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# RELATIONSHIPS OF PHYLLITE, SCHIST AND GNEISS IN THE LA POILE BAY–ROTI BAY AREA (PARTS OF 11O/9 AND 11O/16), SOUTHWESTERN NEWFOUNDLAND

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## ABSTRACT

*Two regional fault lineaments in southwestern Newfoundland, the Bay d'Est and Grand Bruit fault zones, control much of the tectonic development of the La Poile Bay–Roti Bay map area. Thrust bounded and stacked regionally from bottom to top are: 1) amphibolite-facies, metasedimentary and metavolcanic schist of the Ordovician Bay du Nord Group, 2) greenschist-facies, metavolcanic and metasedimentary phyllite of the Silurian La Poile Group and 3) amphibolite-facies, psammitic and amphibolitic gneiss of the Ordovician or earlier Cinq Cerf gneiss.*

*The Silurian Georges Brook Formation of the La Poile Group is locally separated into twenty members that comprise six major lithofacies typical of middle Paleozoic, felsic volcanic centres elsewhere in western Newfoundland. A protracted history of brittle-ductile, early Acadian faulting is indicated by inhomogeneous, polyphase deformation of Silurian strata and syntectonic emplacement of Silurian hypabyssal intrusions and sheet-like plutons. Nevertheless, pre-Silurian isotopic ages of postgneissification plutonic rocks near Grand Bruit and 'younger-over-older' thrust relationships near Bay d'Est suggest that Acadian contraction faults were situated on highly irregular surfaces of unconformity, syndepositional extension faults or exhumed thrust faults. These ancestral features are largely destroyed, but they may have originally separated autochthonous Silurian deposits from older metamorphic rocks represented by the Cing Cerf gneiss and the Bay du Nord schist.*

*The present geometry of the metamorphic rocks in the thrust sheets resulted partly from early Acadian, step-shaped contraction faults, distinguished by bedding-parallel and foliation-parallel 'flats' and 'ramps', and partly from later Acadian, localized upright folds, possibly related to gravity-driven tectonomagmatic domes. The early thrusting produced large variations in regional strain, manifested itself in both recumbent and upright zones of simply folded and mylonitized rocks and was governed by a horizontal, compressive, maximum principal stress. The later doming caused a contrasting type of heterogeneous deformation, in which the original hanging walls of thrusts are displaced downdip on the steep flanks of domal structures. There, thrust-related mylonite zones undergo ductile extension faulting associated with diapiric uplift, tectonic unroofing of metamorphic rocks and contemporaneous emplacement of syntectonic sheet intrusions.*

*From the perspective of the regional geology, gold mineralization and related alteration are most likely produced by synmetamorphic, synplutonic fluids channelled through conduits in the brittle-ductile fault zones.*

## INTRODUCTION

The La Poile Bay–Roti Bay map area is situated between Port aux Basques and Burgeo on the southwest coast of insular Newfoundland (Figure 1). The map area is not serviced by roads and access is either by air or by sea.

During the 1987 field season, a geological mapping program was implemented that emphasized subdivision of the Silurian volcanic and sedimentary rocks of the Georges Brook Formation of the La Poile Group. This stratigraphic unit is host to the Hope Brook gold mine and to numerous other economic mineral occurrences. Other aims were to establish the structural relationships of the La Poile Group to the Ordovician Bay du Nord Group and the Ordovician or older Cinq Cerf gneiss, and to also determine the relationships that all three units have with granitoid and gabbroic rocks.

To the east, the La Poile Bay–Roti Bay map area joins the previously surveyed Grand Bruit–Cinq Cerf map area (Figure 1; O'Brien, 1987). As a result of work carried out in the past field season, the type area of the La Poile Group is now systematically mapped at 1:20,000 scale. Smaller-scale maps of the surrounding region were produced by Cooper (1954) and Chorlton (1978, 1980).

## REGIONAL GEOLOGICAL SETTING

The most prominent feature of any simplified geological map of southwestern Newfoundland (e.g., Figure 2) is the

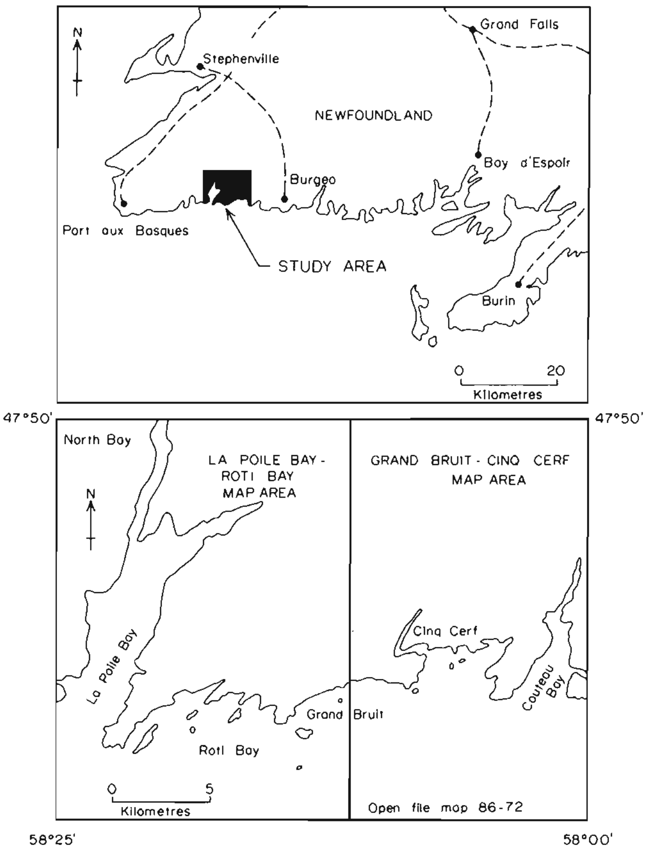


**Figure 1.** *Latitude, longitudes and relative position of the La Poile Bay–Roti Bay and the Grand Bruit–Cinq Cerf map areas in southwestern Newfoundland.*

presence of a series of major brittle–ductile faults, namely, the Long Range Fault (Hayes and Johnson, 1938), the Cape Ray Fault (Brown, 1973), the Bay d'Est Fault (Cooper, 1954) and the Grand Bruit Fault (Chorlton, 1978). These faults bound geological terranes, each of which contrast in metamorphic grade, structural style and stratigraphic framework. North of Port aux Basques, the Long Range Fault delimits the southeastern extent of relatively unmetamorphosed Paleozoic rocks. The terrane between the Long Range and Cape Ray faults is interpreted as relics of highly metamorphosed and dismembered ophiolites that are tectonically interleaved with Grenvillian basement in a belt of Precambrian and Paleozoic gneiss (Brown, 1976; Dunning and Chorlton, 1985; van Berkel, 1987). Farther southeast, the Cape Ray Fault locally coincides with the northwest boundary of a belt of Paleozoic gneiss and schist, probably formed from Ordovician sedimentary and volcanic rocks and typical of those in the Appalachian Gander Zone (Dunning *et al.*, *in press;* O'Neill and Strong, 1988; Figure 2). In the study area, the Bay d'Est Fault juxtaposes Paleozoic phyllite against Paleozoic schist, whereas the Grand Bruit Fault separates gneiss of uncertain age from Paleozoic phyllite (Figure 2). The Lower Ordovician Bay du Nord Group (S. O'Brien *et al.*, 1986) is the local protolith of the Paleozoic schist terrane, whereas Paleozoic phyllite is confined to the outcrop area of the La Poile Group, recently dated by zircon geochronology as Late Silurian (Dunning *et al.*, *in press).* The southeasternmost terrane of questionable Paleozoic or Precambrian gneiss is composed of amphibolitic and metasedimentary migmatite, which is locally undated and referred to as the Cinq Cerf gneiss. Regional faults having both horizontal and vertical displacements tectonically bound Bay du Nord schist, La Poile phyllite and Cinq Cerf gneiss (Figure 2).

## GEOLOGY OF THE LA POILE BAY–ROTI BAY AREA

### Introduction

The La Poile Bay–Roti Bay area is underlain by three groups of metasedimentary and metavolcanic rocks, and six map units of intrusive rocks (Figure 3). In order of decreasing abundance, the nonintrusive rocks are: 1) lower greenschist-facies, metavolcanic and metasedimentary rocks of the Silurian La Poile Group, 2) lower to upper amphibolite-facies, metasedimentary and metavolcanic rocks of the Ordovician Bay du Nord Group, and 3) upper-amphibolite facies, migmatitic, amphibolite gneiss, paragneiss and schist of the Ordovician or older Cinq Cerf gneiss. The six map units of intrusive rocks, listed from oldest to youngest, are: 1) the Cambro-Ordovician Roti Granite (Dunning *et al.*, *in press*), 2) the Ordovician-Silurian(?) Western Head granite, 3) the Ernie Pond gabbro (probably Silurian), 4) the Silurian La Poile granite (Chorlton and Dallmeyer, 1986), 5) the Otter Point granite (probably Silurian) and 6) the Silurian Hawks Nest Pond porphyry (Chorlton and Dallmeyer, 1986).

Episodes of regional deformation that are common to all of these map units occurred during and after the juxtapositioning of the three groups of metasedimentary and metavolcanic rocks, as well as during and after the emplacement of the intrusive rocks. For at least part of the deformation history, progressive dynamothermal metamorphism of La Poile phyllite occurred simultaneously with retrogressive dynamothermal metamorphism of Bay du Nord schist and Cinq Cerf gneiss. Plutonism in the La Poile Bay–Roti Bay area occurred as phyllitic, schistose and gneissic host rocks were being metamorphosed at greenschist-facies conditions.

### Metasedimentary and Metavolcanic Rocks

*Cinq Cerf Gneiss.* The Ordovician or older Cinq Cerf gneiss (CCG) outcrops as small enclaves in the Grand Bruit Fault Zone on the coast and offshore islands of the La Poile Bay–Roti Bay area (Figure 3). It is mostly composed of migmatitic, amphibolite gneiss and psammitic paragneiss, as well as abundant hornblendite and metagabbro.

