	100.00	100.00

Table 6. Continued

	N01-0021	N01-1033	N01-1030	N01-0074	N01-0029D	N01-1039	N01-1046
SiO_2	50.00	49.70	49.40	49.30	47.70	47.60	47.60
TiO_2	2.69	1.82	2.81	1.21	1.55	1.34	1.65
Al_2O_3	14.00	13.80	14.90	18.40	15.80	16.80	15.40
Cr_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe_2O_3	3.41	3.85	6.22	4.64	4.48	2.01	1.41
FeO	7.20	7.00	6.85	4.55	6.13	7.55	8.35
MnO	0.66	0.34	0.34	0.53	0.67	0.23	0.20
MgO	4.15	4.58	5.45	5.66	7.17	8.08	9.22
CaO	8.94	11.50	6.06	7.23	9.16	8.92	10.50
Na_2O	3.39	2.87	3.84	4.73	2.44	2.83	2.28
K_2O	1.00	0.38	0.39	0.61	0.99	0.81	0.53
P_2O_5	1.29	0.35	1.05	0.17	0.21	0.23	0.20
L.O.I.	1.51	3.79	2.11	2.12	1.91	2.16	1.37
TOTAL	98.20	100.08	99.42	99.15	98.21	98.56	98.71
q	5.02	4.02	4.17	0.00	0.00	0.00	0.00
or	6.12	2.34	2.38	3.73	6.09	4.97	3.22
ab	29.66	25.26	33.47	39.42	21.47	24.84	19.82
an	20.71	24.60	22.94	28.06	30.41	31.89	31.05
ne	0.00	0.00	0.00	1.03	0.00	0.00	0.00
di	13.65	26.53	0.77	6.37	12.52	10.09	17.12
hy	11.44	7.81	21.71	0.00	17.91	9.34	11.33
ol	0.00	0.00	0.00	14.55	3.43	12.65	11.67
mt	5.11	5.01	6.56	4.06	4.60	3.02	2.10
il	5.28	3.60	5.50	2.37	3.06	2.64	3.22
ap	3.00	0.84	2.51	0.41	0.51	0.55	0.48
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00

	N01-1039B	K16-1176	K16-1173
SiO_2	47.40	45.60	44.40
TiO_2	1.46	2.00	1.52
Al_2O_3	16.70	15.90	13.70
Cr_2O_3	0.00	0.00	0.00
Fe_2O_3	1.67	5.23	6.03
FeO	8.43	8.35	4.92
MnO	0.27	0.29	0.26
MgO	7.76	7.24	6.71
CaO	8.81	5.78	16.10
Na_2O	2.89	3.17	1.26
K_2O	0.62	1.85	0.40
P_2O_5	0.21	0.27	0.24
L.O.I.	2.35	3.72	2.48
TOTAL	98.57	99.40	98.02
q	0.00	0.00	0.00
or	3.81	11.46	2.48
ab	25.41	28.09	10.56
an	31.97	24.81	32.08
ne	0.00	0.00	0.34
di	9.80	2.76	40.76
hy	10.03	2.16	0.00
ol	13.07	20.79	5.56
mt	2.52	5.31	4.60
il	2.88	3.98	3.03
ap	0.51	0.66	0.58
TOTAL	100.00	100.00	100.00

	N01-1011B	N01-1027
SiO_2	43.70	42.70
TiO_2	1.88	1.17
Al_2O_3	14.00	16.40
Cr_2O_3	0.00	0.00
Fe_2O_3	2.05	1.46
FeO	9.64	6.20
MnO	0.32	0.18
MgO	6.65	6.27
CaO	9.27	9.11
Na_2O	2.68	0.37
K_2O	0.38	4.69
P_2O_5	0.22	0.15
L.O.I.	9.52	10.87
TOTAL	100.31	99.57
or	2.48	30.79
ab	24.97	0.00
an	27.59	32.95
ne	0.00	1.91
lc	0.00	0.38
di	17.65	13.72
hy	6.14	0.00
ol	13.40	14.97
mt	3.27	2.39
il	3.93	2.51
ap	0.56	0.39
TOTAL	100.00	100.00

L.O.I. = Loss on ignition

CIPW norms calculated using Fe_2O_3 ≤% TiO_2 + 1.5

Analyses by X-Ray Assay Laboratory Ltd.

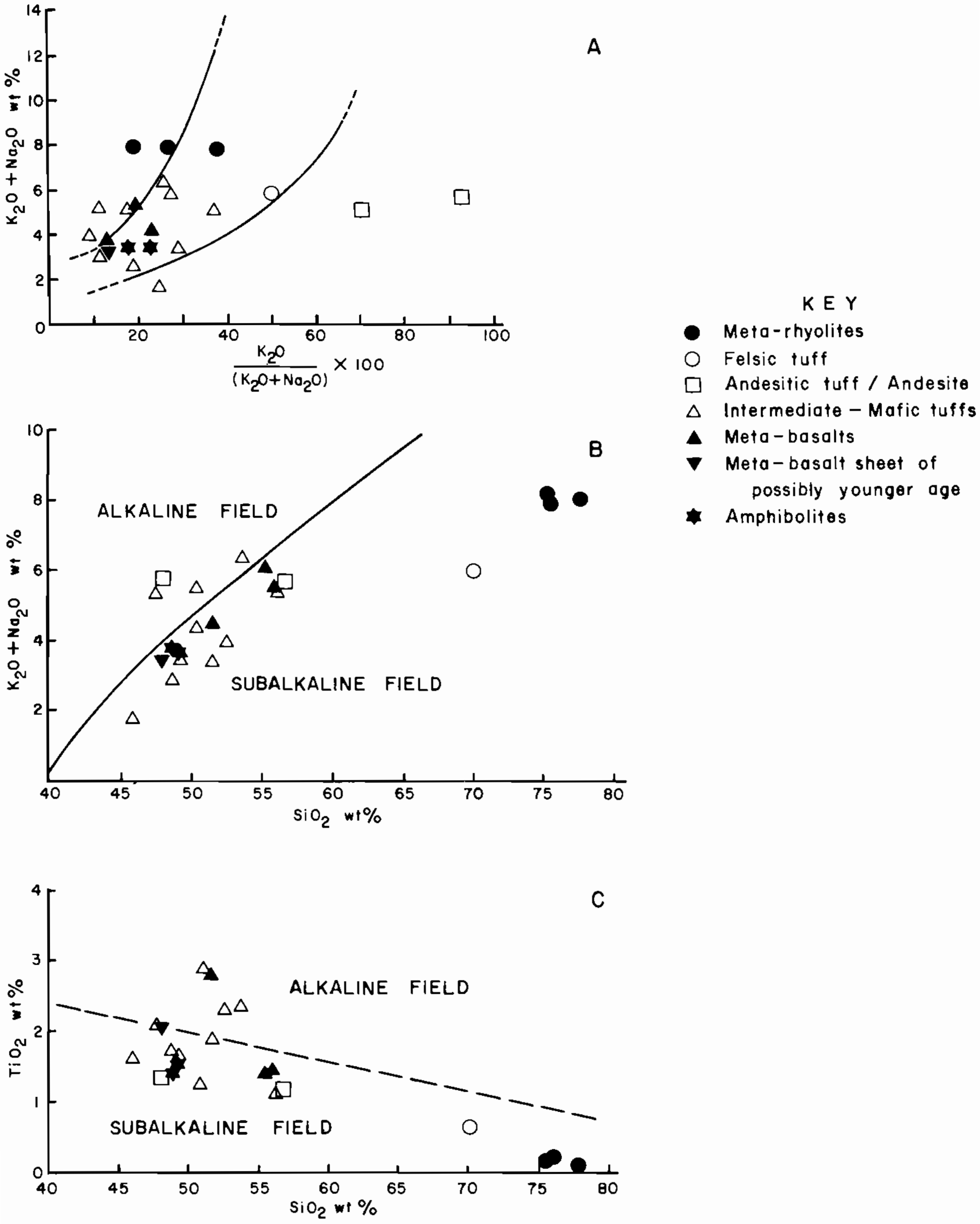


Figure 14. (a) Money Point volcanics plotted on Hughe's "Igneous Spectrum" (see text).
(b) & (c) Geochemical affinities of the Money Point volcanics (alkaline vs. subalkaline).