Within the map area, metasedimentary and metavolcanic rocks of the Cinq Cerf gneiss are lithologically distinct from those of the Bay du Nord and La Poile groups. Furthermore, Bay du Nord and La Poile metasedimentary rocks locally contain large fragments of amphibolitized gabbro that were foliated prior to their incorporation as clasts. Assuming that the Cinq Cerf gneiss was the source of foliated metagabbro,

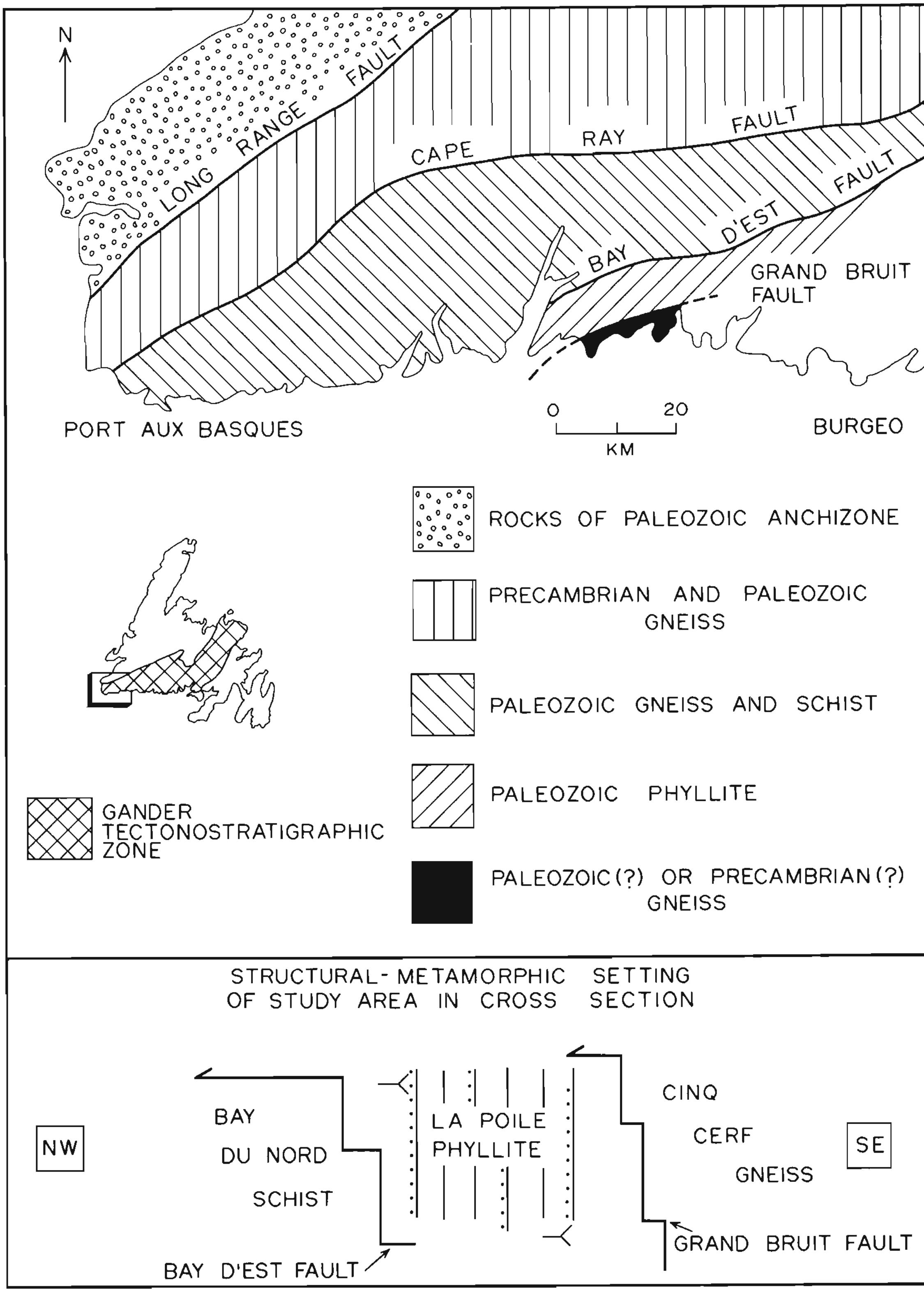


**Figure 2.** *Simplified tectonic map of southwestern Newfoundland. Inset depicts the regional, structural and metamorphic setting of the study area. Arrows indicate stratigraphical facing directions.*

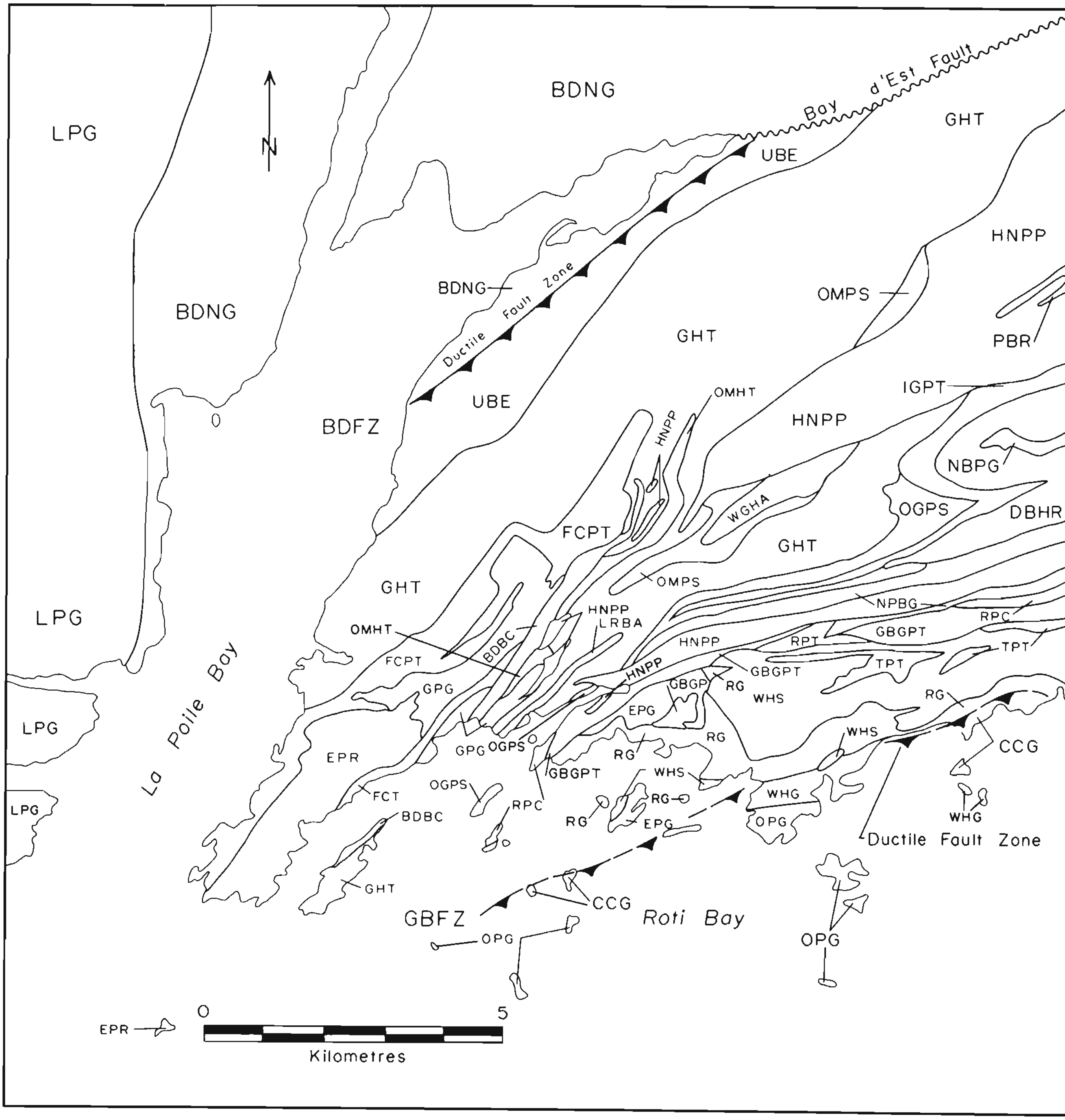


**Figure 3.** *Geological map of the La Poile Bay–Roti Bay area, southwestern Newfoundland. Barbs on ductile faults indicate the regional dip direction of the Bay d'Est Fault Zone (BDFZ) and the Grand Bruit Fault Zone (GBFZ). See legend for explanation of other abbreviations.*

these observations might suggest that it is the oldest rock in the region. Along strike, however, east of the map area in the Grey River enclave, amphibolitic gneiss, paragneiss and orthogneiss similar to the Cinq Cerf gneiss are stated to comprise part of the Bay du Nord Group (Blackwood, 1985). If this inference is correct, then the age of migmatization of the Grey River gneiss is post-Early Ordovician and probably Silurian like the Port aux Basques gneiss to the west and the Little Passage Gneiss farther east (Dunning *et al.*, *in press*).

Although the Cinq Cerf gneiss has been strongly deformed, metamorphosed and intruded by granitoids during the Acadian Orogeny, it was probably already gneissic prior to being thrust over the La Poile Group, and is accordingly designated as Ordovician or earlier in age.

*Bay du Nord Group.* In the La Poile Bay–Roti Bay area, the Ordovician Bay du Nord Group (BDNG) comprises metasedimentary and less common metavolcanic rocks that

## LEGEND

### SILURIAN

#### La Poile Group

| | | | |
|---|---|---|---|
| DBHR | PBR | GBGPT | IGPT |
| WGHA | OMHT | FCT | FCPT |
| RPT | NPBG | GPS | WHS |
| OGPS | OMPS | BDBC | TPT |
| EPR | LRBA | GHT | RPC |

Georges Brook Formation: metavolcanic and metasedimentary phyllite; descriptions of these members are shown in Figure 4

UBE — Georges Brook Formation: unseparated; mostly lithofacies B and E

### ORDOVICIAN

#### Bay du Nord Group

BDNG — unseparated metavolcanic and metasedimentary schist

### ORDOVICIAN OR OLDER

#### Cinq Cerf gneiss

CCG — paragneiss and schist; amphibolite gneiss

#### Plutonic Rocks

HNPP — Hawks Nest Pond porphyry: biotite, quartz–feldspar porphyry

OPG — Otter Point granite: biotite, potassium feldspar-megacrystic granite

LPG — La Poile granite: biotite, potassium feldspar-megacrystic granite

EPG — Ernie Pond gabbro: hornblende-bearing gabbro and diorite; minor pyroxenite

WHG — Western Head granite: biotite–hornblende granodiorite

RG — Roti Granite: blue-quartz-bearing tonalite and granite

are undifferentiated in Figure 3. Metasedimentary and metavolcanic formations of the Bay du Nord Group in the Grand Bruit–Cinq Cerf area illustrate complex map patterns (Cooper, 1954; Chorlton, 1978, 1980) that are produced by the interference of early recumbent and later upright folds (O'Brien, 1987). In the La Poile Bay–Roti Bay map area, however, Bay du Nord Group schist generally dips steeply toward the southeast, except locally near the Bay d'Est Fault Zone, where it dips gently to the southeast beneath the La Poile Group. Despite amphibolite-facies metamorphism, sedimentary and volcanic strata in the Bay du Nord Group are generally dissimilar to those in the structurally overlying La Poile Group. Although the regional younging direction of the Bay du Nord Group is unknown, bed tops at several localities face northwest (away from the younger La Poile Group) and graded metasedimentary rocks face structurally downward on a steeply dipping foliation.

*La Poile Group.* The stratigraphical thickness of the generally steeply dipping, northwest-younging, Silurian La Poile Group is estimated to be in the order of five kilometres. Chorlton (1978) grouped all the volcanic and sedimentary strata of the La Poile Group in the Georges Brook Formation. In the La Poile Bay–Roti Bay area, the Georges Brook Formation comprises twenty members, which are shown at 1:100,000 scale in Figure 3. Including the adjacent Grand Bruit–Cinq Cerf area, the Georges Brook Formation is divisible into twenty-four members within its type area. Informal names and lithological field descriptions of each unit are shown in Figure 4, along with the relative stratigraphical position of each member. Siliciclastic rocks dominate in the lower part, lava and epiclastic rocks in the middle part, and crystal tuff in the upper part of the Georges Brook Formation. Lithic tuff and agglomerate occur throughout all parts of the succession.

From Figures 3 and 4 it is evident that most members are discontinuous along their strike and that only the Whittle Hill sandstone (WHS), at the exposed base of the group, and the Gallyboy Harbour tuff (GHT), in the upper part of the group, were originally extensive enough to presently outcrop throughout and beyond the boundaries of the map area.

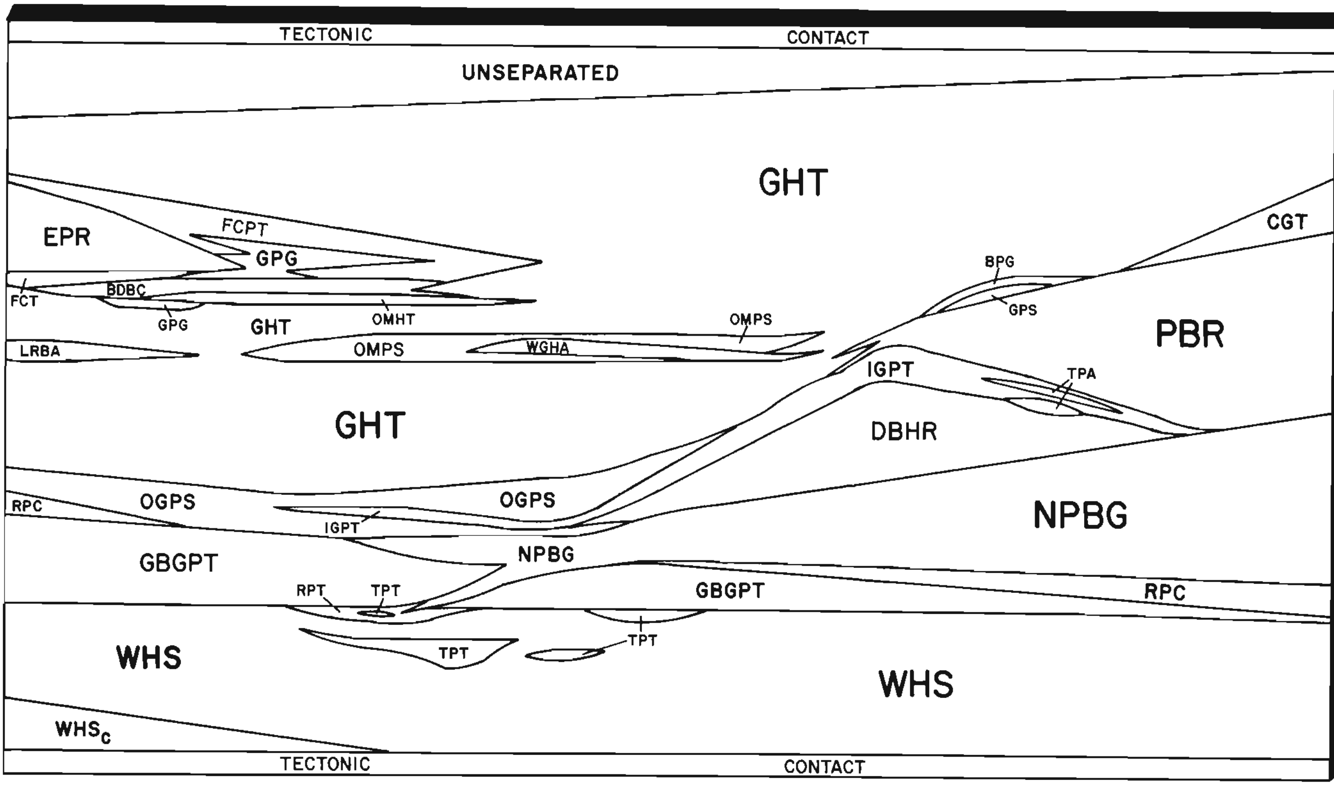


**Figure 4.** *Diagram illustrating the stratigraphical relationships of the twenty-four members of the Georges Brook Formation of the La Poile Group in its type area. Note the relative configuration of members in the La Poile Bay–Roti Bay area and their categorization into six major lithofacies. Note also that this pretectonic reconstruction is not a balanced cross-section and that the shapes of members are approximate or schematic. Lithofacies in accompanying legend are not in stratigraphical order.*

Members of the Georges Brook Formation probably terminate by stratigraphical pinch-out, since facies changes are commonly associated with the resulting wedges and splits. Primary variations in the original form of the members possibly controlled the shape and location of superimposed tectonic folds, e.g., the effect of the Eastern Point rhyolite (EPR). However, map unit terminations bear no set relation to fold geometry, as is exemplified in Figure 3, by the termination of the Inside Gull Pond tuff (IGPT) within the Outside Gull Pond slate (OGPS), or the pinch out of the Outside Gull Pond slate (OGPS) between the Withy Gulch Hill agglomerate (WGHA) and the Inside Gull Pond tuff (IGPT). For the most part, the wavelength and amplitude of the open to close, regional folds are an order of magnitude larger than the depositional strike length and primary thickness of the members. As a result, fold repetition of the Georges Brook Formation is not regionally significant. Nevertheless, due to the effect of primary pinch-out and map unit splitting, northwest-younging volcanosedimentary successions are internally variable and differ in makeup in parallel cross-sections.

Where any one particular member wedges out or is interdigitated with bordering map units, nearby members stratigraphically lower or higher in the succession commonly do likewise (Figure 4). Thus, local facies boundaries separating, for instance, volcanic and sedimentary deposits, persisted in one place for periods of time but then migrated laterally. This is consistent with eruptive centres changing location as deposits accumulated. The relative positions and wedged shapes of the Phillips Brook rhyolite (PBR), Dinner Box Hill rhyolite (DBHR) and Eastern Point rhyolite (EPR) may lend credence to this suggestion (Figures 3 and 4).

In this paper, the term lithofacies is used in the broadest definition of the word. Regionally mappable units comprise distinctive members composed of a plethora of individual rock types. Most members of the Georges Brook Formation can be ascribed to one of six major lithofacies that commonly recur throughout the succession (Figure 4). They are: (A) felsic lava flow, (B) felsic lithic tuff, (C) felsic crystal tuff, (D) epiclastic sediment, (E) quartz-rich clastic sediment and (F) mafic lithic tuff. A rare bed of limestone is locally present between the Guiders Pond grit (GPG) and the Gallyboy Harbour tuff (GHT).

In general, felsic volcanic rocks make up the greatest part of the Georges Brook Formation. In the La Poile Bay–Roti Bay area, volcaniclastic deposits are more voluminous than lava flows. Of the sedimentary rocks, epiclastic grit and wacke are spatially associated with rhyolite lava, whereas quartz-rich sandstone and argillite commonly occur with lithic tuff and felsic agglomerate. The middle part of the Georges Brook Formation contains most of the complexly interfingered lava,

## LEGEND (Figure 4)

### LITHOFACIES (A) : LAVA FLOW

Eastern Point Rhyolite

| EPR | *massive, pink, aphanitic lava; locally welded* |
|---|---|

Dinner Box Hill Rhyolite

| DBHR | *flow-banded and massive, pink, locally phenocrystic lava; rare rhyolite breccia* |
|---|---|

Phillips Brook Rhyolite

| PBR | *massive and finely laminated, cream and pink lava; breccia composed of flow-banded rhyolite* |
|---|---|

### LITHOFACIES (B) : FELSIC LITHIC TUFF

Grand Bruit Gull Pond Tuff

| GBGPT | *fine grained, light green, lithic tuff; red and purple lithic tuff and slate; quartz-pebble conglomerate* |
|---|---|

Inside Gull Pond Tuff

| IGPT | *fine grained, buff-weathered, lithic tuff; local breccia composed of pink rhyolite fragments; welded lithic–crystal tuff* |
|---|---|

Little Roti Bay Agglomerate

| LRBA | *crudely stratified, coarse agglomerate and breccia containing polymictic volcanic blocks; purple lithic tuff* |
|---|---|

Withy Gulch Hill Agglomerate

| WGHA | *agglomerate and breccia composed of massive, flow-banded and flow-folded rhyolite; minor pink and cream rhyolite* |
|---|---|

Old Man Hill Tuff

| OMHT | *buff-weathered, fine grained, lithic tuff composed of pink rhyolite fragments* |
|---|---|

French Cove Tuff

| FCT | *well-stratified, lithic tuff and breccia containing sedimentary and volcanic fragments; minor lithic–crystal tuff* |
|---|---|

Cross Gulch Tuff

| CGT | *lithic tuff composed of a variety of volcanic fragments* |
|---|---|

Flint Cliff Pond Tuff

| FCPT | *buff-weathered lithic tuff; coarse agglomerate composed of massive, pink rhyolite blocks; minor siliciclastic beds and rare lava flows* |
|---|---|

### LITHOFACIES (C) : CRYSTAL TUFF

Gallyboy Harbour Tuff

| GHT | *pink, medium and coarse, locally layered and stratified, quartz–feldspar crystal tuff; rare blocks of volcanic and sedimentary rocks* |
|---|---|

Round Pond Tuff

| RPT | *pink, quartz (± feldspar) crystal tuff* |
|---|---|

### LITHOFACIES (D) : EPICLASTIC SEDIMENT

Northwest Pond Brook Grit

| NPBG | *poorly sorted, grey-brown, massive and stratified, locally graded and crossbedded, quartz-feldspar grit and tuffaceous wacke; rip-up clasts and large blocks of laminated argillite; clasts of metamorphic and plutonic rocks* |
|---|---|

Guiders Pond Grit

| GPG | *poorly sorted, grey-brown, locally stratified, quartz-feldspar grit and tuffaceous wacke; minor boulder conglomerate and olistostrome; rare slate* |
|---|---|

Butterfly Pond Grit

| BPG | *poorly sorted, grey-brown, quartz–feldspar grit and tuffaceous wacke; grey slate* |
|---|---|

### LITHOFACIES (E) : SILICICLASTIC SEDIMENT

Whittle Hill Sandstone

| WHS | *well-bedded, buff-weathered, quartz-rich sandstone; green and grey, laminated argillite; grey slate* |
|---|---|
| $WHS_C$ | *conglomerate subfacies of the Whittle Hill Sandstone; quartz-cobble conglomerate; polymictic cobble conglomerate* |