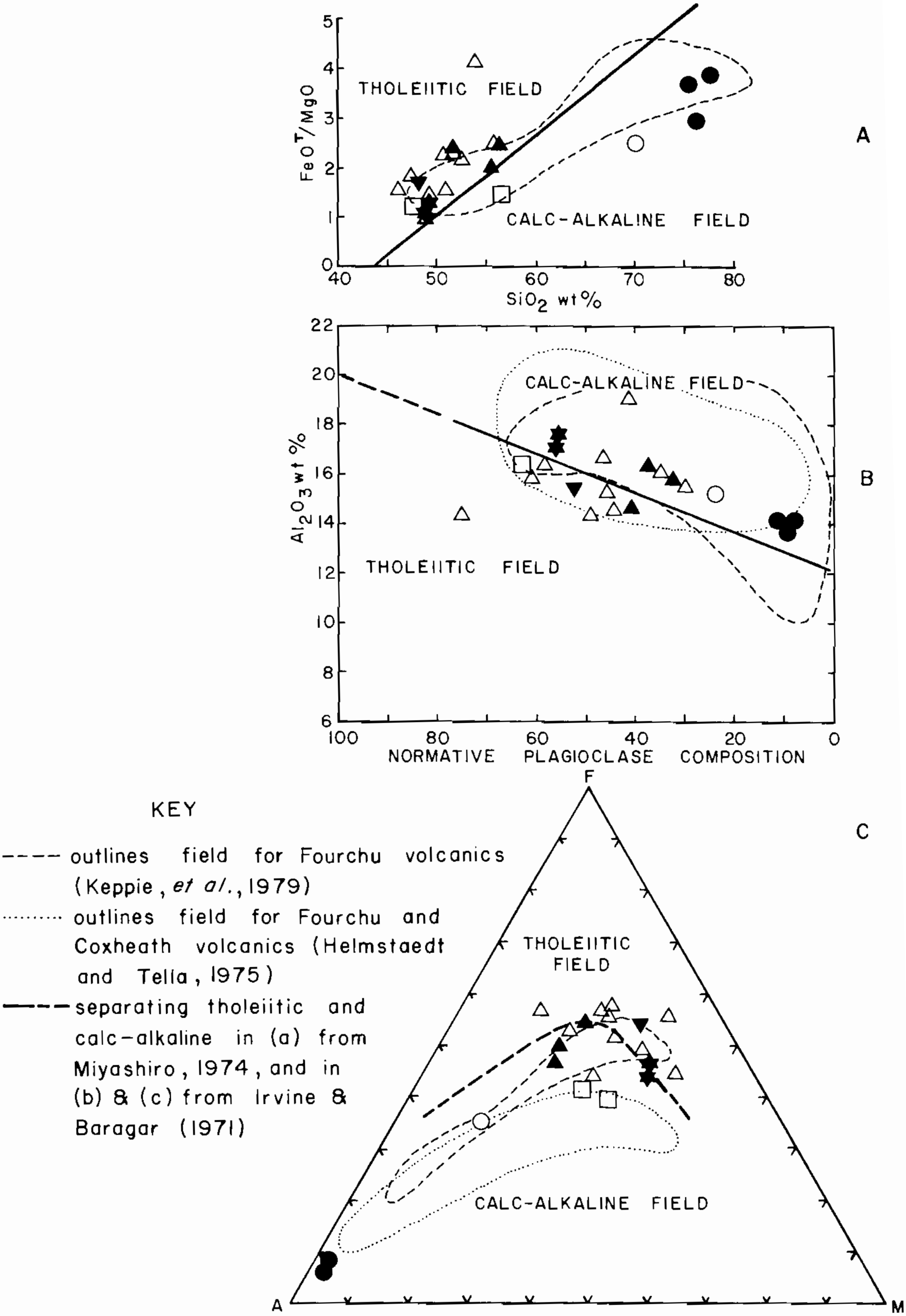


Figure 15. Geochemical affinities of the Money Point volcanics (tholeiitic vs. calc-alkaline).

(b) In a plot of Al_2O_3 vs. Normative Plagioclase Composition (Irvine and Baragar, 1971), the volcanics plot on both sides of the boundary between calc-alkaline and tholeiitic fields (Fig. 15b).

(c) Similarly, in an AFM diagram, as used by Irvine and Baragar (1971), the volcanics again straddle the boundary between the tholeiitic and calc-alkaline fields (Fig. 15c).

Two interpretations seem possible for the apparent transitional character of these volcanic rocks. Either it is real and of primary origin, or it is of secondary origin, probably as a result of metamorphic alteration, and therefore the primary character of the rocks cannot be distinguished on the basis of major element geochemistry alone.

If the major element geochemistry of the Money Point volcanics is compared to those of the Fourchu and Coxheath volcanics of southeastern Cape Breton Island (Helmstaedt and Tella, 1973; Keppie, et al., 1979), it is found that they are crudely similar. The Money Point volcanics plot either within or very close to the fields for the Fourchu and Coxheath volcanics (Figs. 15a-c). An exception occurs in the AFM diagram where the Money Point volcanics fall within or very close to the Fourchu volcanic field of Keppie, et al. (1979), but outside of the more obviously calc-alkaline field for Fourchu-Coxheath volcanics of Helmstaedt and Tella (1973). Undue significance should not perhaps be attached to these geochemical similarities, given the higher metamorphic grade of the Money Point volcanics, and the uncertainty as to the relative ages of these various volcanic units. However, there are also the following broad lithological similarities between Money Point and the upper part, at least, of the Fourchu volcanics as exposed in the Louisbourg area (Murphy, 1977): wide range in composition (mafic to felsic); close association with comagmatic (?) gabbroic rocks; high proportion of pyroclastic to volcanic material; typically thin bedded; and interbedded with shallow-water clastic rocks.

Keppie, et al. (1979) suggested that the Fourchu volcanics near Louisbourg are calc-alkaline with tholeiitic tendencies and were formed in a cratonic island-arc environment. By comparison, the Money Point volcanics could have been formed in a similar environment, but may be even more transitional in their character between tholeiitic and calc-alkaline.

Granites of the Older and Younger Plutons

A total of 24 samples of granite were anlyzed for major elements and for 19 minor elements as shown in Table 7. Of these samples, two were from injected granitic sheets, 13 were from the foliated microgranite plutons (mainly from the Gulch Brook pluton), and nine were from the unfoliated granite plutons (mainly from the Relay Station pluton).

The main purposes for doing a geochemical study of these rocks were (i) to determine whether there were any systematic differences between the various ages of granitic rocks, in particular between the two ages of plutons; and (ii) to determine whether there was any correlation between geochemistry and observed occurrence of mineralization, the older foliated microgranite being the more commonly mineralized.

The samples proved to have very restricted ranges in composition, and all appear to be granites both petrographically and chemically. Means and standard deviations were calculated for analyses from the older Gulch Brook pluton (11 samples) and the younger Relay Station pluton (8 samples) in order to compare them geochemically (Table 8).

In terms of their major elements, there are no really significant differences (at the 95% confidence level), between the two plutons, although the older Gulch Brook pluton may be slightly more felsic (higher mean silica, lower soda and alumina). In terms of their minor elements, the Gulch Brook pluton shows higher mean values and standard deviations for Ba, Cu, Pb, Zn, and S, but is otherwise very similar to the Relay Station pluton. The higher base metal and sulphur values presumably reflect the more common occurrence of Fe-Cu-Mo mineralization observed in the Gulch Brook pluton. The interesting question is: Which of the two plutons was the source of mineralization? In the section describing mineralization, it is inferred from the distribution and modes of occurrence of mineralization, that at least some had its source in the younger Relay Station pluton.

Tauson and Kozlov (1974) suggested several geochemical parameters by which it may be possible to recognize potentially ore-bearing plutons from barren plutons. These parameters include Ba/Rb, (Li x 1000)/K, F/Li, and Li/Zn ratios. The Relay Station pluton has lower Ba/Rb, and higher F/Li and Li/Zn ratios than Gulch Brook pluton (Table 8) and should therefore have a greater potential for mineralization according to the criteria of Tauson and Kozlov (1974).

The same ratios, together with K/Na and K/Rb have also been used by Tauson and Kozlov (1974) to distinguish different genetic types of granite. According to their geochemical classification, both the Cape North plutons show some of the characteristics of both palingenic and plumasitic types, but are not clearly distinguishable from one another as to type.

MINERALIZATION

Approximately 35 metallic and related mineral showings were noted in the course of mapping. Most of these represent trace or minor occurrences, only six of which had previously been recorded (Neale, 1964). The majority occur either within the Money Point Group, or within and adjacent to the granitic plutons (Fig. 5). Four different associations may be recognized.

Stratabound Disseminations (Fe ± Cu ± Zn)

Fine grained disseminations of sulphides and related minerals essentially parallel to the S_1 foliation occur commonly within three rock types: amphibolite, graphitic schist, and pelitic gneiss. As these stratabound disseminations are usually deformed and/or recrystallized they are presumed to have formed before development of the metamorphic foliation.