Roti Point Conglomerate

| RPC | *thick-bedded, polymictic, boulder and cobble conglomerate interstratified with thin-bedded sandstone; local and exotic clasts of volcanic, sedimentary, hypabyssal, plutonic and metamorphic rocks* |
|---|---|

Outside Gull Pond Slate

| OGPS | *grey slate and laminated argillite; rare thin-bedded sandstone* |
|---|---|

Twin Pond Argillite

| TPA | *laminated argillite; minor cobble and boulder, polymictic conglomerate; rare sandstone* |
|---|---|

Georges Pond Slate

| GPS | *grey slate and laminated argillite* |
|---|---|

Old Man Pond Slate

| OMPS | *grey slate and laminated argillite; minor thin-bedded sandstone and lithic tuff* |
|---|---|

Black Duck Brook Conglomerate

| BDBC | *polymictic, cobble and boulder conglomerate; siliciclastic sandstone interbedded with laminated argillite; minor grey slate* |
|---|---|

### LITHOFACIES (F) : MAFIC LITHIC TUFF

Third Pond Tuff

| TPT | *green lithic tuff; minor green agglomerate; rare beds of laminated argillite* |
|---|---|

lithic tuff and epiclastic sediment (e.g., Eastern Point rhyolite–Flint Cliff Pond tuff–Guiders Pond grit or Dinner Box Hill rhyolite–Inside Gull Pond tuff–Northwest Brook Pond grit). These strata were laid down on an extensive floor of mature, continentally derived, quartz-rich sediment (Whittle Hill sandstone) and were capped by a notably thick, homogeneous and laterally continuous deposit of quartz–feldspar crystal tuff (Gallyboy Harbour tuff). Mafic extrusive rocks, found only in the Third Pond tuff (TPT), are volumetrically insignificant, but they represent the earliest volcanic eruption in the La Poile depocentre.

**Syntectonic Intrusive Rocks**

*Roti Granite.* In the map area, the Roti Granite (RG) contains medium grained, blue-quartz-bearing tonalite west of Roti Bay and fine grained, biotite granite east of the bay. Mafic dyke swarms are present in the tonalite and the granite. The relationship between the two bodies is presently unknown but inherited Proterozoic zircons from the tonalite also yield latest Cambrian or earliest Ordovician ages (Dunning *et al., in press).*

Where the boundary of the Roti Granite locally trends northwest, the intrusion transects northeast-trending, gently to steeply plunging, megascopic folds in the Whittle Hill sandstone, which are outlined in part by the contact with the overlying Third Pond tuff. Later, larger-scale, vertically plunging folds, however, are defined by the trace of the intrusive contacts of the granite and the tonalite with the White Hill sandstone (Figure 3). Thus, the Roti Granite was emplaced and locally foliated during the folding of rocks presently included in the Georges Brook Formation.

On the offshore islands (Figure 3), the Roti Granite intrudes rocks as stratigraphically high in the Georges Brook Formation as the Grand Bruit Gull Pond tuff (GBGPT) and, perhaps, the Roti Point conglomerate (RPC). In this part of the map area, the Roti Granite is emplaced into a large, southwest-plunging, periclinal anticline along its northeast-trending, subvertical, fold axial surface (following O'Brien, 1987). In places, the intrusion cuts through the anticline, cored by the Whittle Hill sandstone, and comes in direct intrusive contact with the overlying Grand Bruit Gull Pond tuff in the fold hinge zone. At several localities, the Roti Granite and Silurian mafic dykes within it are themselves deformed by vertically plunging folds or are sheared in vertical mylonite zones.

Hypotheses to reconcile the observed field relationships with the Cambro-Ordovician age of the Roti Granite and the Silurian age of the Georges Brook Formation are discussed in a following section on pre-Silurian basement in the map area.

*Western Head Granite.* In the La Poile Bay–Roti Bay map area, the Western Head granite (WHG) is limited to a small tract of ground near the eastern head of Roti Bay (Figure 3). An Ordovician or Silurian crystallization age is likely, although absolute dates are unavailable. Cooper (1954) originally separated what is here termed the Western Head granite from other granitoids outcropping along the coast. On maps of the area, as well as in a genetic interpretation of the region, Chorlton (1978, 1980) subsequently grouped the Western Head granite with the Cinq Cerf gneiss in the Cinq Cerf complex (see Table 1, O'Brien, 1987). The Western Head granite is a name here proposed to identify the body of biotite–hornblende granodiorite originally mapped by Cooper and to re-exclude it from the older Cinq Cerf gneiss.

In the area mapped, Western Head granite crosscuts Cinq Cerf gneiss on various scales. Enclaves of well-banded gneiss occur in weakly foliated, biotite–hornblende granodiorite. Tectonic contacts of Western Head granite with Whittle Hill sandstone and Roti Granite are located in the Grand Bruit Fault Zone (Figure 3), where all units are highly sheared or mylonitized. In the Grand Bruit–Cinq Cerf area, however, an unfoliated part of the Western Head granite crosscuts penetrative foliation in an Early Cambrian phase (Dunning *et al., in press)* of the Roti Granite, which itself intrudes and includes Cinq Cerf gneiss (O'Brien, 1987). Nevertheless, in some localities, foliated Western Head granite is gradational with hornblende–biotite, leucotonalitic gneiss that comprises part of an amphibolitic agmatite in the Cinq Cerf gneiss. Therefore, it appears that intrusion of the Western Head granite is associated with Ordovician or Silurian agmatization of pre-Early Cambrian gneiss.

*Ernie Pond Gabbro.* The Ernie Pond gabbro (EPG) is best exposed in the La Poile Bay–Roti Bay area, where it consists of hornblende gabbro, diorite and minor pyroxenite. Together, they comprise an ellipsoidal body with a curved elongate tail on the mainland and a smaller, more circular body on the offshore islands (Figure 3). The Ernie Pond gabbro probably belongs to a suite of postophiolite, appinitic, Silurian gabbros in southwestern Newfoundland (van Berkel, 1987; Dunning *et al., in press).*

Part of the mainland body has the apparent shape of an incompletely exposed, subvertical ring dyke. Here, the gabbro–diorite body is largely unfoliated and intrudes variably plunging, open folds in the Grand Bruit Gull Pond tuff and the Whittle Hill sandstone. The margin of the Ernie Pond gabbro crosses the intrusive contact between the Roti Granite and the Grand Bruit Gull Pond tuff (Figure 3). In several localities, particularly within the tail of the intrusive body, the Ernie Pond gabbro carries a penetrative foliation.

Cordierite-bearing hornfels is well developed in the Whittle Hill sandstone where it is intruded by the Ernie Pond gabbro. Northeastward, discontinuous pods of hornfels within the Whittle Hill sandstone indicate the probable subcropping of a series of shallow-level bosses of Ernie Pond gabbro. Porphyroblasts of contact metamorphic origin overgrow an upright foliation but are themselves distorted and locally aligned.

A close spatial relationship exists between the bodies of Ernie Pond gabbro and the mafic dykes previously mentioned in this area and the Grand Bruit–Cinq Cerf map area

(O'Brien, 1987). On the Roti Bay islands, apophyses of Ernie Pond gabbro are chilled against Roti Granite, and gabbro apophyses and granite septae are folded together. The folded Ernie Pond gabbro–Roti Granite intrusive contact is crosscut by foliated mafic dykes. They occupy the vertical axial surfaces of folds of the intrusive contact, yet apparently emanate from the Ernie Pond gabbro. Thus, mafic dyke swarms and gabbro bosses were intruded and deformed during the folding of the Roti Granite, the Whittle Hill sandstone and the Grand Bruit Gull Pond tuff, presumably in the Acadian Orogeny.

*Otter Point Granite.* The Otter Point granite (OPG) is a variably deformed, biotite, potassium feldspar-megacrystic granite that underlies a small part of the coastline and the most seaward of the Roti Bay islands (Figure 3). It intrudes the Western Head granite and locally crosscuts the gneissosity in the Cinq Cerf gneiss. East of the map area, the Otter Point granite is intruded posttectonically by the Lower Devonian Chetwynd Granite (Chorlton and Dallmeyer, 1986). The age of crystallization and intrusion of the Otter Point granite is assumed to be Silurian.

The Otter Point granite is host to mafic dykes like those seen in most of the older map units, although the dykes form swarms near their intrusive contact with the Western Head granite. In the map area, unfoliated mafic dykes crosscut a penetrative foliation in the Otter Point granite. However, in the Grand Bruit–Cinq Cerf area, pegmatitic and aplitic phases of the Otter Point granite intruded the main megacrystic phase, the mafic dykes and the Western Head granite at the time these host rocks were being folded and foliated. Intrusion and deformation of the Otter Point granite overlapped the intrusion and deformation of the mafic dyke swarms in the Grand Bruit Fault Zone.

*La Poile Granite.* The La Poile granite (LPG) is a variably deformed, biotite, potassium feldspar-megacrystic granite that trends northerly and dips subvertically in the La Poile Bay–Roti Bay area (Figure 3). Cooper (1954) believed that it extended offshore and was probably contiguous with the northeast-trending Otter Point granite. In the map area, however, the La Poile granite is only seen in contact with the Bay du Nord Group.

The La Poile granite intrudes and discordantly truncates Bay du Nord schist striking northeast and dipping steeply southeast. Fine grained apophyses of leucogranite, grading from unfoliated or weakly foliated parts of the La Poile granite, crosscut host metasedimentary rocks containing subvertical, downward-facing, folds and foliations. However, in these same exposures, leucogranite apophyses are openly folded by upright folds, which developed on a larger scale and at a slightly later time than those affecting the schists. This implies that the La Poile granite was emplaced during the late upright folding of the Bay du Nord Group.

*Hawks Nest Pond Porphyry.* One major and several satellite bodies of Hawks Nest Pond porphyry (HNPP) occur in the La Poile Bay–Roti Bay area (Figure 3). Biotite-bearing, quartz–feldspar porphyry is the dominant rock type, although different textural varieties are found in most of these bodies. Distinctive green feldspars are saussuritized; secondary pyrite, white mica, and iron carbonate are common where the porphyry is highly altered. Chorlton and Dallmeyer (1986) reported a Silurian age for the crystallization of the Hawks Nest Pond porphyry.

All bodies of Hawks Nest Pond porphyry trend northeast, dip subvertically and intrude the Georges Brook Formation (Figure 3). Those emplaced into the limbs of regional folds (e.g., the body locally separating the Grand Bruit Gull Pond tuff (GBGPT) and the Northwest Pond Brook grit (NPBG) are sills, whereas those emplaced through the hinge zones of regional folds (e.g., the large body intruding the Inside Gull Pond tuff (IGPT), the Gallyboy Harbour tuff (GHT), the Old Man Pond slate (OMPS) and the Withy Gulch Hill agglomerate (WGHA) are dykes. The Hawks Nest Pond porphyry transects map-scale folds in the Georges Brook Formation, has xenoliths showing disoriented intersections of cleavage and bedding, and is itself locally folded and foliated. In the map area, intrusion of the Hawks Nest Pond porphyry occurred during upright Acadian folding of the La Poile Group.

*Intrusive Felsites.* Folded and locally foliated intrusive bodies of aphanitic rhyolite or rhyolite porphyry occur in the Grand Bruit Fault Zone and areas to the northwest. These felsites are not mappable at the 1:100,000 scale of Figure 3 but some can be accurately shown on larger-scale maps. The largest body intrudes the Grand Bruit Gull Pond tuff and the Roti Point conglomerate; smaller dykes intrude the Whittle Hill sandstone and the Roti Granite. The intrusive felsites partially overlap the emplacement of the mafic dyke swarms.

## PROBLEM OF THE PRE-SILURIAN BASEMENT

Because the Grand Bruit Fault Zone has been invaded by copious amounts of magma (O'Brien, 1987), migmatite of the Cinq Cerf gneiss, schist of the Bay du Nord Group and phyllite of the La Poile Group are never seen in direct contact with each other. Greenschist-facies deformation common to all rock types is associated with the syntectonic emplacement of Silurian sheet intrusions. However, magmas of Cambrian, Ordovician and Silurian age (Dunning *et al.*, *in press*) intruded and included gneiss, schist and phyllite in close proximity to each other in the Grand Bruit Fault Zone. These data, and the evidence of locally derived granitoid clasts with a preincorporation foliation in the Bay du Nord and La Poile groups, imply that one or more of the following hypotheses are likely. First, some or all of the migmatitic rocks included in the Cinq Cerf gneiss are pre-Silurian (possibly Precambrian) and that they cannot have their protoliths in either the Bay du Nord Group or the La Poile Group. This is in direct contrast to suggestions made for the central part of the Hermitage Flexure (following S. O'Brien *et al.*, 1986). Second, some phyllitic rocks presently included in the basal part of the Georges Brook Formation are pre-Silurian and, therefore, should be excluded from the La Poile

Group and perhaps be reassigned to either the Bay du Nord Group or the Cinq Cerf gneiss (following Cooper, 1954). Third, some plutons yielding Early Cambrian and Late Cambrian–Early Ordovician zircon ages may have crystallized from magma at that time (Dunning *et al., in press)*. However, this does not preclude reintrusion of the plutons into the Georges Brook Formation cover as the basement of pre-Silurian gneiss and schist was remobilized in the Acadian Orogeny. Finally, some intrusive map units may contain unseparated Silurian and Cambro-Ordovician plutons. As a result, they may locally display field relationships that apparently contradict those observed for the same intrusive unit in other map areas (S. O'Brien, personal communication, 1987) or that appear to be unreconcilable with absolute ages of minerals from other parts of the intrusive unit (O'Brien, 1987). At this stage of the research on the map area, it is difficult to evaluate the relative likelihood of any of these possibilities.

## STRUCTURAL GEOLOGY

The structure of the Cinq Cerf gneiss, the Bay du Nord Group and the La Poile Group has been previously discussed by Chorlton (1978, 1980), Chorlton and Dallmeyer (1986) and O'Brien (1987). Major and minor structures similar to those described in the Grand Bruit–Cinq Cerf map area (O'Brien, 1987) extend into and occur throughout the La Poile Bay–Roti Bay map area.

### An Overview

The major structural features of the metasedimentary and metavolcanic rocks, and the gabbroic to granitic intrusions to which they are host, are summarized in Figure 5. Amphibolite-facies schist and gneiss occur in flat-lying Bay du Nord Group and steeply inclined Cinq Cerf gneiss, respectively, southeast of the Grand Bruit Fault Zone. During amphibolite-facies deformation ($D_{1a}$), a schistose or gneissic foliation ($S_{1a}$) developed parallel to primary layering. This foliation is now concordant with the 'flat' and 'ramp' portion of the Grand Bruit thrust. Within the hanging wall sequence, the unexposed schist–gneiss contact (question mark in Figure 5) could be either a thrust parallel to the Grand Bruit structure or a gradational metamorphic boundary (following Blackwood, 1985). In the Bay du Nord Group northwest of the Bay d'Est Fault Zone, flat-lying and steeply inclined, bedding–parallel, $S_{1a}$ schistosity is present beneath thrust-related, greenschist-facies mylonites (Figure 5). Post-$D_{1a}$ structures in the Cinq Cerf gneiss and the Bay du Nord Group probably formed during greenschist-facies deformation of the La Poile Group, which by then intervened as a thrust sheet between the northwestern and southeastern belts of amphibolite-facies rocks (Figure 5).

Three superposed episodes of regional deformation ($D_{1g}$, $D_{2g}$ and $D_{3g}$) accompanied chlorite-grade, dynamothermal metamorphism of the La Poile Group (O'Brien, 1987). Phyllitic cleavages and folds related to the $D_{1g}$ and $D_{2g}$ deformations are coaxial and locally coplanar; $D_{3g}$ structures are invariably noncoaxial.

The regional $S_{1g}$ slaty cleavage is axial planar to both gently plunging, upright periclinal folds and subrecumbent asymmetrical folds (Figure 5). Above and below the 'flats' of the major thrust faults, the openly folded, right-way-up, generally northwest-younging strata of the La Poile Group were inverted as the regional $D_{1g}$ strain increased and minor $F_{1g}$ subrecumbent folds and gently dipping $S_{1g}$ mylonites developed. The transition from upright to recumbent structures produced Pyrennean-type, half-fans of cleavage and bedding on regional and local scales. Near the 'ramps' of the thrusts, vertical slaty cleavage is axial planar in tight, generally steeply plunging periclines, which are commonly seen on at least three orders of magnitude. With increasing $D_{1g}$ strain, minor $F_{1g}$ folds become isoclinal and neutral as fold axes rotate into the vertical extension direction of ramp-parallel belts of $S_{1a}$ mylonite.

The regional $S_{2g}$ crenulation cleavage is variably penetrative and, where well developed, is spatially associated with faults or intrusions. The invariably upright $F_{2g}$ folds formed after the thrusts had acquired their 'stepped' shape and after the $S_{1g}$ slaty cleavage was fanned into 'one-sided' flower structures. Therefore, near thrust 'flats', gently plunging $F_{2g}$ folds coaxially overprint $F_{1g}$ subrecumbent folds, and vertical $S_{2g}$ cleavage crenulates gently dipping $S_{1g}$ slaty cleavage. In contrast, near thrust 'ramps', vertically plunging $F_{2g}$ and $F_{1g}$ folds are coaxial, and upright $S_{2g}$ and $S_{1g}$ cleavages are coplanar. With increasing $D_{2g}$ strain, concordant intrusions within the ramp-parallel, $D_{1g}$ mylonite belts are themselves mylonitized. In the oldest intrusions, the $D_{2g}$ extension direction accompanying protoclastic deformation is vertical. Assuming that the regionally consistent vergence of the $F_{2g}$ folds is meaningful, the southeast side or original hanging walls of the thrusts were offset downward by ductile $D_{2g}$ faulting (O'Brien, 1987). The youngest mylonitic intrusion in the Grand Bruit Fault Zone is affected by dextral strike-slip movements.

Sheet intrusions of variable size, texture, composition and age were emplaced along $F_{1g}$-fold axial surfaces and $S_{1g}$ slaty cleavage and, as a result, the majority of intrusive bodies dip vertically rather than horizontally (Figure 5). $F_{2g}$ folds of La Poile Group country rocks commonly deform the margins of post-$F_{1g}$ intrusions. In vertical bodies, the primary steep foliation produced near the walls of the intrusions is parallel to the $S_{2g}$ crenulation cleavage in the host rocks. In subhorizontal bodies, $S_{2g}$ cleavage is subperpendicular to the wall of the intrusion and gently plunging, $F_{2g}$ upright folds crenulate the concordant primary foliation. These structures are, however, coplanar with vertical offshoots emanating from the flat-lying sheets (Figure 5). Between faults and away from intrusions, $D_{1g}$ structures are not affected by $D_{2g}$ deformation.

The noncoaxial $D_{3g}$ deformation produced $F_{3g}$ cross-folds and locally developed $S_{3g}$ crenulation cleavage. Such structures overprint a variety of $D_{1a}$, $D_{1g}$ and $D_{2g}$ features and are present in most map units. Steeply plunging $F_{3g}$ minor folds are related to open, Z-shaped flexures of map units, and presumably result from strike-parallel shortening.

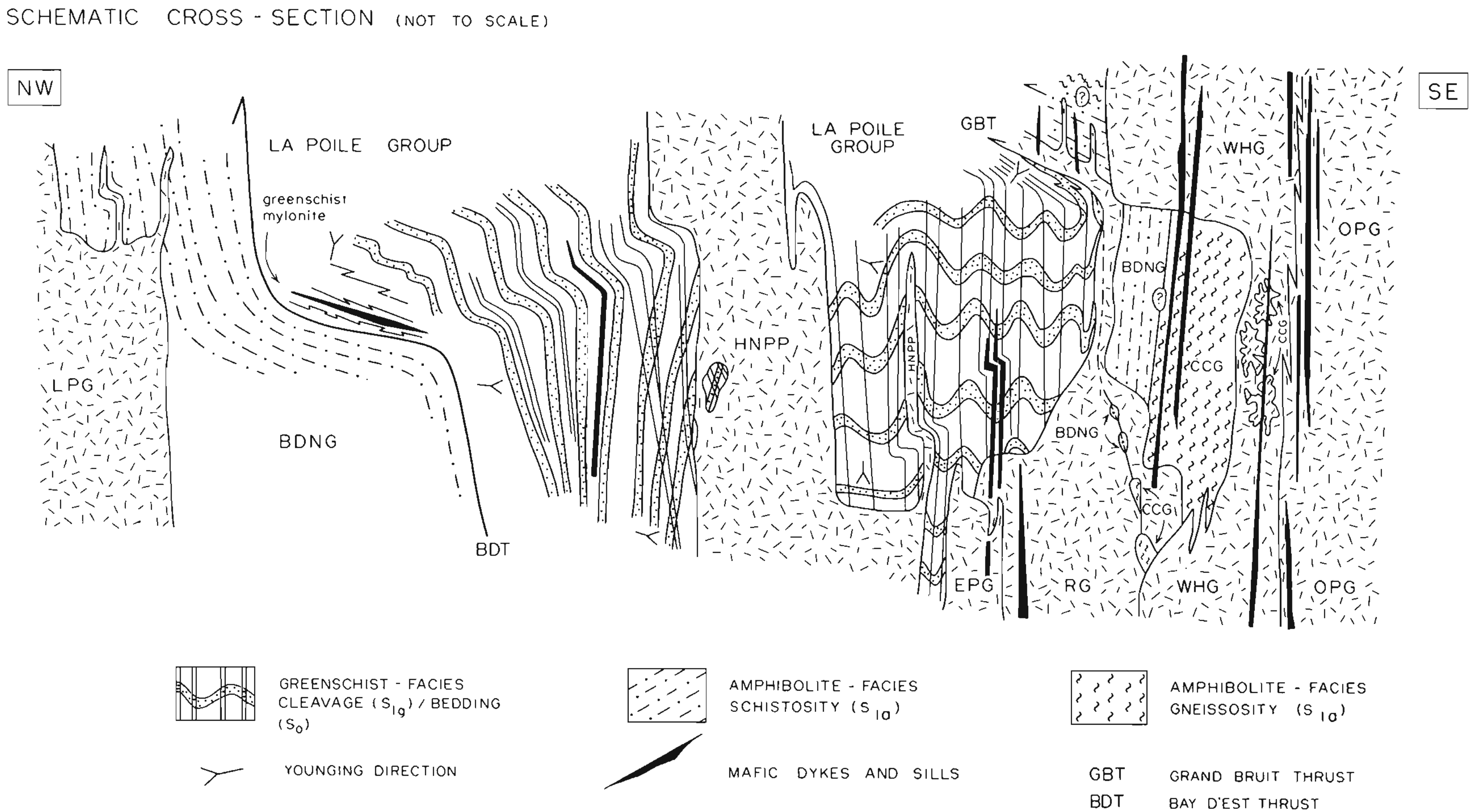


**Figure 5.** *Simplified, regional, vertical cross-section illustrating the structural, metamorphic and intrusive relationships (observed and inferred) of map units in the La Poile Bay–Roti Bay–Grand Bruit–Cinq Cerf area.*