Table 7. Chemical analyses for granitic rocks

	Gulch Brook Microgranite Pluton											Cape North Microgranite		Lit-par-Lit Granitoids	
Sample Number	NO10075	NO11091	NO11092	K160022	K161082	K161175	K161177	K161182	K161183	K161184	K161187	NO11130	NO11135	NO11107	NO11114
Silica	74.16	72.08	74.47	75.65	75.32	75.04	74.57	75.99	76.40	77.87	73.82	70.77	72.90	71.58	73.50
TiO_2	0.18	0.38	0.23	0.20	0.40	0.13	0.15	0.12	0.27	0.18	0.12	0.22	0.16	0.14	0.02
Al_2O_3	13.12	13.68	13.10	13.20	13.98	12.38	12.58	13.25	12.81	12.62	13.12	16.07	14.36	15.61	14.85
Fe_2O_3	0.87	0.81	0.84	0.64	0.96	1.05	0.91	0.13	0.70	0.57	0.29	0.71	0.45	0.56	0.05
FeO	0.65	0.85	0.87	0.73	0.63	0.63	0.68	0.64	0.81	0.46	0.95	1.05	0.85	0.93	0.69
MnO	0.02	0.03	0.02	0.02	0.02	0.02	0.01	0.02	0.05	0.01	0.02	0.03	0.02	0.03	0.11
MgO	0.29	0.29	0.29	0.20	0.22	0.33	0.25	0.22	0.27	0.25	0.26	0.46	0.30	0.43	0.08
CaO	0.77	0.91	0.94	0.77	0.84	0.75	0.69	0.88	1.17	0.63	1.02	1.17	0.87	1.26	0.70
K_2O	4.78	5.00	4.67	4.55	4.93	4.08	4.81	4.67	3.80	4.83	3.41	5.06	4.96	2.05	2.51
Na_2O	3.48	3.70	3.47	3.78	3.61	4.28	3.65	3.80	4.28	2.94	4.68	4.01	3.44	5.38	5.27
H_2O^+	0.50	0.51	0.26	0.60	0.55	0.54	0.37	0.33	0.13	0.25	0.46	0.63	0.33	0.81	0.28
H_2O^-	0.02	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.04	0.07	0.02	0.00	0.00	0.00	0.00
P_2O_5	0.04	0.05	0.06	0.05	0.03	0.06	0.06	0.03	0.05	0.03	0.04	0.11	0.06	0.04	0.10
CO_2	0.68	0.37	0.40	0.29	0.11	0.11	0.84	0.37	0.11	0.07	0.22	0.15	0.11	0.26	0.18
Total Oxides	99.55	98.68	99.64	100.68	101.59	99.40	99.57	100.45	100.88	100.78	98.43	100.44	98.80	99.07	98.33
TRACE ELEMENTS (in ppm)															
Ba	610	650	650	470	545	590	570	490	690	380	1340	770	405	1000	48
Rb	237	173	224	218	226	160	213	232	198	218	106	158	135	61	162
Sr	88	90	92	90	80	118	90	70	86	62	515	168	175	675	63
Zr	190	250	250	245	190	285	150	375	185	255	170	135	230	155	143
F	620	540	470	420	440	250	3900	540	490	500	440	350	300	470	180
Li	14	10	14	19	13	7	9	15	33	49	18	46	32	31	37
Be	5	8	6	6	7	8	5	6	7	6	5	6	8	4	16
B	5	6	4	4	4	6	5	4	5	10	11	11	6	15	7
Y	25	38	26	21	19	43	12	17	23	19	9	13	21	7	12
Sn	3	4	4	5	3	4	4	5	6	6	3	7	8	3	6
W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8	0.0	0.0	20	0.0	0.0	0.0
S	10	40	260	60	20	90	10	50	20	1230	50	20	20	30	60
Cu	3	1	2	2	1	2	1	8	1	250	12	1	1	7	1
Mo	2	1	1	2	2	3	2	2	2	5	2	1	1	1	1
Pb	28	32	46	22	28	22	18	26	24	80	20	44	48	25	36
Zn	146	42	62	47	44	26	17	26	43	380	44	47	48	67	24
As	11	15	11	15	11	12	14	14	10	10	12	12	15	15	10
Sb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bi	0.2	0.4	2.4	2.0	0.4	0.1	1.0	0.3	0.4	2.1	0.1	0.2	0.2	0.1	1.2

Analyses by Atlantic Industrial Research Institute,
Nova Scotia Technical College, Halifax

Table 7. Continued

	Relay Station granite pluton								Sugarloaf Pluton	Dyke Rocks			
Sample Number	N010071	N011016	N011158	N011159	K161087	K161160	K161170	K161181	K161188	N010072	N010073	N011011	K161178
Silica	72.72	74.09	72.33	75.81	72.73	74.40	73.20	74.58	73.41	45.37	44.22	47.54	54.48
TiO_2	0.20	0.12	0.16	0.04	0.13	0.18	0.18	0.16	0.20	1.50	1.20	1.50	1.04
Al_2O_3	14.73	13.45	14.39	13.10	12.66	13.90	13.78	12.40	13.97	17.56	19.07	13.15	15.44
Fe_2O_3	0.99	0.19	1.20	0.60	0.94	0.42	0.86	0.27	1.22	2.15	1.20	10.55	2.26
FeO	0.70	0.98	0.71	0.23	0.63	1.30	0.77	0.71	0.79	7.09	8.29		3.90
MnO	0.02	0.02	0.03	0.01	0.01	0.01	0.02	0.01	0.03	0.57	0.20	0.34	0.02
MgO	0.35	0.33	0.60	0.08	0.31	0.36	0.49	0.27	0.41	8.36	9.33	6.75	5.10
CaO	1.00	0.91	0.82	0.69	0.54	0.74	1.02	0.67	1.08	6.30	4.32	8.27	5.71
K_2O	4.37	3.87	4.49	4.69	4.78	4.36	4.38	4.63	4.29	3.17	1.95	0.57	3.57
Na_2O	4.30	4.41	3.90	4.22	3.60	4.13	4.28	4.07	4.37	2.30	2.39	2.86	4.05
H_2O^+	0.95	0.44	1.00	0.44	0.66	0.98	0.56	0.62	0.82	3.93	5.56	4.09	0.95
H_2O^-	0.04	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.22	0.41	0.00	0.00
P_2O_5	0.06	0.04	0.07	0.02	0.09	0.06	0.06	0.07	0.07	0.11	0.12	0.19	0.51
CO_2	0.23	0.33	0.04	0.11	0.11	0.11	0.11	0.81	0.22	0.14	0.08	4.64	0.26
Total Oxides	100.66	99.19	99.73	100.04	97.21	100.95	99.72	99.27	100.89	98.78	98.33	100.45	97.28
TRACE ELEMENTS (in ppm)													
Ba	500	280	630	66	395	495	470	585	470	2280	320	320	2300
Rb	221	212	248	353	278	270	215	174	191	149	108	23	157
Sr	208	118	175	81	128	190	195	160	210	402	165	366	2650
Zr	180	150	275	145	250	168	285	375	170	105	95	106	190
F	570	740	390	430	490	440	450	600	490	620	1110	650	1600
Li	24	17	29	5	9	12	15	10	33	159	165	47	78
Be	8	6	6	14	7	9	8	6	5	4	6	4	10
B	18	12	16	5	8	9	11	4	10	365	94	165	9
Y	18	4	8	7	22	20	20	17	7	70	58	59	40
Sn	2	3	3	1	2	2	2	2	3	2	2	3	3
W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12	0.0	16	0.0
S	20	10	30	10	10	10	10	30	10	1300	310	170	190
Cu	8	24	3	2	2	13	2	1	4	111	106	57	2
Mo	2	1	2	2	2	1	2	2	2	2	2	2	1
Pb	28	25	32	36	22	36	28	20	22	20	8	18	24
Zn	38	36	35	14	28	24	33	26	63	152	65	128	231
As	16	15	10	14	10	13	9	14	12	14	13	13	13
Sb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bi	2.1	0.2	0.2	0.3	0.2	0.3	0.8	0.3	0.3	0.2	0.2	0.3	0.8

Table 8. Geochemical comparison of Gulch Brook and Relay Station granitic plutons.

		Gulch Brook Pluton			Relay Station Pluton		
		n = 11			n = 8		
		Mean		S. D.	Mean		S.D.
SiO_2		75.03	±	1.51	73.70	±	1.12
TiO_2		0.21		0.09	0.15		0.05
Al_2O_3		13.08		0.47	13.60		0.77
Fe_2O_3		0.71		0.28	0.76		0.41
FeO		0.72		0.14	0.76		0.28
MnO		0.02		0.01	0.02		0.01
MgO		0.27		0.03	0.24		0.19
CaO		0.85		0.16	0.83		0.18
K_2O		4.50		0.51	4.43		0.27
Na_2O		3.79		0.45	4.29		0.29
P_2O_5		0.04		0.01	0.06		0.02
Ba		635	±	251	432	±	170
Rb		200		40	240		54
Sr		126		130	163		45
Zr		230		67	222		79
F		464		96	511		109
Li		18		12	17		10
Be		6		1	8		3
B		6		2	10		5
Y		23		10	14		7
Sn		4	±	1	2	±	1
W		0		-	0		-
S	*	167		359	16		9
Cu	*	26		75	7		7
Mo		2		1	2		1
Pb	*	31		18	28		6
Zn	*	80		105	33		13
As		12		2	12		2
Sb		0		-	0		-
Bi		1		1	1		1
K/Na		1.33			1.16		
K/Rb		93.5			76.7		
Ba/Rb		3.18			1.80		
(Li x 1000)/K		0.96			0.92		
F/Li		25.8			30.1		
Li/Zn		0.23			0.52		

* means and/or standard deviations significantly different at 95% level.

AMPHIBOLITE SHEETS

Amphibolite sheets occurring within both Cape North and Money Point Groups, generally contain sparse disseminations (1-2%) of ilmenite (closely associated with leucoxene or sphene), pyrrhotite, pyrite and/or marcasite. These occur as elongate anhedral aggregates of grains parallel to the foliation, and as local knot-like concentrations up to 2-3 mm in diameter. They are presumed to have had a magmatic syngenetic origin prior to regional metamorphism, as such an association is not uncommon in gabbroic rocks.

GRAPHITIC SCHISTS

In graphitic schists of the Money Point Group, pyrrhotite is the most obvious and abundant opaque mineral forming elongate anhedral and granoblastic-polygonal grain aggregates, several millimetres long, strung out parallel to L_1 within the S_{0-1} schistosity. Pyrite usually forms discrete small euhedral grain aggregates, whereas marcasite tends to form irregular replacements of pyrrhotite. Small amounts of chalcopyrite occur as tiny anhedral to rounded grains within pyrrhotite, whereas sphalerite in trace amounts locally fringes the pyrrhotite. The graphite occurs as pervasive, finely divided, poorly crystallized material. Given the close association between graphitic schists and metavolcanic schists of the Money Point Group, the possibility exists that this mineralization is volcanogenic sedimentary in origin.

PELITIC GNEISS

Polished sections of pelitic gneiss from six different localities within the Cape North Group were all found to contain minor amounts (1-2%) of very fine grained sulphides and opaque or semiopaque minerals distributed along the gneissic foliation (S_1). Coarse, kinked graphite flakes, subhedral to euhedral rutile, and elongate anhedral to subhedral pyrrhotite (0.2 mm) are the most common components. In addition, pyrite and marcasite respectively form discrete polycrystalline aggregates and local replacements of pyrrhotite. Chalcopyrite occurs as smaller discrete anhedral grains and as patches (displaying mutual boundaries), up to 0.1 mm, within pyrrhotite and marcasite. However, the chalcopyrite is present only in trace amounts (0.1-0.2% by volume). The origin of this mineralization is not clear, but it closely resembles that occurring in the graphitic schists, described above. However, any obvious association with volcanic rocks is lacking in the gneisses.

Irregular Disseminations, Fracture and Vein Fillings (Fe-Cu-Zn-Pb)

Minor amounts of fine grained sulphides occur as sparse irregular disseminations adjacent to and within rusty quartz-filled seams and lensoid quartz veins at several localities within the Money Point Group (Fig. 5). Pyrite, as subhedral to euhedral grains, is generally the most common and abundant sulphide, but pyrrhotite locally (e.g. in calc-silicate schists) is more abundant and may be accompanied by chalcopyrite either mutually intergrown with the pyrrhotite or as sparsely disseminated small anhedra. Sphalerite, containing exsolved chalcopyrite and blebs of pyrrhotite, and rare galena occur in small irregular concentrations and in quartz-filled seams. The origin of this mineralization is not clear. It could represent either volcanogenic sedimentary mineralization redistributed during deformation and regional metamorphism, or distal hydrothermal mineralization related to emplacement of the granitic plutons (older or younger).

Irregular Disseminations, Fracture and Vein Fillings (Fe-Cu-Mo)

Pyrite generally accompanied by trace amounts of either chalcopyrite or molybdenite, occurs at several localities within the older foliated Gulch Brook microgranite pluton and adjacent to the younger Relay Station and Sugarloaf granite plutons (Fig. 5). This mineralization forms localized disseminations and fracture coatings, and is commonly partly oxidized to hematite, goethite and malachite. At one locality within the Gulch Brook pluton, native copper, covellite, cuprite and malachite cement a small area (30 X 50 cm) of fracture stockwork. The mineralization is presumed to be of hydrothermal origin resulting from emplacement of the younger granite plutons and therefore, indirectly related to the association described below.

Regular Crosscutting Quartz-Barite-Fluorite Veins (Fe-Mo-Bi)

Coarse grained, vuggy pyrite, sparse large flakes of molybdenite, and traces of bismuthinite (Neale, 1964) occur in regular quartz veins up to 30-40 cm in width which crosscut schists of the Money Point Group. The best developed veins occur in an east-southeast trending swarm exposed on the seacliffs about 0.5 km west of Money Point (Neale, 1964). Barite commonly accompanies quartz, and fluorite is a less common accessory. The veins are characterized by the presence of strongly sericitized fringes developed in the wall rocks over distances up to 3 cm. Such veins are clearly hydrothermal in origin and relatively young in age and are therefore, attributed to activity associated with emplacement of the younger granite plutons.

SUMMARY AND CONCLUSIONS

Two lithological groups of metamorphic rocks have been distinguished in Cape North area. The apparently older medium- to high-grade Cape North Group consists mainly of banded semipelitic gneisses, but includes a distinctive marker horizon of graphitic marble and adjacent pelitic gneiss. These rocks are presumed to represent part of a miogeoclinal sequence, formed under distal continental shelf or upper slope conditions. The apparently young and conformable, low- to medium-grade Money Point Group consists of a variety of thin-bedded pelitic and semipelitic schists, pyroclastic and volcanic schists of mafic to felsic composition. These rocks are presumed to have formed in shallow-water marine conditions, as part of a cratonic volcanic arc.

Both groups appear to have been affected by essentially the same sequence of structural and metamorphic events. Two phases of penetrative coaxial folding (D_1 and D_2), one or more phases of complex kink banding and related folding (D_3), and perhaps an additional phase of upright cross folding (D_4?) can be recognized. Regional metamorphism prevailed during coaxial folding, with the peak (medium pressure, medium- to high-temperature) having been attained synchronously with D_2 folding and having culminated with development of a granitoid lit-par-lit injection complex within the kyanite and sillimanite zones. Retrograde metamorphic effects were produced during D_3 and subsequent events.

Two ages of granitic plutons are recognized. The older foliated microgranite plutons petrologically resemble some components of, and locally grade into, the lit-par-lit injection complex, whereas the younger unfoliated granite plutons are clearly crosscutting. These plutons are thought to respectively predate and postdate the D_3 structural event.

Traces of mineralization are common in the area, presumably reflecting the varied and potentially favourable volcano-sedimentary and plutonic conditions which have prevailed at different times in the area.

Field evidence indicates that the main folding (D_1 and D_2), metamorphism, and granitoid injection and related plutonism predate deposition of Carboniferous rocks.

Rb/Sr dating (Cormier, 1980) of older foliated granite (Gulch Brook pluton) is inconclusive, but suggests that the radiometric age of this plutonic event has been updated during the Acadian Orogeny; micas yielded ages of 347-361 Ma, while quartz-plagioclase assemblages and whole rock samples yielded an essentially two-point isochron apparent age of about 458 Ma. Similarly metamorphic biotites from staurolite schist on St. Paul Island (Phinney, 1963) and from gneisses at Black Brook Cove, 25 km south of Cape North (Cormier, 1972), gave K/Ar and Rb/Sr ages in the range 350-374 Ma, while the gneisses yielded a Rb/Sr whole rock isochron age of 550 ± 80 Ma (Cormier, 1972; Keppie and Smith, 1979).

One of the younger crosscutting unfoliated granitic plutons occurring adjacent to the Aspy Fault (Relay Station pluton) has also been dated as part of this study, giving a Rb/Sr isochron age of 330 ± 23 Ma (Cormier, 1980). Other granitoid plutons in the same general area which have been dated, include the White Point and Cape Smoky plutons which have yielded Rb/Sr isochron ages of 403 ± 22 Ma and 453 ± 42 Ma (Cormier, 1972; Keppie and Smith, 1979).

It would therefore appear that the main deformations (D_1 and D_2), associated prograde metamorphism and older plutonism are of Late Precambrian-Cambrian age reflecting the effects of the Avalonian or Cadomian Orogenies (Keppie, 1978). The later deformations (D_3-D_5 ?), retrograde metamorphism, and younger plutonism are of Devono-Carboniferous age, presumably reflecting the Acadian Orogeny, the thermal effects of which were sufficiently pervasive to widely reset mica radiometric ages and to disturb Rb/Sr whole rock ages in older crystalline rocks.

Lithological and structural relationships, very similar to those in Cape North, were observed on St. Paul Island and along Clyburn Brook near Ingonish (Fig. 1), suggesting that these relationships are typical for northern Cape Breton as a whole.

The distinctive marble-pelitic gneiss horizon recognized at Cape North can be traced south-southwest from Cape North for 25 km to where it converges with, and apparently reappears on the eastern side of the Aspy Fault (Macdonald and Smith, 1979), 15 km northwest of Clyburn Brook where gneissic rocks of lithologies typical of the George River Group are exposed (Weibe, 1972; Murray, 1977). The Cape North Group is thus tentatively correlated with the George River Group. It follows therefore that the Money Point Group could be a correlative of the upper part of the George River Group (as in the Coxheath Hills and Crowdis Mt. areas), or perhaps even a part of the Fourchu Group, but there is still considerable uncertainty as to where such a predominantly volcanic Group fits into the regional stratigraphy of northern Cape Breton Island. Given such uncertainties, together with the medium- to high-grade metamorphic grades attained, it seems preferable at this time to identify the metamorphic groups in Cape North and adjacent areas by local names.

Although the relative sequence of geological events distinguished for Cape North area is similar in many respects to that described by Neale and Kennedy (1975), this study does not recognize an unconformable basement-cover relationship between rocks of the Cape North and Money Point Groups which correspond to the "gneissic basement" (George River Group?) and "deformed cover sequence" (Fourchu Group?) proposed by Neale and Kennedy (1975) for the Cape North area, and also by Weibe (1972) for the Clyburn Brook area near Ingonish. Specifically, this study indicates that there is a continuous progression in metamorphic grade from low- into high-grade rocks, and that the same structural events can be recognized within both the low- and the high-grade rocks. In addition, this study shows that the stratigraphy of the Cape North Group has survived lit-par-lit granitoid injection and was not reduced to isolated septa within intrusive gneissic granite as described by Neale and Kennedy (1975).

Weibe (1972) considered "granitic dyke injection" (lit-par-lit injection?), related migmatite and high-grade metamorphism in the Clyburn Brook area to have occurred synchronously with intrusion of younger granites of Devonian age, and concluded from this that the Devonian plutons were emplaced at depths of about 15 km. The results of this study would suggest that the injection complex and related metamorphism were of Late Precambrian-Cambrian age and thus are not related to emplacement of the Devonian granites.