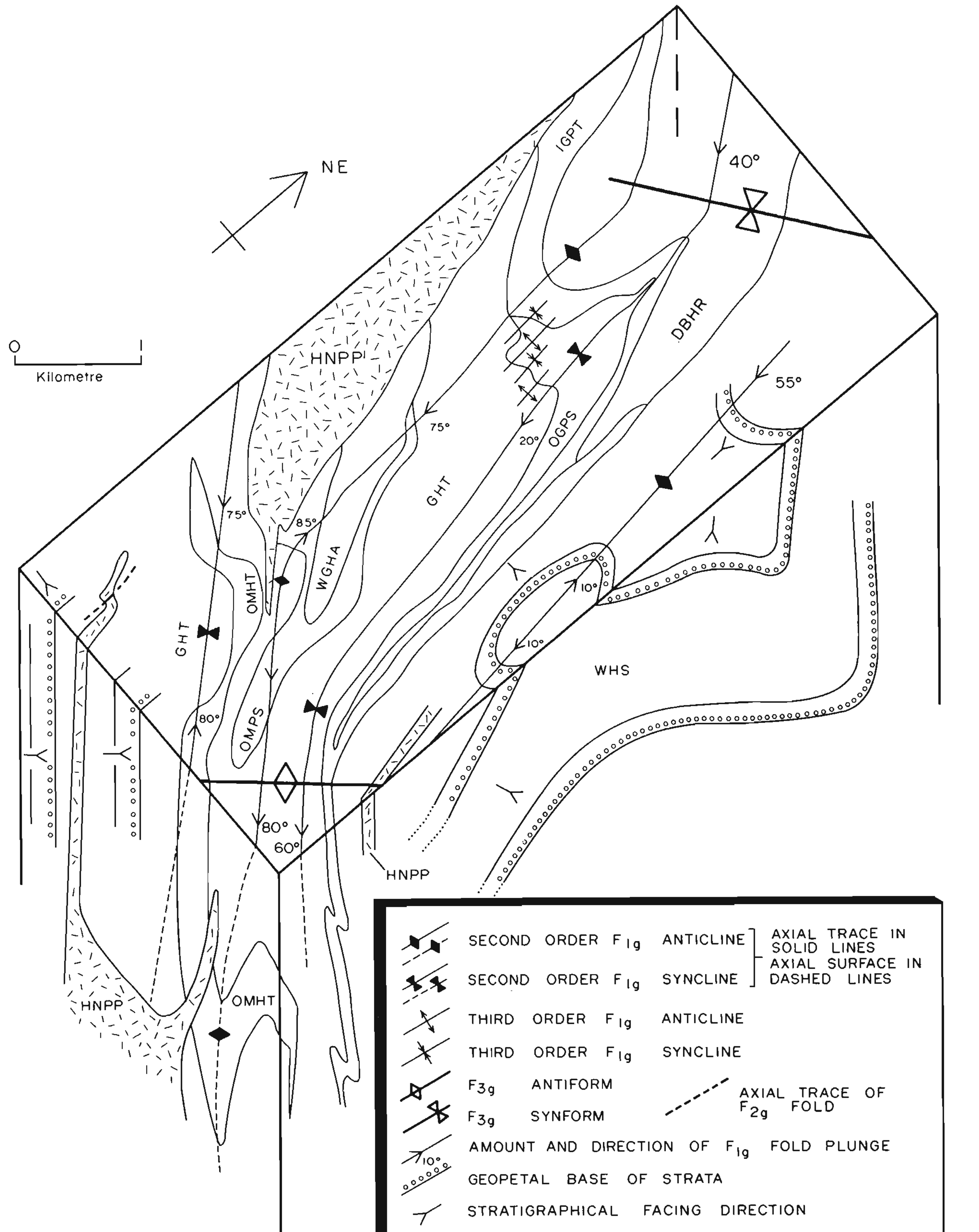


**Figure 6.** *Block diagram illustrating the typical structure of the La Poile Group throughout most of the La Poile Bay–Roti Bay map area. Note the post-$F_{1g}$, pre-$F_{2g}$ age of the intrusion and the relation of map unit terminations to the $F_{1g}$ folds. See legend to Figure 3 for explanation of abbreviations.*

## STRUCTURE OF THE MAP AREA

In the La Poile Bay–Roti Bay map area, the discontinuously exposed Cinq Cerf gneiss marks the trace of the Grand Bruit Fault Zone. Small, lenticular, partly digested enclaves of gneiss containing subvertical $S_{1a}$ foliation occur in mylonitized parts of the Western Head and Otter Point granites. Tight to isoclinal, vertically plunging $F_{2g}$ folds of foliated mafic dykes and $S_{1a}$ gneissosity are commonly observed.

The Bay du Nord Group has been affected by the regional $D_{1a}$, $D_{2g}$ and $D_{3g}$ deformations in the La Poile Bay–Roti Bay area. Bedding-parallel $S_{1a}$ schistosity and $L_{1a}$ lineation dip and plunge steeply to the southeast and are overprinted by a variably penetrative, upright, locally downward-facing, $S_{2g}$ crenulation cleavage. The $S_{2g}$ foliation is axial to minor $F_{2g}$ folds that illustrate vergence consistent with that of $F_{2g}$ folds in the La Poile Group and Cinq Cerf gneiss. Regional $F_{2g}$ fold vergence is toward a synform lying southeast of the map area (O'Brien, 1987). White micas of metamorphic origin grew syn- to post-kinematically with respect to the $S_{2g}$ crenulation cleavage. In zones where the $D_{2g}$ strain is large, grain-size reduction of the relatively coarse grained minerals of the $S_{1a}$ schistosity accompanied $S_{2g}$ foliation development. In $D_{2g}$ mylonite zones porphyroclasts of coarse grained, polymineralic aggregates, representing relics of the climactic $S_{1a}$ assemblage, sit in a fine grained, sericite–quartz matrix. West-northwest-trending $F_{3g}$ minor folds and axial-planar, $S_{3g}$ crenulation cleavage overprint northeast-trending $S_{1a}$ and $S_{2g}$ foliations.

In the La Poile Bay–Roti Bay area, excellent examples of superimposed $D_{1g}$, $D_{2g}$ and $D_{3g}$ structures are present in the Georges Brook Formation. The second-order $F_{1g}$ folds depicted in Figure 6 are developed parasitically on the right-way-up, southeast limb of a first-order, regional fold called the La Poile Syncline (Cooper, 1954). The northwest limb of this fold is not found in the type area of the La Poile Group. Since it is unlikely that southeast-younging rocks are everywhere concealed within mylonites of the Bay d'Est Fault Zone (Figure 3), the La Poile Group is believed to be inverted where it overlies gently southeast-dipping schist of the Bay du Nord Group (Figures 5 and 6).

Away from the 'flats' of the northwest-directed $D_{1g}$ thrusts, all members, intrusions and major structures in the northwest-facing Georges Brook Formation are generally steeply dipping. The structure typical of most of the La Poile Group is illustrated in Figure 6 as a block diagram representing an approximate volume of 55 cubic kilometres. Noteworthy are: 1) variably plunging, second- and third-order $F_{1g}$ periclines that fold discontinuous, originally discoidal members, 2) the upright to steeply inclined, axial surfaces of the $F_{1g}$, $F_{2g}$ and $F_{3g}$ folds, 3) the coaxial relationship between $F_{1g}$ and $F_{2g}$ folds, 4) the post-$F_{1g}$, pre-$F_{2g}$ intrusive age of the Hawks Nest Pond porphyry, and 5) the noncoaxial $F_{3g}$ crossfolds and their relation to the Z-shaped flexures of map units and earlier folds.

## RELATIONSHIP OF $D_{1a}$ AND $D_{1g}$ DEFORMATION

The regional cross-section illustrated in Figure 7 is a simplified representation of the relationship between the Ordovician Bay du Nord Group and the Silurian La Poile Group near the Bay d'Est Fault Zone. The amphibolite-facies $D_{1a}$ and greenschist-facies $D_{1g}$ episodes of regional deformation produced recumbent folds in regionally inverted successions, presently seen above and below the 'flats' of domed thrust faults. Episodes of $D_{1a}$ and $D_{1g}$ deformation predated sheet intrusion, upright folding and extension faulting, and greenschist-facies metamorphism during regional $D_{2g}$ deformation. Although overprinting of $S_{1a}$ gneissosity or schistosity by $S_{2g}$ crenulation cleavage is associated with grain-size reduction and retrogression, $S_{1a}$ and $S_{1g}$ foliations are not observed in direct contact. Two possible relationships, however, are outlined below.

First, belts of thrust-related mylonite commonly separate map units of metavolcanic and metasedimentary rocks carrying either $S_{1a}$ or $S_{1g}$ foliation. Although the depositional ages of nonintrusive units may vary across thrusts, the Silurian or later metamorphic age of $S_{1a}$ and $S_{1g}$ foliation may be similar. Assuming that horizontal Acadian isograds were ductilely displaced by Acadian thrust faults, belts of mylonite should contain a series of concordant, very closely spaced, isograd surfaces. In the Grand Bruit Fault Zone, where upper-amphibolite-facies rocks are separated from lower-greenschist-facies rocks by as little as 10 m of mylonite, a notably steep, inverted, Acadian metamorphic gradient is required to produce parallel $S_{1a}$ and $S_{1g}$ foliations. The lack of evidence of heat transfer between low-grade and high-grade thrust sheets presumably implies that insufficient time was available to permit re-equilibriation prior to cooling. However, in the Bay d'Est Fault Zone, where 'cold' greenschist-facies rocks overthrust 'hot' amphibolite-facies rocks, such explanations are unlikely (Figure 7).