Given that similar lithologies, metamorphic grades and structural styles are found on both sides of the Aspy Fault (cf. Cape North area and Clyburn Brook area, near Ingonish), it seems highly unlikely that the Aspy Fault represents a cryptic suture separating different basement terranes, as does the Cape Wray Fault with which it has been correlated (Brown, 1973). Neale and Kennedy (1975) recognized both similarities and differences in the metamorphic rocks on both sides of the Aspy Fault, but were reluctant to reject the concept of the Fault as representing the continuation of a major lithospheric suture along at least part of its length.

There have been several attempts to correlate between northern Cape Breton Island and southwestern Newfoundland across the Cabot Strait and these have usually involved correlating the Aspy Fault with the Cape

Wray Fault (Brown, 1973; Neale and Kennedy, 1975). However, Kennedy (1976) suggested that northernmost Cape Breton Island may include rocks which are equivalents of the Gander Group of Newfoundland. Indeed, there do appear to be close similarities in lithologies and in structural and metamorphic histories between the Money Point Group and the Bay du Nord Group as described by Chorlton (1977), and incidentally between the Cape North Group and Port aux Basques Group as described by Brown (1977). However, there may be a very significant difference in age between the former two Groups; the Bay du Nord Group is considered to be "Devonian or earlier" (Chorlton, 1977) whereas the Money Point Group is considered to be Late Precambrian (Hadrynian) in age (this paper). Nor do the rocks of northern Cape Breton Island appear to correlate with those of the Avalon Zone of eastern Newfoundland although it has been suggested (Keppie, 1978) that they could correlate with rocks of that zone farther offshore in the Grand Banks-Flemish Cap area.

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APPENDIX I

PETROGRAPHIC SUMMARY

(to accompany sample location map, Fig. 16, in pocket)

Symbols used:

X = major phase (generally > 10% by volume)
x = minor phase (< 10% by volume)
O = accessory or retrograde or alteration phase (< 1% by volume)
? = identification uncertain due to alteration

SEMIPELITIC GNEISSES OF CAPE NORTH GROUP

SPECIMEN NUMBER N.T.S.	SPECIMEN NUMBER NUMBER	QUARTZ	ORTHOCLASE	MICROCLINE	PLAGIOCLASE	An %	ORTHO-Px	CLINO-Px	AMPHIBOLE SPECIES *1	AMPHIBOLE SPECIES *2	AMPHIBOLE SPECIES *3	MUSCOVITE	BIOTITE	SERICITE	CHLORITE	EPIDOTE SP	OLIVINE	WOLLASTONITE	GARNET SP	STAUROLITE	ANDALUSITE	SILLIMANITE	KYANITE	CORDIERITE	CHLORITOID	GRAPHITE	CARB SPECIES	OPAQUES	SPHENE	TOURMALINE	ZIRCON	CORUNDUM	APATITE	RUTILE	IDOCRASE	COMMENTS
N01-	0085				x	30					X		X		O				x										O		O					garnets with S_{0-1} ? inclusion trails in S_{1-2} ? foliation
N01	0094	X	x		X								X	O	x													O					O			
N01-	0132				X					X			X						x										x		O					
N01	0136		X		X					?			X		x												O	O	O				O			strong retrograde alteration
N01-	1046	X	x		X	27				X					x													O								
N01	1048	x			X	32				X			X	O	x	x											O		O							retrograde alteration
N01-	1049	X		X	X	28						X	x		O																					lenses of microcline, quartz and myrmekite
N01	1096	X	X	x	X	20						x	X						x																	interstitial microcline and myrmekite
N01-	1099	X	x		X	32				X			X																							
N01	1102	X			X	28							X	O	O				x														O			kinked biotites, bent plagioclase twin lamellae
N01-	1104	X			X	36							X						x									O					O			
N01	1106	X			X	20					x		X		O				x									O								
N01-	1108				?					X			X	O		X												O	O							weak crenulation cleavage (?)
N01	1109	X			X					X				O		X											O	O	O							
N01-	1112	X			X						X		X																		O					
N01	1131	X	x		X	20							X						x									O	O							
N01-	1132	x	X		X	38							X			x													O							
N01	1136	X	X		X	30							X			x			x										O							relatively abundant sphene
N01-	1138	X	x		X	28						x	X		O	X												O	O				O			local concentrations of sphene and opaques with clinozoisite
N01	1139	X	x		X	27							X		O													O	O				O			
N01-	1140	X	X		X								X			X													O				O			complex structure F_1(?) hinge
N01	1163	X	x		X	28				X			X																				O			
N01-	1202	X			X	28							X		O				x																	retrograde alteration; plagioclase kinked
N01	1204B	X			X								X		O				X										x							very large poikiloblastic garnets
N01-	1205	X			X					X			x		O				x								O	O								extensive chlorite veining
K16	0001	X	X		X										x				x									O								retrograde alteration
K16-	0004	x	X		X					X			X	O	O														O				O			
K16	0025	X			X	20							x		O																		O			
K16-	0026	X		X	X	25							x																							microcline and minor myrmekite
K16	0027	X			X					X			X																O				O			
K16-	0028	X		X	X								X		O																O					microcline and myrmekite
K16	1007	X			X					X				O		X			x										O				O			
K16-	1053	X			X					X									x									O								
K16	1055	X	?		X					X				O		X			x																	
K16-	1074		?		X					X				O		X													O							transposed gneissic foliation S_{1-2} (?)
K16	1083B	X	X		X							X	X	O	O																					strong S_2 crenulation cleavage; F_3 kink bands
K16-	1119A	X	?		?					X			X	O	O	x												O	O							
K16	1185	x	X		X	40				X			X																							gneissic foliation around F_2 (?) hinge
-																																				
-																																				

*1. ACTINOLITE - TREMOLITE 2. HORNBLENDE 3. CUMMINGTONITE - GEDRITE

PELTIC GNEISSES OF CAPE NORTH GROUP

SPECIMEN NUMBER		QUARTZ	ORTHOCLASE	MICROCLINE	PLAGIOCLASE	An %	ORTHO-Px	CLINO-Px	AMPHIBOLE SPECIES			MUSCOVITE	BIOTITE	SERICITE	CHLORITE	EPIDOTE SP	OLIVINE	WOLLASTONITE	GARNET SP	STAUROLITE	ANDALUSITE	SILLIMANITE	KYANITE	CORDIERITE	CHLORITOID	GRAPHITE	CARB SPECIES		OPAQUES	SPHENE	TOURMALINE	ZIRCON	CORUNDUM	APATITE	RUTILE	IDOCRASE	TALC	COMMENTS
N.T.S.	NUMBER								*1	*2	*3																											
N01-	0086	X	x		X							X	X		O				x				x			O						O						
N01	0099	x								X	X	X	X		O																	O						
N01-	0100	x	x		X	35							X	O	O								x							O		O						
N01	0120	X			X								X	O		X				X										O		O						two mica orientations; zoned plagioclase
N01-	0121				X							X	X						x				x									O						
N01	0125	x			X					X				O									x									O						mimetic (?) amphiboles around F_1 or F_2 hinge
N01-	0126				X								X	O	O					x										O								
N01	0129		X		X	33						X			O				x			x	x			O			O			O		O				abundant staurolite porphyroblasts
N01-	0130	X		X								X	X						x																O			microcline prophyroblasts with fringing myrmekite
N01	1097	X	X									X	X		O				x			x	x															
N01-	1098	X			X							X	X						x	?																		
N01	1115	X			X	25						X	X		O				x										O			O	O					weak S_2 crenulation cleavage; garnets with S_{0-1} trails
N01-	1116	X			x							X	X		O				x	x													O					
N01	1164	X			X	26						X	X		O				x			x												O				garnets locally flattened, sillimanite forming from muscovite
N01-	1165	X			X							X	X	O	O				x	?		?	x															sericite - chlorite pseudomorphs after staurolite
N01	1193	X			X	28						X	X						x																			
-																																						
K16-	0019	X			X							X	X						x										O									
K16	1079	X			X							X	X		O				x			?	x															
K16-	1080	X			X	20						X	X		O				x				x															
K16	1126	X			X							x	X	O	O	O			x				x															retrograde alteration
K16-	1127	X			X	26						x	X	O	O				x													O						

CALC-SILICATE GNEISSES AND MARBLE OF CAPE NORTH GROUP

	N.T.S.	NUMBER	QUARTZ	ORTHOCLASE	MICROCLINE	PLAGIOCLASE	An %	ORTHO-Px	CLINO-Px	AMPHIBOLE SPECIES *1	AMPHIBOLE SPECIES *2	AMPHIBOLE SPECIES *3	MUSCOVITE	BIOTITE	SERICITE	CHLORITE	EPIDOTE SP	OLIVINE	WOLLASTONITE	GARNET SP	STAUROLITE	ANDALUSITE	SILLIMANITE	KYANITE	CORDIERITE	CHLORITOID	GRAPHITE	CARB SPECIES		OPAQUES	SPHENE	TOURMALINE	ZIRCON	CORUNDUM	APATITE	RUTILE	IDOCRASE	TALC	COMMENTS
Calc-Silicate Gneiss	N01-	1101		X		X			X					X					?												x						O		
	N01	1190	X			X	32				X			X		O	X														O								
	N01-	1192	X		x	X	33		X		X						X														x								grain shapes flattened in gneissic foliation
	N01	1194		x		X					X					O	X											X			x								distinct compositional banding
	N01-	1198			X	X			X		X		x	x			X											x			x								retrograde alteration
	-																																						
Marble	N01-	0080								x			x														O	X									O		kinked micas
	N01	0131	x																									X									O		
	N01-	1100											O														O	X									O		
	K16	1003	O																								O	X											strongly deformed
	K16-	0016											O															X									O		
	K16	1125	O										O														O	X	x								O	O	strongly deformed calcite, kinked graphite

MYLONITES AND RETROGRADED GNEISSES (?)

N.T.S.	NUMBER	QUARTZ	ORTHOCLASE	MICROCLINE	PLAGIOCLASE	An %	ORTHO-Px	CLINO-Px	AMPHIBOLE SPECIES *1	AMPHIBOLE SPECIES *2	AMPHIBOLE SPECIES *3	MUSCOVITE	BIOTITE	SERICITE	CHLORITE	EPIDOTE SP	OLIVINE	WOLLASTONITE	GARNET SP	STAUROLITE	ANDALUSITE	SILLIMANITE	KYANITE	CORDIERITE	CHLORITOID	GRAPHITE	CARB SPECIES		OPAQUES	SPHENE	TOURMALINE	ZIRCON	CORUNDUM	APATITE	RUTILE	IDOCRASE	TALC	COMMENTS
K16-	1005	X			X							X	X		x				x																			strong retrograde alteration and kink bands
K16	1008	X			X									O	X	x													O									mylonite (?)
K16-	1088	X			X							X																										phyllonite (?)
K16	1089	X			?							X	X	O	x																							strong retrograde alteration
K16-	1179	X			?							X	X	O	x				x																			strong retrograde alteration, transposed foliation
K16	1228	X			X							X															x											mylonite (?)
K16-	1229	X			X							X								?																		phyllonite (?)
K16	1230	X										X	X													O	x											phyllonite (?)

*1. ACTINOLITE - TREMOLITE 2 HORNBLENDE 3. CUMMINGTONITE - GEDRITE

METAVOLCANIC SCHISTS OF MONEY POINT GROUP

	SPECIMEN NUMBER		QUARTZ	ORTHOCLASE	MICROCLINE	PLAGIOCLASE	An %	ORTHO-Px	CLINO-Px	AMPHIBOLE SPECIES			MUSCOVITE	BIOTITE	SERICITE	CHLORITE	EPIDOTE SP	OLIVINE	WOLLASTONITE	GARNET SP	STAUROLITE	ANDALUSITE	SILLIMANITE	KYANITE	CORDIERITE	CHLORITOID	GRAPHITE	CARB SPECIES	OPAQUES	SPHENE	TOURMALINE	ZIRCON	CORUNDUM	APATITE	RUTILE	IDOCRASE	COMMENTS
	N.T.S.	NUMBER								*1	*2	*3																									
Meta-rhyolites	NO1 –	0005	X	X		X								x		x												O									porphyroclastic texture
	NO1	0117	X	X		X	12							x						x																	quartz porphyroclasts recrystallized
	NO1 –	1024	X	X		X	08						x															O									porphyroclastic augen texture
	NO1	1026	X	X		X							x																								porphyroclastic augen texture
Felsic to Intermediate Meta-tuffs	NO1 –	0011				X										X	X											O	O								S_2 foliation dominant ?
	NO1	0018	X			X							X		O	X	x											O									two micaceous foliations
	NO1 –	0018B				X	30			X					O	X	X												O								augen texture
	NO1	0021				X										X	X											O	O								meta-andesite ?
	NO1 –	0022	X							X				X	O	X												x	O								
	NO1	0023	X			?				X					O	X	X												O								elongate lithic fragments
	NO1 –	0025B	x							X					O	X													O								
	NO1	0029B				X	30									X	X												O								porphyritic dacite orginally ?
	NO1 –	0029C	X	x		X	31							X		X													O								porphyritic dacite originally ?
	NO1	0029D													O	X	X											x	O								meta-tuff ?
	NO1 –	0032	X			X	30				X			X		X	X											O		O				O			meta-lithic tuff
	NO1	0032A	X			X	32			X						X	X												O								meta-lithic tuff
	NO1 –	0111	X			X	30						x	X						x									O			O					schistose felsic lithic tuff
	NO1	1002	X	?		X	06						X			X												O	O								schistose felsic lithic tuff
	NO1 –	1025	X			?							X			X												x	O								meta-andesite ?
	NO1	1031	X			X					X			X			X												O								intermediate lithic tuff
	NO1 –	1034B	X			X	30						X	X															O				O				biotite porphyroblasts and plagioclase porphyroclasts
	NO1	1035	X			X					X			X			X												O								intermediate lithic tuff
	NO1 –	1035C	X			X					X			X		x												x	O								banded schist with hornblende aligned in S_2 cleavage
Intermediate to Mafic Meta-tuffs and Metavolcanics	NO1 –	0076	x			X	39					X			O	X	x											O	O				O				
	NO1	0079		x		X						X			O															x							
	NO1 –	0087	x	?		X					X																		O	x							weak S_1 foliation
	NO1	0105				X	50					X		X	O	O														O		O					
	NO1 –	0112	X			x					X		x																	O							
	NO1	0116	X			x				X	X			x		X																					porphyroblastic hornblende enclosing actinolite prisms
	NO1 –	1029	X			?					X			x		X												O	O								relatively massive (metavolcanic)
	NO1	1033	X			x					X					X	X												O								relatively massive (metavolcanic)
	NO1 –	1035	X			X					X			x			X											O	O								weak foliation (metavolcanic)
	NO1	1035B	X			x					X			X			x											O	O								two micaceous foliations
	NO1 –	1036	X			x					X			x		X	x											O	O								S_2 crenulation cleavage
	NO1	1050	X			X	48				X			X			X												O	x			O				compositional banding
	NO1 –	1095	X			X					X				O		x												O	x							
	NO1	1143	X	?		X					X			x																x							
	NO1 –	1145	X			X					X			x	O	O				x									x							O	
	NO1	1146	x			X	32				X						X												O	x							
	NO1 –	1148	X			x	30							x		x													O								weak foliation
	NO1 –	1149	X								X			X															O								compositional banding
	NO1	1152	X										X	X													O		O								S_2 crenulation cleavage; pyrohotite-rich
	K16 –	0021	X			X					X																		O	x							
	K16	1007	x			X					X																		O	x							
	K16 –	1118	X			X	34				X			X			x												O	x							
	K16	1122	x			X	30				X						X																				compositional banding
	K16 –	1176				X					X			X	O	O													O								

*1 ACTINOLITE - TREMOLITE 2. HORNBLENDE 3. CUMMINGTONITE - GEDRITE

METASEDIMENTARY PHYLLITES AND SCHISTS OF MONEY POINT GROUP

Pelitic and semi-pelitic phyllites and schists

SPECIMEN NUMBER N.T.S.	NUMBER	QUARTZ	ORTHOCLASE	MICROCLINE	PLAGIOCLASE	An %	ORTHO-Px	CLINO-Px	AMPHIBOLE SPECIES *1	*2	*3	MUSCOVITE	BIOTITE	SERICITE	CHLORITE	EPIDOTE SP	OLIVINE	WOLLASTONITE	GARNET SP	STAUROLITE	ANDALUSITE	SILLIMANITE	KYANITE	CORDIERITE	CHLORITOID	GRAPHITE	CARB SPECIES	OPAQUES	SPHENE	TOURMALINE	ZIRCON	CORUNDUM	APATITE	RUTILE	IDOCRASE	COMMENTS
NO1-	1009	X			X							X	x		X													O				O				spotted phyllite, incipient biotite
NO1	1010	X										X	X		X												X	O								F_1 microfold cut by S_2 crenulation cleavage
NO1-	1012	X			X					x			x		X												X	O				O				diffuse chloritic spotting
NO1	1013	X										X	X		X																					strong spotting; S_2 crenulation cleavage
NO1-	1017B	X			X										X	X											X									hornfelsed (?)
NO1	1018	X			X	34			X			X	X															O	O							hornfelsed; strong compositional layering
NO1-	1021	X	X	X	X	28						X																O								quartz schist
NO1	1022																																			quartz schist with tectonic mimic of crossbedding
NO1-	1023A	X										X	X											?				O								spotted phyllite, incipient cordierite (?)
NO1	1023B	X			X							X	X											?												ovoid cordierite spots aligned in S_{0-1}
NO1-	0002	X	x		X							X			X	x												O								chloritic spots deformed in S_2 (?)
NO1	0004	X										X	X		X													O								S_2 crenulation cleavage
NO1-	0007	X			X																						X									
NO1	0030	X							X				X		X																					prophyroblastic actinolite and biotite
NO1-	0034	X										X	X		X	x												O								
NO1	0034B	X							x				X		X				x					x			x	O								poikiloblastic cordierite
NO1-	0035	X			X				?				X		x				x																	
NO1	0037	X										X	X															O								
NO1-	0040B	X											X			X			x								x									quartz schist
NO1	0041	X								X			X						x									O								conglomeratic schist
NO1-	0043	X			x				?				X		X				x								X	O								
NO1	0044	X										X	X		O	x			x									O								F_1 microfold cut by S_2 crenulation cleavage
NO1-	0046	X			X							x			X				x																	F_2 microfold (?)
NO1	0047B	X										X	X														x				O					recrystallized quartz pebbles in schistose matrix
NO1-	0048	X										X	X														x				O					recrystallized quartz pebbles in schistose matrix
NO1	0049	X										X			X				x						x			O			O					small chlorite and chloritoid prophyroblasts
NO1-	0050	X										X			X									X												recrystallized quartz pebbles in schistose matrix
NO1	0050B	X										X	X			x			x					X												cord. prophyroblasts & recryst. qtz. pebs. in crenulated schist. matrix
NO1-	0050C	X										X			X									X												cord. prophyroblasts & recryst. qtz. pebs. in crenulated schist. matrix
NO1	0051	X										X	x															O								quartzite
NO1-	0052	X										X			X					?				X				O								
NO1	0056	X										X	X		O				x	X				?												
NO1-	0056B	X										X	X						x	X								O								staurolite prophyroblasts; strong S_2 crenulation cleavage
NO1	0059	X			x								X															O								
NO1-	0060	X			x							X	X		O					?								O								flattened garnets with inclusion trails; S_2 crenulation cleavage
NO1-	0062	X			?							X	?	O	X																					
NO1	0063	X			X				X			X		x	X												X	O								retrograde alteration
NO1-	0064	X										X			X									x				O								
NO1	0066	X			X								X		x																O					
NO1-	0068	X			X									O	X	x												O								
NO1	0070	x			X	38						x	X		x																					deformed plagioclase augen
NO1-	0090	X			x	07						X	X		O																		O			two micaceous foliations
NO1	0102	X										X	X						x	x								O								garnet prophyroblasts with inclusion trails ; S_2 crenulation cleavage
NO1-	0106	X			X					x			X		O													O								