A second possible relationship is that the $S_{1a}$ schistosity in the Bay du Nord Group and the $S_{1a}$ gneissosity in the Cinq Cerf gneiss formed prior to the deposition of the Upper Silurian La Poile Group. The fact that pre-La Poile Group ($S_{1a}$) and post-La Poile Group ($S_{1g}$) foliations are parallel to each other on the 'flats' and 'ramps' of thrusts is simply a measure of the regional Acadian strain. Although agmatization of Cinq Cerf gneiss may have accompanied syntectonic intrusion of Upper Silurian granitoids, $S_{1a}$ gneissosity may have developed prior to the Early Cambrian. In contrast, in the Bay du Nord Group, the age of $S_{1a}$ schistosity is presumably post-Early Ordovician, pre-Late Silurian. In this explanation, the younger $S_{1g}$ foliation would likely overprint the older $S_{1a}$ foliation, and gneiss and schist would be retrogressed near thrust-related $D_{1g}$ mylonites (Figure 7).

## ALTERATION AND MINERALIZATION

Zones of silicic, pyritic or sericitic alteration are widespread in the La Poile Bay–Roti Bay area (Figure 8).

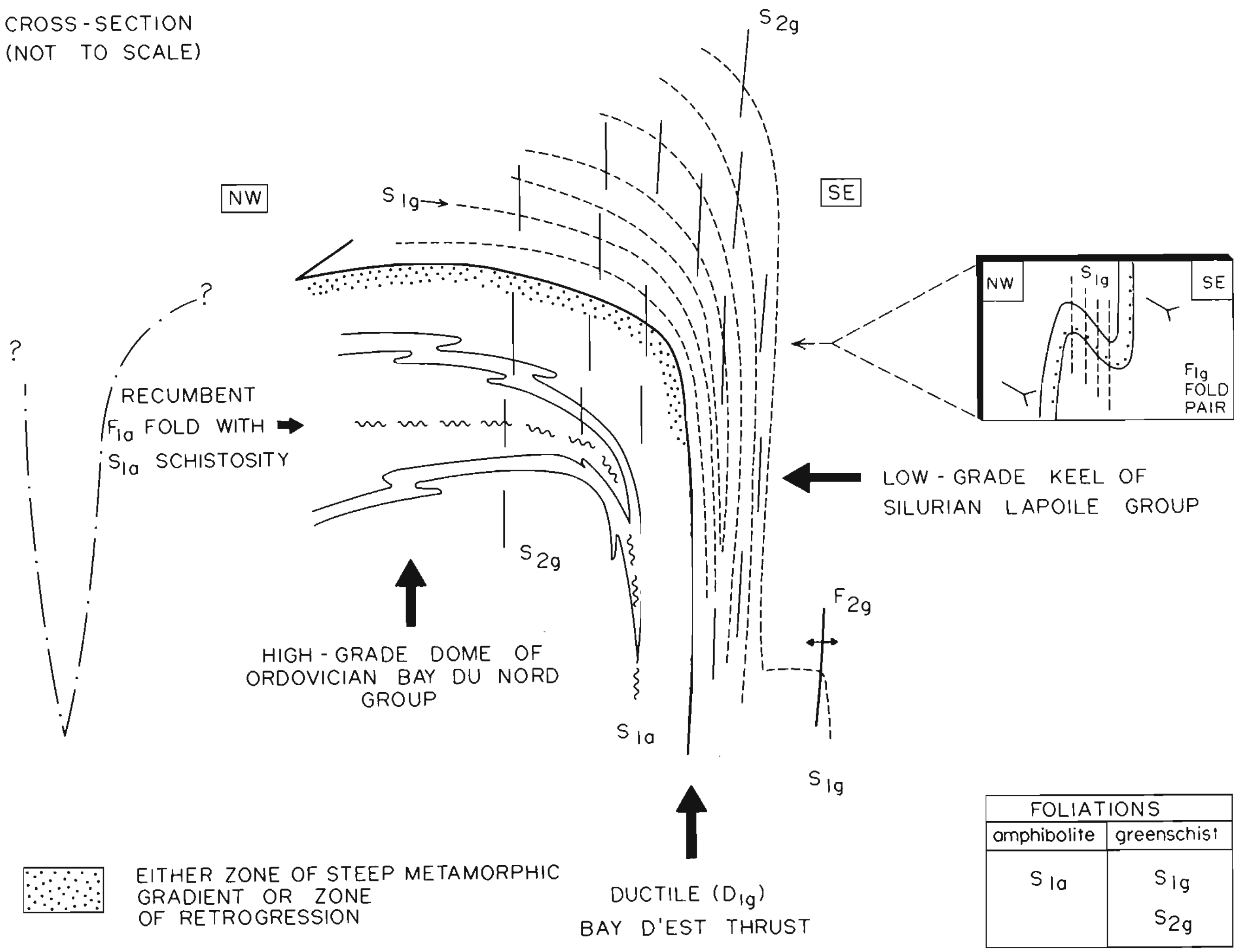


**Figure 7.** *Idealized, vertical, sketch-section showing the structural relationship between the Ordovician Bay du Nord Group and the Silurian La Poile Group. Applying models of Archean greenstone belts, this 'dome-keel' geometry may be caused by vertical gravitational forces (as opposed to horizontal compressional forces). Inset shows the vergence and facing directions of the $F_{1g}$ folds in the La Poile Group. Note how these features contrast with those of the $F_{2g}$ folds related to the Ordovician-cored dome.*

Alteration zones are located in the Georges Brook Formation, the Bay du Nord Group, the Hawks Nest Pond porphyry and the Roti Granite. Lake sediment geochemistry maps of southwestern Newfoundland show that the region southeast of the Bay d'Est Fault Zone is anomalously enriched in Sb, As, Pb, Se and Au (Davenport and Nolan, 1987; McConnell, 1987).

Within the Georges Brook Formation, discontinuous stratabound zones of alteration occur in the Whittle Hill sandstone, the Third Pond tuff, the Northwest Pond Brook grit, the Roti Point conglomerate, the Grand Bruit Gull Pond tuff, the Withy Gulch Hill agglomerate, the Gallyboy Harbour tuff, the Flint Cliff Pond tuff and unseparated rocks (UBE) at the top of the La Poile succession. Phyllosilicate- and sulphide-bearing alteration products in nonintrusive map units are commonly deformed indicating either a pretectonic or syntectonic origin. Any pretectonic alteration must be older than the alteration affecting the granitoids. If it is related to the accumulation of Upper Silurian volcanic rocks, then it is evident that stratabound alteration does not depend on stratigraphic position. Furthermore, a unique relationship does not exist between alteration horizons and particular members or broad lithofacies of the Georges Brook succession. Alternatively, if the alteration process accompanies syn-$D_{2g}$ intrusion of granitic and gabbroic rocks, and synmetamorphic faulting of the Georges Brook Formation, then proximity to concordant sheet intrusions and/or major faults may be an important factor in locating gold mineralization (Figure 8).

## SUMMARY AND CONCLUSIONS

In the La Poile Bay—Roti Bay area, metavolcanic and metasedimentary rocks of the Upper Silurian Georges Brook Formation of the La Poile Group are separable into twenty

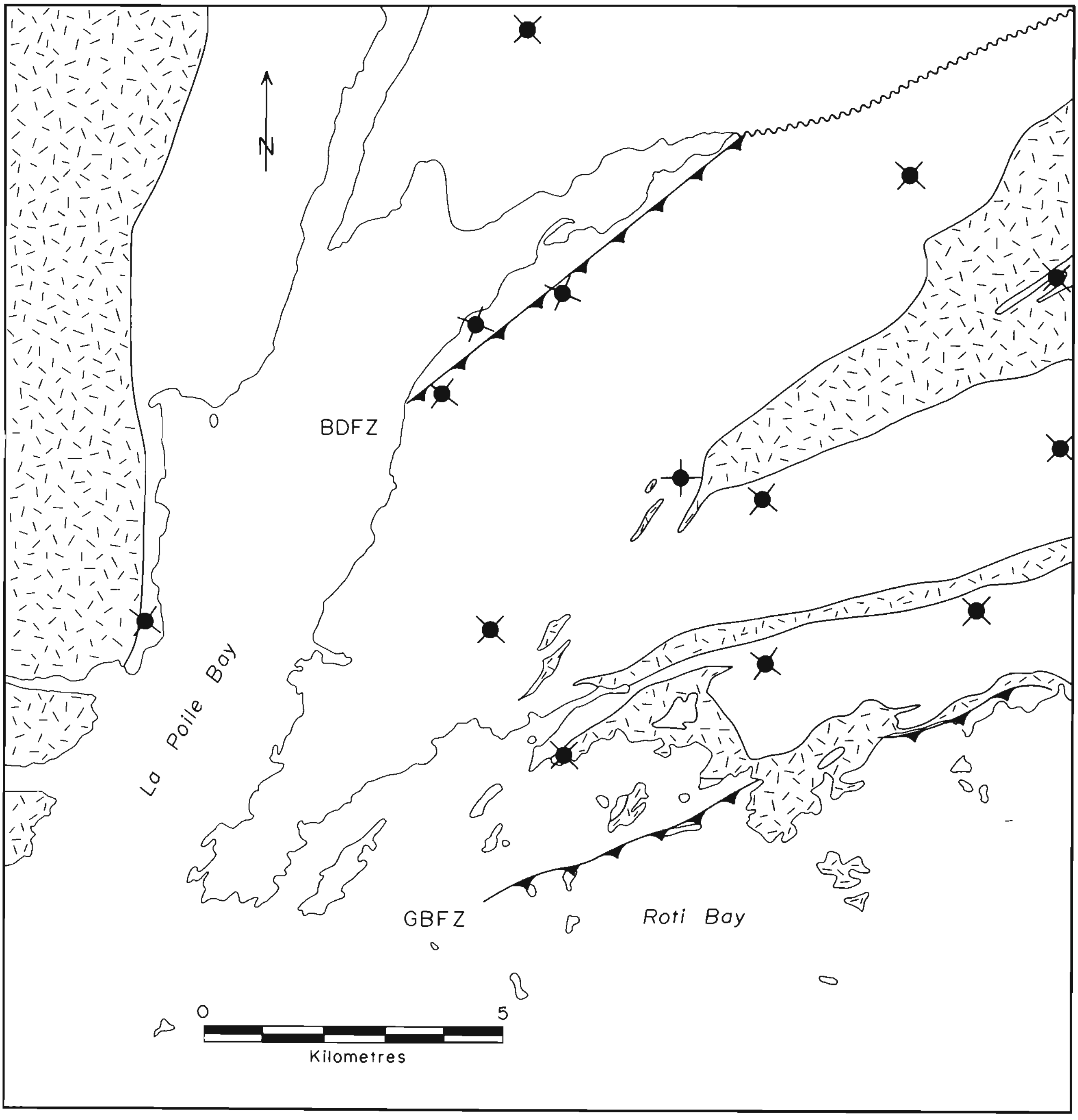


**Figure 8.** *Map of the La Poile Bay–Roti Bay area illustrating zones of silicic, pyritic or sericitic alteration (stars). Note the proximity of alteration zones to syntectonic intrusive rocks (stipled), and the Bay d'Est (BDFZ) and Grand Bruit (GBFZ) fault zones.*

members belonging to six major lithofacies. The most extensive units, the Whittle Hill sandstone and the Gallyboy Harbour tuff, are located near the structural top and base of the group, respectively. The Gallyboy Harbour tuff comprises a thick, laterally continuous deposit of water-laid, felsic crystal tuff near the stratigraphical top of the La Poile Group. The Whittle Hill sandstone is composed of continentally derived, texturally mature, quartzose sediments, which form the stratigraphically lowest exposed part of the La Poile Group. The primary features of the other complexly arranged members of the Georges Brook Formation are well preserved in an essentially steeply dipping, 5-km thick, homoclinal succession, which occurs in the negligibly strained internal portion of a crustal-scale thrust sheet.