*1. ACTINOLITE-TREMOLITE 2 HORNBLENDE 3.CUMMINGTONITE-GEDRITE

	SPECIMEN NUMBER		QUARTZ	ORTHOCLASE	MICROCLINE	PLAGIOCLASE	An %	ORTHO-Px	CLINO-Px	AMPHIBOLE SPECIES			MUSCOVITE	BIOTITE	SERICITE	CHLORITE	EPIDOTE SP	OLIVINE	WOLLASTONITE	GARNET SP	STAUROLITE	ANDALUSITE	SILLIMANITE	KYANITE	CORDIERITE	CHLORITOID	GRAPHITE	CARB SPECIES	OPAQUES	SPHENE	TOURMALINE	ZIRCON	CORUNDUM	APATITE	RUTILE	IDOCRASE	COMMENTS
	N.T.S.	NUMBER								*1	*2	*3																									
Pelitic and semi-pelitic phyllites and schists	NO1-	0107	x		x	X	28							X						x	X											O	O				garnet & staurolite porphyroblasts
	NO1	0108	x	x		X							X	X		O	x							x			O										
	NO1-	0109	X										X	X		O				x	x						O					O	O				
	NO1	0118	X										X	X															O								biotite porphyroblasts crudely aligned in S_2 crenulation cleavage
	NO1-	1038	X											X													O		x								pyrrhotite-rich; S_2 crenulation cleavage
	NO1	1043	X										X	X			x																O				recrystallized quartz pebbles in schistose matrix
	NO1-	1044	X			X	32						X	X		O				x	x																flattened garnets
	NO1	1094	X										X	X		O				x																	
	NO1-	1142	X			X				X				X															O			O	O				
	NO1	1147	X			X	30							X						X									O								very large garnet porphyroblasts with folded inclusion trails (S_1?)
	NO1-	1150	X			X				X				X		O				x								x	O	O						x	compositional banding
	NO1	1153	X										X	X		O	x			x									O								
	NO1-	1156	X										X	X		O				x									O				O				S_2 crenulation cleavage
	K16-	1056	X			X							X		O	O				x																	retrograde alteration
	K16	1084	X										X	X						x	x												O				garnet and staurolite porphyroblasts; small corundums; kink bands
	K16-	1121	X										X	X		O					x								O				O				
	K16	1128	X			X							X	X	O	O				x	x								O				O				strong retrograde alteration; intense S_2 crenulations
	K16-	1172	X			X							X			O													O			O					
	K16	1174	X			X							X	X	O	O				x																	
Calc-silicate schists	NO1-	0024A	X			X	12						x			x	X											X	O								
	NO1	0027	X													x	X											X									
	NO1-	1014												X		x												X	O							x	S_2 strain-slip cleavage
	NO1	1019								X			X	X		x	X											x	O								compositional banding (pelitic and calcareous)
	NO1-	1013	X										X	X		X	X											X									coarse marble (?) laminae in semipelitic schist
	NO1	1047	X			X	38				X						X											X	O							x	strong compositional banding (calc-silicate and semipelitic)

*1 ACTINOLITE-TREMOLITE 2. HORNBLENDE 3. CUMMINGTONITE-GEDRITE

AMPHIBOLITES

SPECIMEN NUMBER		QUARTZ	ORTHOCLASE	MICROCLINE	PLAGIOCLASE	An %	ORTHO-Px	CLINO-Px	AMPHIBOLE SPECIES			MUSCOVITE	BIOTITE	SERICITE	CHLORITE	EPIDOTE SP	OLIVINE	WOLLASTONITE	GARNET SP	STAUROLITE	ANDALUSITE	SILLIMANITE	KYANITE	CORDIERITE	CHLORITOID	GRAPHITE	CARB SPECIES	OPAQUES	SPHENE	TOURMALINE	ZIRCON	CORUNDUM	APATITE	RUTILE	IDOCRASE	COMMENTS
N.T.S.	NUMBER								*1	*2	*3																									
NO1-	0053	x			x					X					O	x											O	O	x							
NO1	0081		x		X						X			O	O														O							
NO1-	0122	x			X	43					X		X		O														O							
NO1	0133	x			X	30				X					O				x									O	x							garnet poikiloblasts; retrograde alteration
NO1-	0138	x			X					X				O	O				x								O	O								garnet poikiloblasts
NO1	1039	x			X	34				X			X		O	X												O								
NO1-	1039B	x			x					X		x	X		O	X																				
-																																				
K16	1064	x			?					X				O													O	O								
K16-	1065	x			x					X			X		x													O				O				
K16	1073	x			X					X				O		X											O	O	x							

GRANITOID ROCKS

	N.T.S.	NUMBER	QUARTZ	ORTHOCLASE	MICROCLINE	PLAGIOCLASE	An %	ORTHO-Px	CLINO-Px	AMPHIBOLE SPECIES *1	*2	*3	MUSCOVITE	BIOTITE	SERICITE	CHLORITE	EPIDOTE SP	OLIVINE	WOLLASTONITE	GARNET SP	STAUROLITE	ANDALUSITE	SILLIMANITE	KYANITE	CORDIERITE	CHLORITOID	GRAPHITE	CARB SPECIES	OPAQUES	SPHENE	TOURMALINE	ZIRCON	CORUNDUM	APATITE	RUTILE	IDOCRASE	COMMENTS
Injected Granitoid Rocks	NO1-	0101		X	X	X							X		O	O																					gneissic foliation; large microcline phencrysts
	NO1	0103	X		X	X	17						X	X		O												O									
	NO1-	0119		X	X								X	X		O																O		O			microcline and perthite phenocrysts, some mymerkite
	NO1	1107	X		X	X	20						x	x		O																					
	NO1-	1114	X		X	X	24						x							x																	foliated; pegmatitic; garnetiferous
	NO1	1130	X	x	X	X							x	x	O	O																					myrmekite common
	NO1-	1135	X		X	X	20						x	x																				O			
	NO1	1196	X		X	X	20						x	x																							micaceous foliation
	-																																				
	K16	0006	X	X		X							x	?		O																					gneissic foliation; kinking of plagioclase and micas
	K16-	0020	X	X	X	X							x	x																							gneissic foliation
	K16	1052																																			
	K16-	1066	X	X		X	12							x		O				x																	foilated, garnetiferous
	K16	1186	X	X		X							x	x						x												O					contorted gneissic foliation
	K16-	1187																																			
Foliated Fine Grained Granite	NO1-	0075	X		X	X	17						x	x															O								weak botite alignment
	NO1	1091	X		X	X							x	x		O																					weak botite alignment
	NO1-	1092	X		X	X								x		O																		O			weak botite alignment
	K16-	1082	X	X	X	x							x	x		O													O								
	K16	1177	X	X	X	X							x	x															O					O			weak biotite alignment
	K16-	1182	X	X	X	X							x	x		O													O								
	K16-	1183	X		X	X								x																							
	K16	1184	X	X	X	x							x	x															O								aplitic
	-																																				
Unfoliated Coarse Grained Granite	NO1-	0071	X	X		X							x	x	O	O													O								leucocratic
	NO1	1016	X	X	X	X							x	x	O	O												O	O					O			
	NO1-	1158	X	X	X	X	18						x	x	O	O																					
	NO1	1159	X	X	X	X	12						x																								leucocratic
	K16-	1087	X	X	X	X								x	O	O													O					O			leucocratic
	K16	1160	X	X	X	X	09							x	O	O																					
	K16-	1175	X	X	x	X								x	O														O	O							strong cataclastic deformation and alteration
	K16	1181	X	X	X	X							x	x	O	O												O	O	O				O			strong cataclastic deformation and alteration
	K16-	1188	X	X	X	X	18							x		O													O					O			

*1. ACTINOLITE - TREMOLITE 2 HORNBLENDE 3 CUMMINGTONITE - GEDRITE

DYKES

	SPECIMEN NUMBER		QUARTZ	ORTHOCLASE	MICROCLINE	PLAGIOCLASE	An %	ORTHO-Px	CLINO-Px	AMPHIBOLE SPECIES			MUSCOVITE	BIOTITE	SERICITE	CHLORITE	EPIDOTE SP	OLIVINE	WOLLASTONITE	GARNET SP	STAUROLITE	ANDALUSITE	SILLIMANITE	KYANITE	CORDIERITE	CHLORITOID	GRAPHITE	CARB SPECIES	OPAQUES	SPHENE	TOURMALINE	ZIRCON	CORUNDUM	APATITE	RUTILE	IDOCRASE	COMMENTS
	N.T.S.	NUMBER								*1	*2	*3																									
Basalt	NO1-	0072				X	54		X						O	O		X										O	O								slightly altered
	NO1	0073				X	64								O	X												X	O								strongly altered
	NO1-	0074				X	35		X							x													O								strongly altered
	NO1	1011	x			?									O	X												x	O								foliated & strongly altered; possibly metamorphosed ?
	NO1-	1011B	x			?									O	X												x	O								crudely foliated and strongly altered
	-																																				
Microdiorite	K16	1178B	x	X	X	X					X			X		x												O									lamprophyre?

MISCELLANEOUS ROCKS

Fault Breccias	NO1-	1028																																			Brecciated felsic metavolcanics (?) with quartz calcite veining
	K16	1067																																			Brecciated felsic metavolcanics (?) with quartz clacite veining
	-																																				
	-																																				
Lithic Sandstone	K16	0009	X	X	x	X								x		x																-					Plus rock fragments

*1. ACTINOLITE-TREMOLITE 2. HORNBLENDE 3. CUMMINGTONITE-GEDRITE

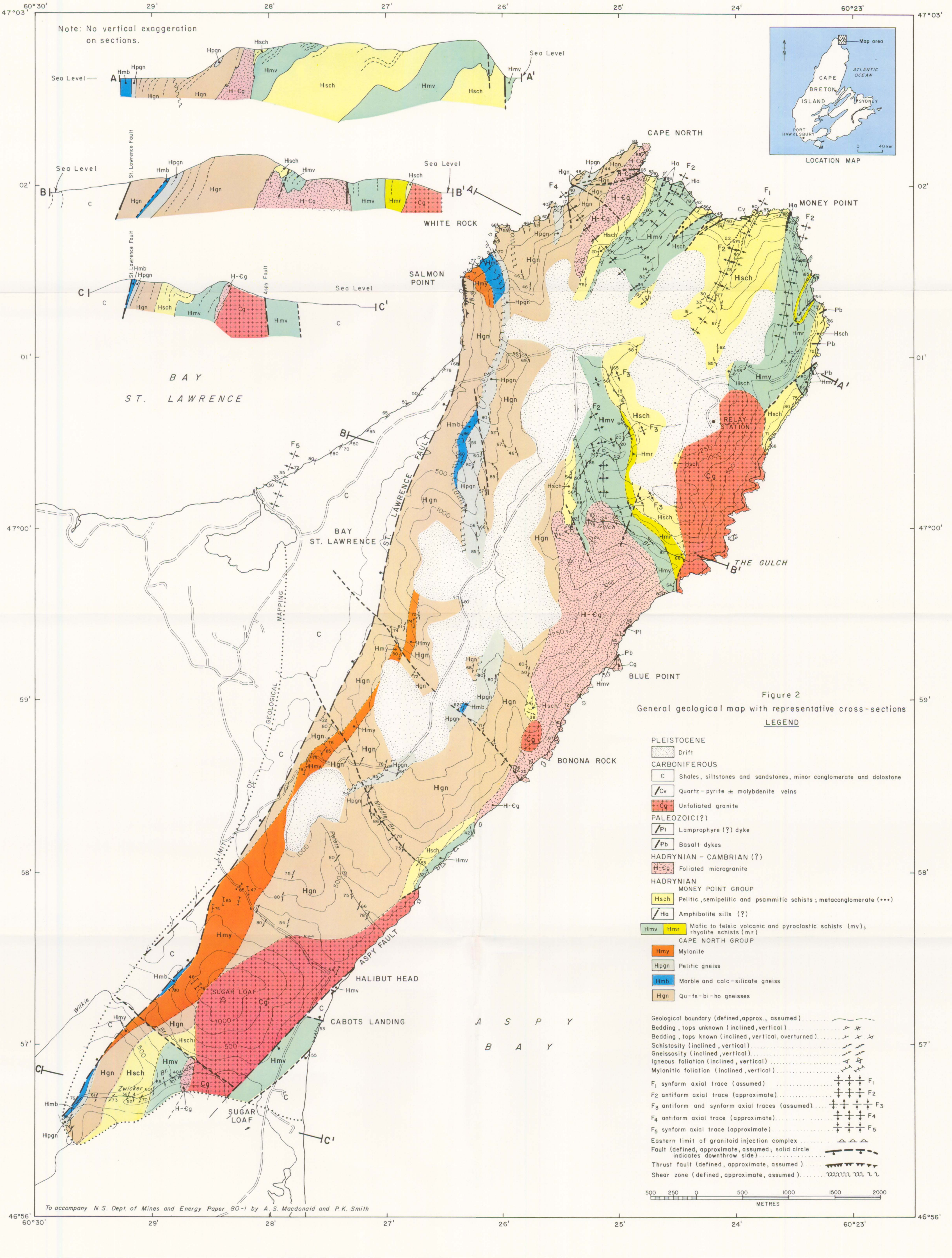

Figure 2
General geological map with representative cross-sections

To accompany N.S. Dept. of Mines and Energy Paper 80-1 by A. S. Macdonald and P. K. Smith

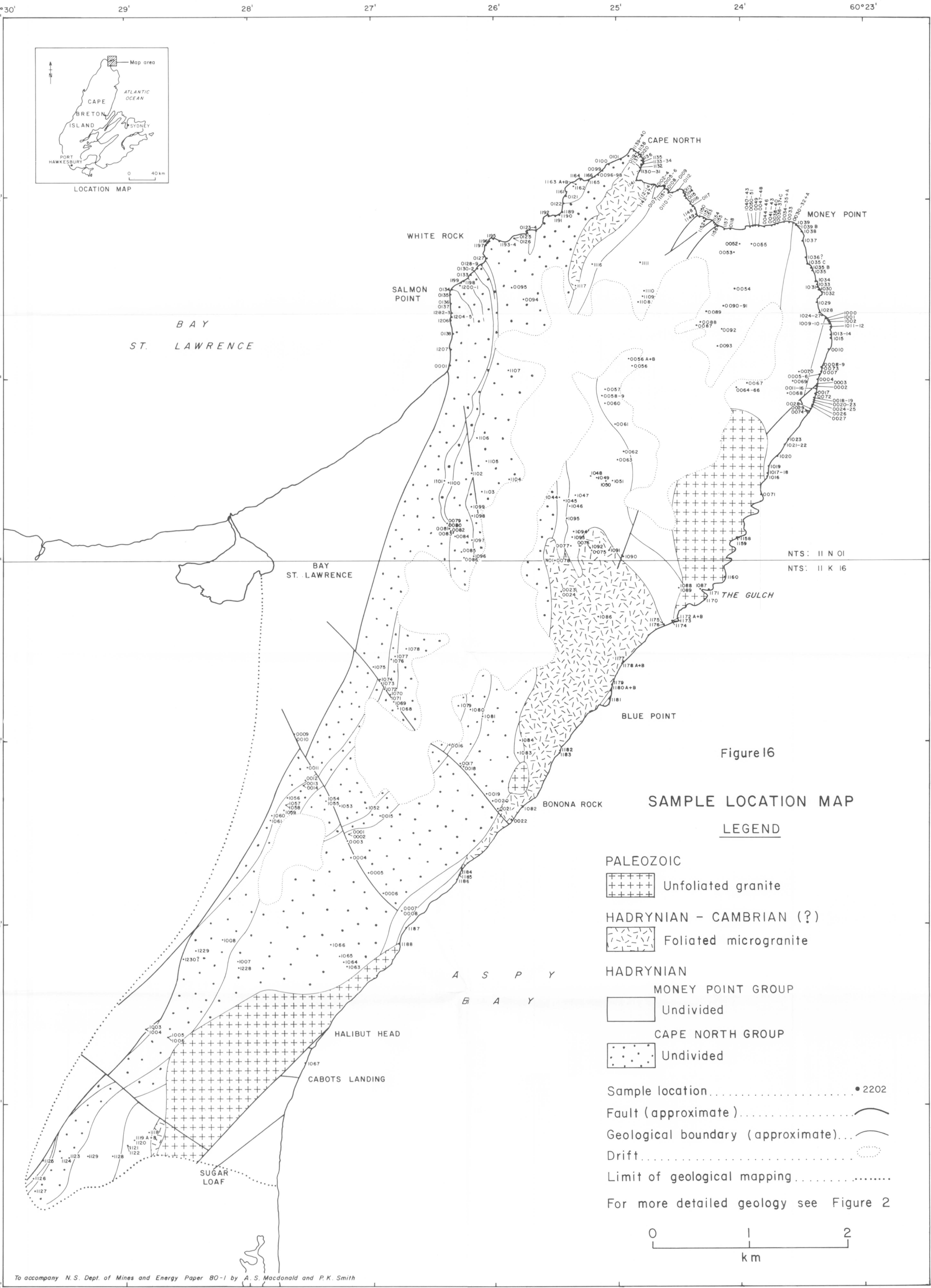

Figure 16

SAMPLE LOCATION MAP

To accompany N.S. Dept. of Mines and Energy Paper 80-1 by A.S. Macdonald and P.K. Smith