Northwesterly directed, step-shaped, $D_{1g}$ thrust faults separate low-grade rocks of the Late Silurian La Poile Group from rocks of high metamorphic grade in structurally overlying and underlying thrust sheets. The highest thrust sheet contains the Lower Ordovician Bay du Nord Group and the Ordovician or older Cinq Cerf gneiss, whereas the lowest thrust sheet is composed solely of the Bay du Nord Group. In this part of the metamorphic hinterland of southwest Newfoundland, ductile Acadian thrusts display large-scale 'flats' and 'ramps', which contrast strongly with the equivalent brittle structures observed in most foreland thrust belts. Near the 'flats' and 'ramps' of the Bay d'Est and Grand Bruit faults, for example, bedding-parallel, amphibolite-facies, $S_{1a}$ schistosity in the Bay du Nord Group and $S_{1a}$ gneissosity in the Cinq Cerf gneiss are concordant with bedding-parallel, greenschist-facies, $S_{1g}$ slaty cleavage in the La Poile Group. Subhorizontal and subvertical belts of $D_{1g}$ mylonite occur at the 'flats' and 'ramps' of thrusts, respectively. In the La Poile Group, the transition from upright to recumbent structures produces a partial flower structure or half-fan of slaty cleavage and bedding that is consistent with northwestward translation of the thrust sheets.

Although the relative or absolute ages of primary cleavage, schistosity and gneissosity are unproven, the writer tentatively suggests that they have two or possibly three distinct ages based on the presence of clasts with preincorporation foliations in the Bay du Nord and La Poile groups. The regional $S_{1g}$ slaty cleavage developed in the Late Silurian between the accumulation of La Poile volcanics and their intrusion by granitoids. However, the $S_{1a}$ schistosity probably formed during an earlier episode of recumbent folding and synamphibolite-facies thrusting that affected sedimentary and volcanic strata of the Bay du Nord Group. These post-Lower Ordovician, pre-Upper Silurian thrust sheets were exposed and provided high-grade metamorphic detritus to deposits in the La Poile depocentre. However, the Bay du Nord Group itself contains clasts of Cinq Cerf gneiss and Roti Granite. This might indicate the existence of older post-Lower Cambrian, pre-Lower Ordovician thrust sheets that were eroded and the resulting sediment deposited in the Bay du Nord depocentre. It also suggests that $S_{1a}$ gneissosity in the Cinq Cerf gneiss is much older and formed at much greater depths than $S_{1a}$ schistosity in the Bay du Nord Group. This history of metamorphism differs from and may predate that described from other parts of the Gander Zone, where isograds are commonly concentrically arranged about domal welts of migmatite and syntectonic plutons (Colman-Sadd, 1985; O'Neill, 1987).

Regardless of whether they are steep or flat, all intrusive bodies in the La Poile Bay—Roti Bay area were intruded during regional $D_{2g}$ deformation; more specifically, intrusions postdated recumbent $F_{1a}$, and upright and recumbent $F_{1g}$ folding but predated cessation of upright $F_{2g}$ folding. Intrusions that appear to be 'forcefully' injected as sheets are emplaced along pre-existing foliations or fold-axial surfaces during periods of horizontal $D_{2g}$ extension, which was intermittently brittle and ductile. For example, vertical, dyke-filled fractures parallel to the upright axial surfaces of periclines were produced by brittle failure, whereas horizontal sills near thrust 'flats' developed concordant (pre-$F_{2g}$) foliation by lateral ductile flow. As steep beds carrying $S_{1g}$ cleavage were extended horizontally near the tops of underlying granites and gabbros, gently plunging bending folds were created due to the buttressing effect of massive intrusions or the spreading lobes of diapiric bodies. These extensional folds locally flattened the original subvertical $S_{1g}$ cleavage and bedding into subhorizontal attitudes immediately prior to the formation of vertical fractures filled with resurgent magma (O'Brien, 1987).

Margin-parallel foliations in upright dykes and sills formed by vertical ductile flow, a process that achieved horizontal shortening of intrusions and neighbouring host rocks. It explains: 1) the localization of upright $F_{2g}$ folds near the margins of intrusions, 2) the coaxial and coplanar relationship between $S_{2g}$ crenulation cleavage and the primary foliation in intrusions, and 3) the fact that the most voluminous swarms of strongly foliated intrusions are hosted by rocks that have suffered the largest $D_{2g}$ strains. Where upright dykes transected thrust 'flats' or gently dipping limbs of bending folds, wall rocks had either $S_{1a}$ or $S_{1g}$ foliation in the $F_{2g}$ buckling field and, therefore, $S_{2g}$ crenulation cleavage developed parallel to dyke margins. In places, vertical sheet intrusions containing steep internal foliations form either T-junctions with, or crosscut both margins of, flat-lying, concordantly foliated sills. This not only implies that brittle and ductile deformation overlapped, but also that upward ductile flow during vertical extension was contemporaneous with lateral ductile flow during horizontal extension.

The inhomogeneous horizontal shortening achieved by $F_{2g}$ folding, $S_{2g}$ crenulation cleavage and $D_{2g}$ mylonitization is due to the complex interplay of horizontal and vertical extension near intrusive bodies. $D_{1g}$ thrust faults and intervening thrust sheets are folded by large-scale $D_{2g}$ domes that are cored by syntectonic intrusions. The rise of magma within these probably gravity-driven domes was checked by two competitive processes. Upright doming and subvertical extension faulting thinned the crust as magmas rose and deep-seated metamorphic rocks were tectonically uplifted. In contrast, horizontal extension produced vertical dilatant fractures filled with granite and gabbro, which thickened the crust. These processes interacted in an effort to maintain a constant-volume crust. However, horizontal extension also permitted the lateral flow of magma and the ponding of laccolithic bodies, which spread the rising magmas over increasing widths of crust. Vertically flowing offshoots from laterally flowing bodies signalled the upward readvance of magmas.

From the perspective of the geology of the La Poile Bay—Roti Bay area, alteration and gold mineralization are probably related to synmetamorphic, syntectonic plutons sited near regional fault lineaments (following Wilton and Strong, 1986).

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## REFERENCES

Blackwood, R.F.
1985: Geology of the Grey River area, southwest coast of Newfoundland. *In* Current Research, Newfoundland Department of Mines and Energy, Mineral Development Division, Report 85-1, pages 153-164.

Brown, P.A.
1973: Possible cryptic suture in southwest Newfoundland. Nature, Volume 245, Number 140, pages 9-10.

1976: Ophiolites in southwest Newfoundland. Nature, Volume 264, pages 712-715.

Chorlton, L.B.
1978: The geology of the La Poile map area (110/9), Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 78-5, 14 pages.

1980: Geology of the La Poile River area (110/16), Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 80-3, 86 pages.

Chorlton, L.B. and Dallmeyer, R.D.
1986: Geochronology of Early to Middle Paleozoic tectonic development in the southwest Newfoundland Gander Zone. Journal of Geology, Volume 94, pages 67-89.

Colman-Sadd, S.P.
1985: Geology of the Burnt Hill map area (2D/5), Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 85-3, 94 pages.

Cooper, J.R.
1954: The La Poile-Cinq Cerf map area, Newfoundland. Geological Survey of Canada, Memoir 276, 62 pages.

Davenport, P.H. and Nolan, L.W.
1987: Gold and associated elements in lake sediment from regional surveys in the Port aux Basques area (NTS 110) and the White Bay area (NTS 12H/9, 10, 11, 15, 16 and 12I/1). Newfoundland Department of Mines, Mineral Development Division, Open File Nfld 1582, 25 pages.

Dunning, G.R. and Chorlton, L.B.
1985: The Annieopsquotch ophiolite belt of southwest Newfoundland: geology and tectonic significance. Geological Society of America Bulletin, Volume 96, pages 1466-1476.

Dunning, G.R., Krogh, T.E., O'Brien, S.J., Colman-Sadd, S.P. and O'Neill, P.P.
*In press:* Geochronologic framework for the Central Mobile Belt in southwestern Newfoundland and the importance of Silurian Orogeny. Program with Abstracts, Joint Annual (1988) Meeting of the Geological Association of Canada, Mineralogical Association of Canada and Canadian Society of Petroleum Geologists, St. John's, Newfoundland.

Hayes, A.O. and Johnson, H.
1938: Geology of the Bay St. George Carboniferous area. Bulletin of the Geological Survey of Newfoundland, Number 12, 62 pages.

McConnell, J.W.
1987: Gold and associated trace elements in Newfoundland lake sediment from four areas of known gold mineralization. Newfoundland Department of Mines and Energy, Mineral Development Division, Open File Nfld 1509.

O'Brien , B.H.
1987: The lithostratigraphy and structure of the Grand Bruit–Cinq Cerf area (parts of NTS areas 110/9 and 110/16), southwestern Newfoundland. *In* Current Research Newfoundland Department of Mines and Energy, Mineral Development Division, Report 87-1, pages 311-334.

O'Brien, S.J., Dickson, W.L. and Blackwood, R.F.
1986: Geology of the central part of the Hermitage Flexure area, Newfoundland. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 86-1, pages 189-208.

O'Neill, P.P.
1987: Geology of the Weir's Pond map area (2E/1), Newfoundland. Newfoundland Department of Mines, Mineral Development Division, Open File Map 87-84, 1:50,000 scale.

O'Neill, P.P. and Strong, D.F.
1988: The Isle aux Morts Prospect: the first significant base metal discovery in the Port aux Basques Complex of southwest Newfoundland. CIM Bulletin, Volume 81, pages 59-68.

van Berkel, J.T.
1987: Geology of the Dashwoods Pond, St. Fintan's and Main Gut map areas, southwest Newfoundland. *In* Current Research, Part A. Paper 87-1A, pages 399-408.

Wilton, D.H.C. and Strong, D.F.
1986: Granite-related gold mineralization in the Cape Ray Fault Zone, southwestern Newfoundland. Economic Geology, Volume 81, pages 281-295.